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NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION

A STATUS REVIEW OF THE **FOOTHILL YELLOW-LEGGED FROG** (*Rana boylii*) IN CALIFORNIA

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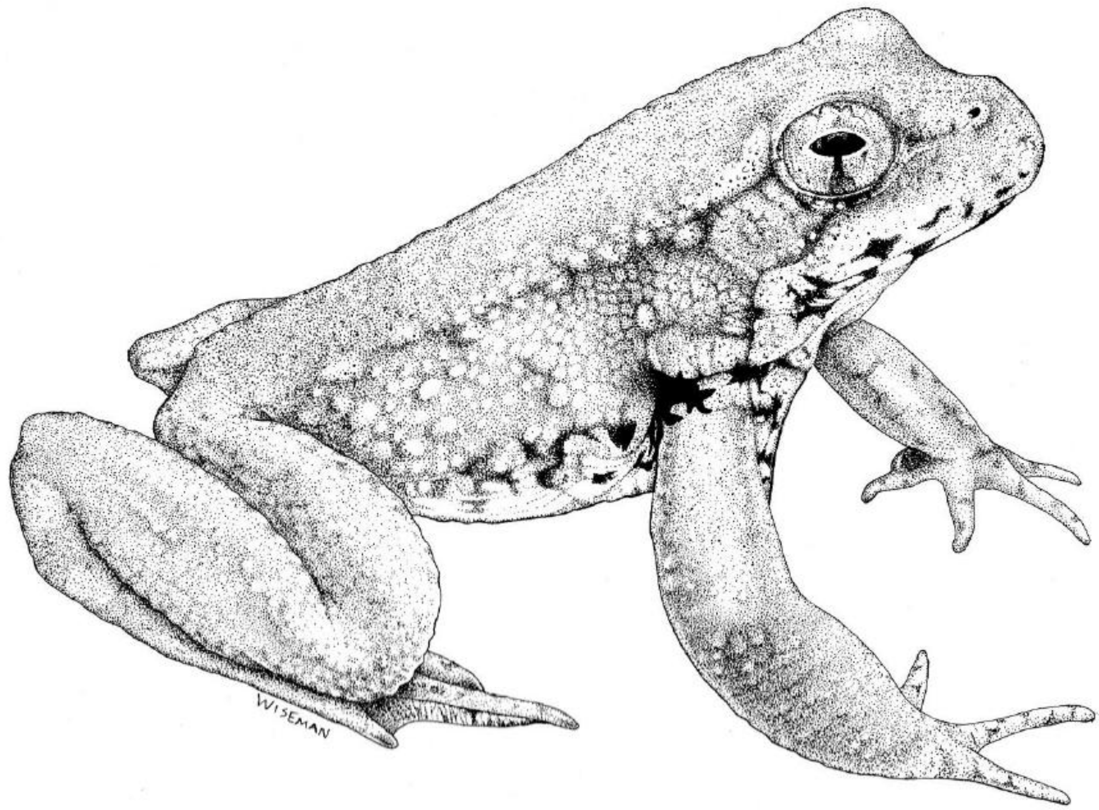

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EXECUTIVE SUMMARY

This status review report contains the most current information available on the Foothill Yellow-legged Frog (*Rana boylii*) and serves as the basis for the California Department of Fish and Wildlife's (Department) recommendation to the California Fish and Game Commission (Commission) on whether to list the species as threatened or endangered under the California Endangered Species Act. The Center for Biological Diversity submitted a "Petition to List the Foothill Yellow-legged Frog (*Rana boylii*) as Threatened Under the California Endangered Species Act" (Petition) to the Commission on December 14, 2016. At its scheduled public meeting on June 21, 2017, the Commission considered the Petition, and based in part on the Department's petition evaluation and recommendation, found sufficient information exists to indicate the petitioned action may be warranted and accepted the Petition for consideration. The Foothill Yellow-legged Frog was designated a candidate species on July 7, 2017 upon publication of the Commission's notice of its findings.

Foothill Yellow-legged Frogs are currently recognized as a California Species of Special Concern, a non-regulatory designation intended to focus attention on animals at conservation risk, stimulate research on poorly known species, and achieve conservation and recovery of these animals before they meet criteria for listing as threatened or endangered under the California Endangered Species Act (CESA; Fish & G. Code, § 2050 et seq.). Additionally, the Foothill Yellow-legged Frog throughout its range in California and Oregon is currently under review by the U.S. Fish and Wildlife Service for listing as threatened or endangered under the federal Endangered Species Act.

Foothill Yellow-legged Frogs are small- to medium-sized frogs that are typically gray, brown, olive, or reddish with brown-black flecking and mottling, which often matches the local substrate. Foothill Yellow-legged Frogs have a relatively squat body and granular skin, giving them a rough appearance like toads, and their dorsolateral folds are indistinct compared to other western North American ranids. Their abdomen is white with variable amounts of dark mottling on the chest and throat, and as their name suggests, the undersides of their hind limbs are often yellow. Foothill Yellow-legged Frogs reach sexual maturity around two to three years old and can live over a decade. Adult females likely lay one clutch of eggs per year. Egg masses resemble a cluster of grapes with several hundred embryos, and tadpoles metamorphose in the same season the eggs were laid.

Foothill Yellow-legged Frogs historically ranged from the Willamette River drainage in Oregon west of the Sierra-Cascade crest to at least the San Gabriel River drainage in Los Angeles County in California, and a disjunct population was discovered in the mid-1960s in the Sierra San Pedro Mártir, Baja California Norte, México. In California, the species has been reported from foothill and mountain streams in the Klamath, Cascade, Sutter Buttes, Coast, Sierra Nevada, and Transverse ranges from sea level to 6,400 ft, although rarely above 5,000 ft. Foothill Yellow-legged Frog populations exhibit strong genetic variation across their range. Two recent landscape genomics studies recovered five and six deeply divergent clades, respectively, and genetic diversity within clades is generally lower in the southern part of the species' range, making them less capable of adapting to changing conditions.

Foothill Yellow-legged Frogs inhabit rivers and streams ranging from primarily rain-fed (coastal populations) to primarily snow-influenced (most Sierra Nevada and Klamath-Cascade populations) from headwater streams to large rivers. Occupied rivers and streams flow through a variety of vegetation types including hardwood, conifer, and valley-foothill riparian forests; mixed chaparral; and wet meadows. The species is an obligate stream-breeder, which sets it apart from other western North American ranid frogs. Foothill Yellow-legged Frog habitat is generally characterized as partly-shaded, shallow, perennial rivers and streams with a low gradient and rocky substrate that is at least cobble-sized; however, the species also uses intermittent and ephemeral streams. Appropriate flow velocity, temperature, and timing are critically important to the success of Foothill Yellow-legged Frog populations. The habitats in which Foothill Yellow-legged Frogs are found can generally be categorized as breeding and rearing habitat, nonbreeding season habitat, and overwintering habitat. Foothill Yellow-legged Frog densities are often higher in areas with greater habitat heterogeneity likely because the diversity of habitats can support all life stages within a relatively short distance.

Foothill Yellow-legged Frog diet varies by life stage and likely by body size. Tadpoles graze on algae scraped from rocks and vegetation. Post-metamorphic Foothill Yellow-legged Frogs primarily feed on a wide variety of terrestrial arthropods but also some aquatic invertebrates, mostly insects and arachnids. In the fall when they are abundant, young-of-year Foothill Yellow-legged Frogs may provide an important source of nutrition for adults prior to overwintering. Foothill Yellow-legged Frogs are preyed upon by several native and introduced species, including aquatic insects, crayfish, salamanders, frogs, birds, and several species of fish and gartersnakes.

Few historical data on Foothill Yellow-legged Frog distribution and abundance exist, but widespread disappearances were documented as early as the 1970s and 80s in southern California, the southern Coast Range, and the central and southern Sierra Nevada foothills. In 1994, the authors of the first edition of *Amphibians and Reptile Species of Special Concern in California* concluded that Foothill Yellow-legged Frogs could be considered endangered in central and southern California south of the Salinas River in Monterey County, threatened in the west slope drainages of the Cascade Mountains and Sierra Nevada east of the Central Valley, and a species of special concern in the remainder of California. In 2005, a range-wide assessment determined the species was likely extirpated from over 50% of historically occupied sites, and in another wide-ranging survey effort at least one Foothill Yellow-legged Frog was detected at 26.5% of sites with suitable habitat in California. In the latter study, fewer than 20 adults were observed at approximately 86% of the occupied sites, but the North Coast possessed the greatest proportion of occupied sites and most robust populations. The coarse-scale trend of Foothill Yellow-legged Frog populations in California is one of greater declines and extirpations in lower elevations and latitudes.

Several past and ongoing activities have changed the watersheds upon which Foothill Yellow-legged Frogs depend, and many interact with each other in ways that exacerbate their adverse impacts. In addition, because many Foothill Yellow-legged Frog populations are small, isolated from other populations, and possess low genetic diversity, they are at greater risk of extirpation than robust populations.

Most of the factors threatening the Foothill Yellow-legged Frog's ability to persist and thrive involve habitat destruction or degradation. The most widespread, and potentially most significant, impacts are associated with dams and their flow regimes, particularly in areas where dams are concentrated and occur in a series along a river or use hydropeaking to generate power. Dams can result in up- and downstream effects, including aseasonal or asynchronous breeding cues, scouring and stranding of egg masses and tadpoles, reducing quality and quantity of breeding and rearing habitat, lessening tadpole growth rate, impeding gene flow among populations, and creating conditions that support the establishment and spread of non-native species. The average abundance of Foothill Yellow-legged Frog populations below dams is one-fifth of those in unregulated rivers (undammed), and populations in regulated rivers face a 4- to 13-fold greater extinction risk in 30 years than populations in unregulated rivers due to smaller population sizes.

Another widespread threat to Foothill Yellow-legged Frog habitat is climate change. While drought, wildland fires, floods, and landslides are natural and often necessary disturbance events for preservation of native biodiversity, climate change is expected to result in increased frequency and severity of these events in ways that may exceed species' abilities to adapt. These disturbance events, which can lead to local extirpations, will occur across a landscape of fragmented and small populations, so the likelihood of natural recolonization may be highly impaired. Some climate models predict unprecedented dryness in the latter half of the century, and altered flow regimes may lead to increased competition, predation, and disease transmission as species become concentrated in remnant pools. Impacts from extended droughts will likely be greatest in areas that are naturally more arid, the lower elevations and latitudes of southern California and the foothills surrounding the Central Valley, where remaining populations are already small and isolated. In addition, loss of riparian vegetation from wildland fires can result in increased stream temperatures or concentrations of nutrients and trace heavy metals that inhibit growth and survival. Sedimentation from landslides following fire or excessive precipitation can also destroy or degrade breeding and rearing habitat.

Like many other amphibians across the globe, Foothill Yellow-legged Frogs are susceptible to the lethal and sublethal effects of disease and pollution. The fungal pathogen *Batrachochytrium dendrobatidis* (Bd) is linked to the greatest recorded loss of biodiversity attributable to a disease and is responsible for dramatic declines and extinctions in hundreds of species of amphibians around the world. Bd is widespread in the environment and likely contributed to the Foothill Yellow-legged Frog's disappearance from southern California and other parts of its range is implicated as the causative factor in two recent mass-mortality events in the Bay Area. As the nation's largest agricultural producer and exporter, tons of agricultural chemicals are applied to California farms annually and can travel substantial distances through the atmosphere. Disappearance and declines in Foothill Yellow-legged Frog populations correlate with proximity and proportion of nearby agriculture. The species is particularly sensitive to some of the commonly used organophosphates, which disrupt nerve impulse transmission. Pesticide exposure can result in direct mortality, immunosuppression, reduced resistance to the parasites that cause limb malformations, decreased growth and activity, and increased vulnerability to predation.

Predation likely contributed, and continues to contribute, to Foothill Yellow-legged Frog population declines, particularly where the habitat is degraded by one or many other risk factors. Predation by and competition with introduced species like American Bullfrogs can have substantial adverse effects; abundance of Foothill Yellow-legged Frogs was nearly an order of magnitude (i.e., 10 times) lower in stream reaches where bullfrogs were well established. Bullfrogs are also asymptomatic carriers of Bd.

Additional threats that can contribute to Foothill Yellow-legged Frog habitat degradation and population declines include mining, livestock grazing, recreational activities, urban and agricultural land use and expansion, cannabis cultivation, timber harvest, and some biological surveys and habitat restoration activities.

Several environmental laws and regulations reduce adverse impacts on Foothill Yellow-legged Frogs. Efforts to avoid, minimize, or mitigate these threats have been incorporated into many environmental impact assessments, regional conservation plans, and permits and licenses. Nevertheless, remaining populations throughout a large portion of the species' California range continue to be small and are losing genetic diversity. Additional actions are needed to conserve and improve existing populations in many areas and to re-establish populations in areas where they have been extirpated.

The scientific information available to the Department indicates that Foothill Yellow-legged Frog faces varying degrees of imperilment throughout its range. The Department recommends that the Commission find that the petitioned action to list Foothill Yellow-legged Frog as threatened is warranted for the Feather River and Northeast/Northern Sierra clades; that the East/Southern Sierra, West/Central Coast, and Southwest/South Coast clades be listed as endangered; and that listing of the Northwest/North Coast clade is not warranted at this time.

1.0 REGULATORY SETTING

1.1 Petition Evaluation Process

A petition to list the Foothill Yellow-legged Frog (*Rana boylii*) as threatened under the California Endangered Species Act (CESA) was submitted to the Fish and Game Commission (Commission) on December 14, 2016 by the Center for Biological Diversity. Commission staff transmitted the petition to the Department of Fish and Wildlife (Department) pursuant to Fish and Game Code section 2073 on December 22, 2016 and published a formal notice of receipt of the petition on January 20, 2017 (Cal. Reg. Notice Register 2017, No. 3-Z, p. 46). A petition to list or delist a species under CESA must include "information regarding the population trend, range, distribution, abundance, and life history of a species, the factors affecting the ability of the population to survive and reproduce, the degree and immediacy of the threat, the impact of existing management efforts, suggestions for future management, and the availability and sources of information. The petition shall also include information regarding the kind of habitat necessary for species survival, a detailed distribution map, and any other factors that the petitioner deems relevant" (Fish & G. Code, § 2072.3).

On April 17, 2017, the Department provided the Commission with its evaluation of the petition, "Evaluation of the Petition from the Center For Biological Diversity to List the Foothill Yellow-legged Frog (*Rana boylii*) as Threatened under the California Endangered Species Act," to assist the Commission in making a determination as to whether the petitioned action may be warranted based on the sufficiency of scientific information (Fish & G. Code, §§ 2073.5 & 2074.2; Cal. Code Regs., tit. 14, § 670.1, subds. (d) & (e)). Focusing on the information available to the Department relating to each of the relevant categories, the Department recommended to the Commission that the petition be accepted.

At its scheduled public meeting on June 21, 2017 in Smith River, the Commission considered the petition, the Department's petition evaluation and recommendation, and comments received. The Commission found that sufficient information existed to indicate the petitioned action may be warranted and accepted the petition for consideration. Upon publication of the Commission's notice of its findings, the Foothill Yellow-legged Frog was designated a candidate species on July 7, 2017 (Cal. Reg. Notice Register 2017, No. 27-Z, p. 986).

1.2 Status Review Overview

The Commission's action designating the Foothill Yellow-legged Frog as a candidate species triggered the Department's process for conducting a status review to inform the Commission's decision on whether listing the species is warranted. At its scheduled public meeting on June 21, 2018 in Sacramento, the Commission granted the Department a six-month extension to complete the status review and facilitate external peer review.

This status review report is not intended to be an exhaustive review of all published scientific literature relevant to the Foothill Yellow-legged Frog; rather, it is intended to summarize the key points from the best scientific information available relevant to the status of the species. This final report, based upon the best scientific information available to the Department, is informed by independent peer review of a draft report by scientists with expertise relevant to the Foothill Yellow-legged Frog. This review is intended to provide the Commission with the most current information on the Foothill Yellow-legged Frog and to serve as the basis for the Department's recommendation to the Commission on whether the petitioned action is warranted. The status review report also identifies habitat that may be essential to continued existence of the species and provides management recommendations for recovery of the species (Fish & G. Code, § 2074.6). Receipt of this report is to be placed on the agenda for the next available meeting of the Commission after delivery. At that time, the report will be made available to the public for a 30-day public comment period prior to the Commission taking any action on the petition.

1.3 Federal Endangered Species Act Review

The Foothill Yellow-legged Frog is currently under review for possible listing as threatened or endangered under the federal Endangered Species Act (ESA) in response to a July 11, 2012 petition submitted by the Center for Biological Diversity. On July 1, 2015, the U.S. Fish and Wildlife Service (USFWS) published its 90-day finding that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted and initiated a status review of the species (USFWS 2015). On March 16, 2016, the Center for Biological Diversity sued the USFWS to compel issuance of a 12-month finding on whether listing under the ESA is warranted. On August 30, 2016, the parties reached a stipulated settlement agreement that the USFWS shall publish its 12-month finding in the Federal Register on or before September 30, 2020 (Center for Biological Diversity v. S.M.R. Jewell (D.D.C. Aug. 30, 2016, No. 16-CV-00503)).

2.0 BIOLOGY AND ECOLOGY

2.1 Species Description and Life History

> *"In its life-history* boylii *exhibits several striking specializations which are in all probability related to the requirements of life of a stream-dwelling species"* – Tracy I. Storer, 1925

The Foothill Yellow-legged Frog is a small- to medium-sized frog; adults range from 1.5 to 3.2 inches snout-to-urostyle length (SUL) with females attaining a larger size than males and males possessing paired internal vocal sacs (Zweifel 1955, Nussbaum et al. 1983, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs are typically gray, brown, olive, or reddish with brown-black flecking and mottling, which generally matches the substrate of the stream in which they reside (Nussbaum et al. 1983, Stebbins and McGinnis 2012). They often have a pale triangle between the eyes and snout and broad dark bars on the hind legs (Zweifel 1955, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs have a relatively squat body and granular skin, giving them a rough appearance similar to a toad, and fully webbed feet with slightly expanded toe tips (Nussbaum et al. 1983). The tympanum is also rough and relatively small compared to other ranids (frogs in the family Ranidae) at around one-half the diameter of the eye (Zweifel 1955). The Foothill Yellow-legged Frog's dorsolateral folds (glandular ridges extending from the eye area to the rump) are indistinct compared to other western North American ranids (Stebbins and McGinnis 2012). Ventrally, the abdomen is white with variable amounts of dark mottling on the chest and throat, which are unique enough to be used to identify individuals (Marlow et al. 2016). As their name suggests, the undersides of their hind limbs and lower abdomen are often yellow; however, individuals with orange and red have been observed within the range of the California Red-legged Frog (*Rana draytonii*), making hindlimb coloration a poor diagnostic characteristic for this species (Jennings and Hayes 2005).

Adult females likely lay one clutch of eggs per year and may breed every year (Storer 1925, Wheeler et al. 2006). Foothill Yellow-legged Frog egg masses resemble a compact cluster of grapes approximately 1.8 to 3.5 inches in diameter lengthwise and contain anywhere from around 100 to over 3,000 eggs (Kupferberg et al. 2009c, Hayes et al. 2016). The individual embryos are dark brown to black with a lighter area at the vegetative pole and surrounded by three jelly envelopes that range in diameter from approximately 0.15 to 0.25 inches (Storer 1925, Zweifel 1955, Hayes et al. 2016).

Foothill Yellow-legged Frog tadpoles hatch out around 0.3 inch long and are a dark brown or black (Storer 1925, Zweifel 1955). They grow rapidly to 1.5 to 2.2 inches and turn olive with a coarse brown mottling above and an opaque silvery color below (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012). Their eyes are positioned dorsally when viewed from above (i.e., within the outline of the head), and their mouths are large, downward-oriented, and suction-like with several tooth rows (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012, Hayes et al. 2016). Foothill Yellow-legged Frogs metamorphose at around 0.55 to 0.67 of an inch SUL (Fellers 2005). Sexual maturity is attained at around 1.2 to 1.6 inches SUL and 1 to 2 years for males and around 1.6 to 2.0 inches SUL and 3 years for females, although in some populations this has been accelerated by a year (Zweifel 1955, Kupferberg et al. 2009c, Breedveld and Ellis 2018). During the breeding season, males can be distinguished from females by the presence of nuptial pads (swollen darkened thumb bases that aid in holding females during amplexus) and calling, which frequently occurs underwater but sometimes from the surface (MacTague and Northen 1993, Stebbins 2003, Silver 2017).

The reported lifespan of Foothill Yellow-legged Frogs varies widely by study. Storer (1925) estimated a maximum age of 2 years for both sexes, and Van Wagner (1996) stated that Foothill Yellow-legged Frogs rarely exceeded 2 years old at his study site. Breedveld and Ellis (2018) calculated the typical lifespan of males at 3-4 years and 5-6 years for females. Bourque (2008), using skeletochronology, found an individual over 7 years old and a mean age of 4.7 and 3.6 years for males and females, respectively. Drennan et al. (2015) estimated maximum age at 13 years for both sexes in a Sierra Nevada population and 12 for males and 11 for females in a Coast Range population.

2.2 Range and Distribution

Based on the current understanding of the Foothill Yellow-legged Frog's historical distribution, which is sparse in many areas, the species likely ranged from the Willamette River drainage in Oregon west of the Sierra-Cascade crest to at least the San Gabriel River drainage in Los Angeles County, California (Zweifel 1955, Nussbaum et al. 1983, Stebbins 2003). In addition, a disjunct population was reported from 6,700 ft in the Sierra San Pedro Mártir, Baja California Norte, México (Loomis 1965). In California, the species has been reported from foothill and mountain streams in the Klamath, Cascade, Sutter

Buttes, Coast, Sierra Nevada, and Transverse ranges from sea level to around 6,000 ft, although Hemphill (1952) describes observing them as high as 6,400 ft at one North Coast location (Stebbins 2003, Olson et al. 2016). Zweifel (1955) considered Foothill Yellow-legged Frogs to be present and abundant throughout their range where streams possessed suitable habitat.

Figure 1 depicts the Department's approximation of the Foothill Yellow-legged Frog's historical range. The majority of the range boundaries in California were taken directly from Thomson et al. (2016) and are used for the Department's California Wildlife Habitat Relationships (CWHR) range. Their methodology included plotting observations in a geographic information system (GIS), intersecting those points with watershed boundaries, developing an approximate range boundary using interpolation between the observations and watershed boundaries, and expert opinion (Ibid.). The Sutter Buttes were added for this report based on Olson et al. (2016). The range in Oregon was based on the species' range map in Nussbaum et al. (1983), and the range in México was estimated from the locality description in Loomis (1965).

As described in more detail below, Foothill Yellow-legged Frog taxonomy has changed many times since originally described, and consequently, some museum specimens collected before the 1960s are erroneous. As stated in the Petition, to date, all recently reevaluated Foothill Yellow-legged Frog-labeled museum specimens south of the San Gabriel mountains in California were determined to be Southern Mountain Yellow-legged Frogs (*Rana muscosa*). No evidence suggests that those not re-evaluated would be reconciled another way. This likely happened in some places in the Sierra Nevada as well, as Foothill Yellow-legged Frogs are rarely found above 5,000 ft (R. Peek pers. comm. 2019a). Based on recent genetics work in the northern Sierra Nevada, all yellow-legged frogs located above 5,000 ft were Sierra Nevada Yellow-legged Frogs (*R. sierrae*) (Bedwell 2018, Peek 2018).

2.3 Taxonomy and Phylogeny

Foothill Yellow-legged Frogs belong to the family Ranidae (true frogs), which inhabits every continent except Antarctica and contains over 400 species (AmphibiaWeb 2019b). The species was first described by Baird (1854) as *Rana boylii*. After substantial taxonomic uncertainty with respect to its relationship to other ranids, several name changes (including the specific epithet spelling of *boylei*), and recognition of three subspecies over the next century, the Foothill Yellow-legged Frog (*R. boylii*) was again recognized as a monotypic species (i.e., without subspecies) by Zweifel (1955, 1968). The phylogenetic relationships among the western North American *Rana* spp. have been revised several times and are still not entirely resolved (Thomson et al. 2016). The Foothill Yellow-legged Frog was previously thought to be most closely related to the higher-elevation Sierra Nevada Yellow-legged Frog and Southern Mountain Yellow-legged Frog (Zweifel 1955; Green 1986a,b; Vredenburg et al. 2007). However, more recent genetic analyses suggest they are most closely related to Columbia Spotted Frogs (*R. luteiventris*) (Macey et al. 2001, Hillis and Wilcox 2005, Yuan et al. 2016).

Figure 1. Estimated historical range of the Foothill Yellow-legged Frog (adapted from Loomis [1965], Nussbaum et al. [1983], Olson et al. 2016, CWHR 2014). See Section 2.2 Range and Distribution for map construction methods and stipulations.

2.4 Population Structure and Genetic Diversity

Genetic divergence among populations and genetic diversity within those populations are critical to species protection. Genetic divergence is a measure of the number of mutations accumulated between population lineages since they last shared a common ancestor. It represents the amount of time that lineages have been separated; the longer the time, the greater the genetic divergence. Given that evolutionary processes, including local adaptation and speciation, tend to accumulate over time, a general principle in conservation genetics is that deeply diverged lineages need to be individually managed and protected to preserve the full evolutionary potential of a species. Molecular genetic/genomic analyses allow one to quantify genetic divergence and clearly delimit the geographic boundaries of populations and the amount of gene flow or isolation among them (McCartney-Melstad and Shaffer 2015). Genetic divergence is often depicted as a phylogenetic tree (see Figure 2), which visually summarizes the evolutionary relationships among populations and taxa (AmphibiaWeb 2019a). A branch on a phylogenetic tree that contains a group of lineages comprised of an ancestor and all its descendants is referred to as a monophyletic group, or a clade (Ibid.). Clades are nested hierarchically in a phylogenetic tree, and effective conservation strategies often identify the “major” clades, which represent populations from the most divergent lineages in that tree, as key management units. These major clades may be sufficiently differentiated into diagnosable species or subspecies, or they may diverge to that point if the evolutionary process continues.

Because the processes that drive genetic divergence among populations and among species are the same (i.e., mutation, natural selection, genetic drift), it can be difficult to determine when populations within species have differentiated enough to suggest they are evolving independently and may be considered separate species or subspecies (Hey and Pinho 2012). Hey and Pinho (2012) examined use of gene flow and separation time measures to distinguish between intraspecific and interspecific differences. The most widely used summary measure of population divergence is the fixation index F_{ST}, a quantitative measure of the proportion of the total genetic variance in a study among populations or lineages. Hey and Pinho’s analyses indicated that F_{ST} values greater than 0.35 among lineages correlated best with species designations, while values below 0.35 were more consistent with within-species variation (Ibid.). This population-genetics based approach to estimating genetic divergence can help reveal cryptic diversity within a putative species, and in some cases may lead to the recognition of previously unrecognized species (AmphibiaWeb 2019a).

In contrast to divergence among populations, genetic diversity summarizes variation within a population or lineage, which provides information on population health and indicates the extent to which populations have the capacity to adapt (i.e., evolve) to changing conditions (Hughes et al. 2008). Loss of genetic diversity often signals extreme reductions in population size (genetic bottlenecks) and greatly increases the potential for inbreeding depression that can reduce survival and reproductive success (Lande and Shannon 1996, Frankham 2005, Hoffmann and Sgrò 2011, McCartney-Melstad et al. 2018). Amphibians as a group may be particularly vulnerable to the effects of low genetic diversity; there are several documented instances of reduced fitness as a result of eroded genetic diversity in amphibians that may be contributing to global declines in this taxon (Allentoft and O’Brien 2010).

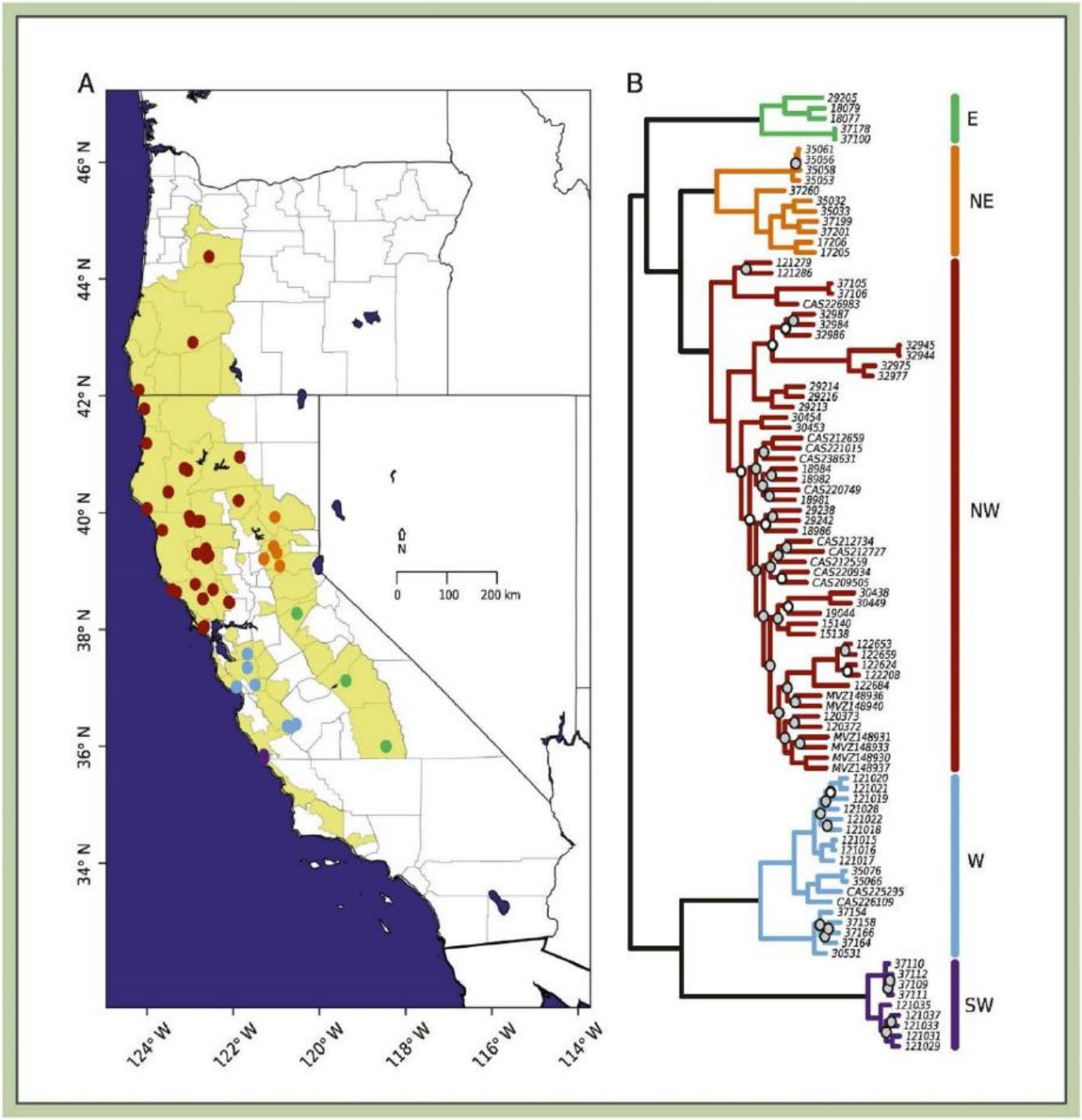

Figure 2. Foothill Yellow-legged Frog clades identified by McCartney-Melstad et al. (2018) Yellow polygons = International Union for Conservation of Nature's range map; colored circles = sampling sites.

Foothill Yellow-legged Frog populations exhibit varying levels of genetic divergence and diversity depending on the spatial scale of comparison. At the coarse scale, comprised of variation across the species' extant range, McCartney-Melstad et al. (2018) recovered five deeply divergent, geographically cohesive, genetic clades from their analyses (Figure 2), while Peek (2018) utilized expanded geographic sampling and recovered six (Figure 3). Both analyzed thousands of genomic loci generated using RADseq approaches. The lowest F_{ST} value McCartney-Melstad et al. (2018) calculated among their five recognized lineages was 0.312 between the Northwest and Northeast clades (see Figure 2 and below for details on estimated clade boundaries), and the highest was 0.794 between the Southwest and East clades. Peek (2018) calculated F_{ST} between pairs of populations across the Foothill Yellow-legged Frog's

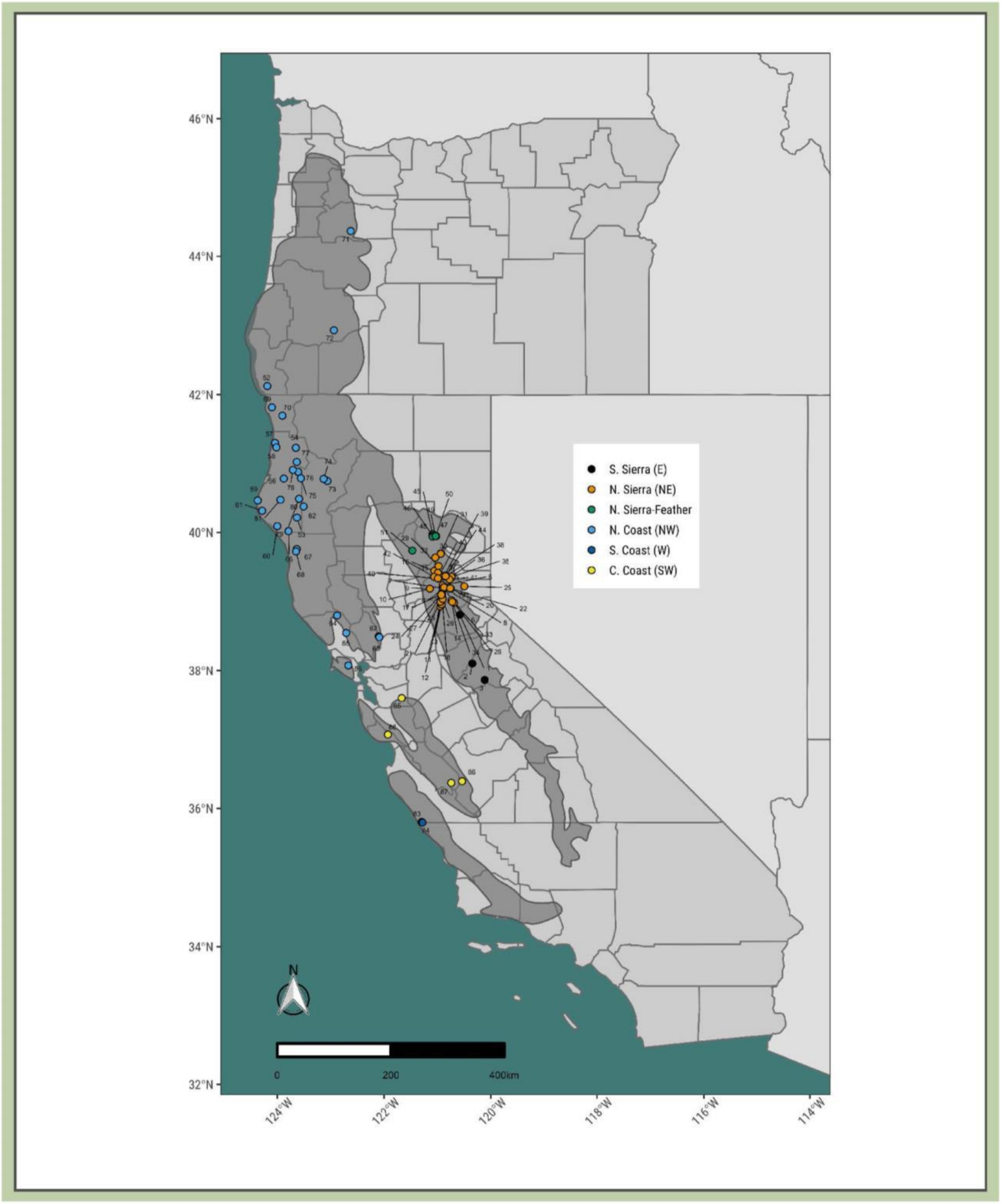

Figure 3. Foothill Yellow-legged Frog clades identified by Peek (2018) Dark gray polygon = presumed range and colored circles and numbers represent specific sampling sites and their clade assignments.

range (1,953 total combinations) and obtained values between 0 and 0.646, with the greatest divergence occurring between the South Coast and Southern Sierra clades (see Figure 3). The results of these two studies, which utilized independent sets of genes and tissues, are virtually identical in recognizing clades and their very high level of divergence (McCartney-Melstad et al. 2018, Peek 2018). These high genetic divergence values indicate that few to no genes have been exchanged between these clades for extended periods of evolutionary time, suggesting a long history of reproductive isolation from each other. These clades represent unique, largely non-overlapping, genetic lineages within the species that are important for the preservation of genetic variation within this wide-ranging species. Additional study may better delineate clade boundaries and suggest that they represent distinct species.

The geographic breaks among the five Foothill Yellow-legged Frog clades were similar between the studies; however, Peek (2018) identified a unique deeply divergent genetic clade in the Feather River watershed that is distinct from the rest of the northern Sierra Nevada clade. The five clades common to both studies include the following [Note: naming conventions follow McCartney-Melstad et al. (2018) and Peek (2018)]:

(1) Northwest/North Coast: north of San Francisco Bay in the Coast Ranges and east into Tehama County;

(2) Northeast/Northern Sierra: northern El Dorado County (North Fork American River watershed, includes Middle Fork American River) and north in the Sierra Nevada to southern Plumas County (Upper Yuba River watershed);

(3) East/Southern Sierra: El Dorado County (South Fork American River watershed) and south in the Sierra Nevada [no samples from Amador County were tested, but they would most likely fall within this clade because it is located between two other populations that occur within this clade];

(4) West/Central Coast: south of San Francisco Bay in the Coast Ranges to San Benito and Monterey counties, presumably east of the San Andreas Fault/Salinas Valley; and

(5) Southwest/South Coast presumably west of the San Andreas Fault/Salinas Valley in Monterey County and south in the Coast Ranges.

The Feather River clade is found primarily in Plumas and Butte counties (Peek 2018). Peek's analysis found that this clade is as distinct from the other Sierra Nevada clades as the Sierra Nevada populations are from all coastal clades, meaning it was found to be deeply divergent from the rest of the clades. McCartney-Melstad et al. (2018) also recognized the Feather River watershed as distinct from the rest of the northern Sierra but not as deeply divergent from the other clades as Peek. The Feather River watershed is also the only known location where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs co-occur and where three F1 hybrids (the offspring from a cross between parents of the two species) were found (Peek 2018, R. Peek pers. comm. 2019b). In addition, Peek's (2018) genetic data provided weak support for dividing the West/Central Coast and Southwest/South Coast groups into separate clades; however, his data set consisted of fewer samples from these localities than McCartney-Melstad et al. (2018).

Previous work conducted by Lind et al. (2011), using one nuclear and two mitochondrial genes, found a somewhat similar pattern, and their results suggested that hydrologic regions and river basins were important landscape features that influenced the genetic structure of Foothill Yellow-legged Frog populations. McCartney-Melstad et al. (2018), using a much larger genomic data set with thousands of genes rather than just three, also found evidence for divergence among river basins. However, they also found nearly twice the variation among the five phylogenetic clades than among drainage basins, indicating that other geological factors in addition to current riverine basins contributed to current population structure (Ibid.). They also report that the depth of genetic divergence among Foothill Yellow-legged Frog clades exceeds that of any frog or toad species for which similar data are available on earth and recommend treating them as key management units instead of the previously suggested watershed boundaries (Ibid.). Peek (2018) concurred and stated that the Foothill Yellow-legged Frog clades represented important units that should be carefully considered during planning and implementation of conservation actions.

Levels of genetic diversity within the clades differed significantly. Genetic diversity provides populations with the evolutionary capacity to adapt to changing conditions (i.e., evolve), and its loss often signals extreme population size reductions, which can result in genetic bottlenecks and inbreeding depression that can reduce survival and reproductive success (Lande and Shannon 1996, Hoffmann and Sgrò 2011, McCartney-Melstad et al. 2018). Loss of genetic diversity in Foothill Yellow-legged Frogs largely follows a north-to-south pattern, with the southern clades (Southwest/South Coast and East/Southern Sierra) particularly exhibiting the greatest loss of nucleotide diversity (McCartney-Melstad et al. 2018, Peek 2018). In addition, these study results demonstrate that Foothill Yellow-legged Frogs have lost genetic diversity over time across their entire range except for the large Northwest/North Coast clade, which appears to have undergone a relatively recent population expansion (McCartney-Melstad et al. 2018, Peek 2018).

At a watershed scale, Dever (2007) found that tributaries to rivers and streams are important for preserving genetic diversity, and populations separated by more than 6.2 mi show signs of genetic isolation. In other words, even in the absence of anthropogenic barriers to dispersal (e.g., dams and reservoirs), individuals located more than 6.2 mi are not typically considered part of a single interbreeding population (Olson and Davis 2009). Peek (2010, 2018) reported that at this finer-scale, population structure and genetic diversity appear to be more strongly influenced by river regulation type (i.e., dammed or undammed) than to geographic distance or watershed boundaries. In general, regulated (dammed) rivers had limited gene flow and higher genetic divergence among subpopulations compared with unregulated (undammed) rivers (Peek 2010, 2018). In addition, differences in hydrologic regimes within regulated rivers affected genetic connectivity and diversity (Peek 2010, 2018). Subpopulations in hydropeaking reaches, in which pulsed flows are used for electricity generation or whitewater boating, exhibited significantly lower gene flow and genetic diversity than those in bypass reaches where water is diverted from upstream in the basin down to power generating facilities (Figure 4; Peek 2018, R. Peek pers. comm. 2019b). River regulation had a greater influence on genetic

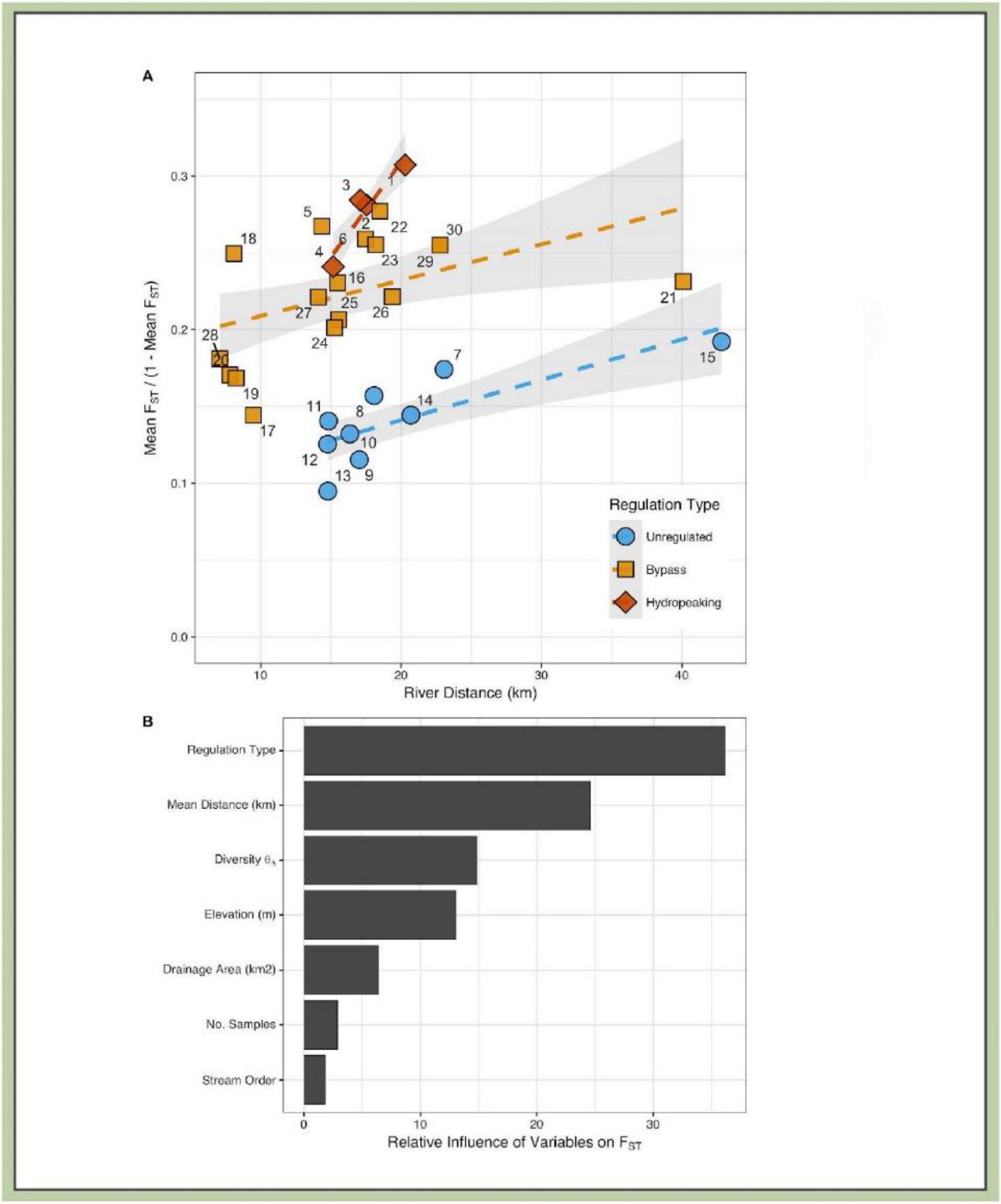

Figure 4. River regulation's relative influence on genetic differentiation from Peek (2018). A) Mean pairwise F_{ST} vs. mean river distance for each location (denoted by unique numbers); B) Relative influence of variables on F_{ST} from boosted regression tree models.

differentiation among sites than geographic distance in the Alameda Creek watershed as well (Stillwater Sciences 2012). Reduced connectivity among sites leads to lower gene flow and a loss of genetic diversity through genetic drift, which can diminish adaptability to changing environmental conditions (Palstra and Ruzzante 2008). Peek (2010) posits that given the *R. boylii* species group is estimated to be 8 million years old (Macey et al. 2001), the significant reductions in connectivity and genetic diversity over short evolutionary time periods in regulated rivers (often less than 50 years from the time of dam construction) is cause for concern with respect to population viability and persistence, particularly when combined with small population sizes.

2.5 Habitat Associations and Use

> *"These frogs are so closely restricted to streams that it is unusual to find one at a greater distance from the water than it could cover in one or two leaps."* – Richard G. Zweifel, 1955

Foothill Yellow-legged Frogs inhabit rivers and streams ranging from primarily rain-fed (coastal populations) to primarily snow-influenced (most Sierra Nevada and Klamath-Cascade populations) from headwater streams to large rivers (Bury and Sisk 1997, Wheeler et al. 2014). Occupied rivers and streams flow through a variety of vegetation types including hardwood, conifer, and valley-foothill riparian forests; mixed chaparral; and wet meadows (Hayes et al. 2016). Because the species is so widespread and can be found in so many types of habitats, the vegetation community is likely less important in determining Foothill Yellow-legged Frog occupancy and abundance than the aquatic biotic and abiotic conditions in the specific river, stream, or reach (Zweifel 1955). The species is an obligate stream-breeder, which sets it apart from other western North American ranids (Wheeler et al. 2014). Foothill Yellow-legged Frog habitat is generally characterized as partly-shaded, shallow, perennial rivers and streams with a low gradient and rocky substrate that is at least cobble-sized (Zweifel 1955, Hayes and Jennings 1988). However, the use of intermittent and ephemeral streams by post-metamorphic Foothill Yellow-legged Frogs may not be all that uncommon in some parts of the species' range in California (R. Bourque pers. comm. 2019). The species has been reported from some atypical habitats as well, including small impoundments, isolated pools in intermittent streams, and meadows along the edge of streams that lack a rocky substrate (Fitch 1938, Zweifel 1955, CDFW 2018a, Wilcox and Alvarez 2019). In addition, Wilcox and Alvarez (2019) described observations of Foothill Yellow-legged Frogs climbing a vertical, but undulating, dam wall covered in algae, suggesting that landscape features like steep, slick rock slopes may not preclude movement.

As stream-breeding poikilotherms (animals whose internal temperature varies with ambient temperature), appropriate flow velocity, temperature, and water availability are critically important to Foothill Yellow-legged Frogs (Kupferberg 1996a, Van Wagner 1996, Wheeler et al. 2006, Lind et al. 2016, Bedwell 2018). Habitat quality is also influenced by hydrologic regime (regulated vs. unregulated), substrate, presence of non-native predators and competitors, water depth, and availability of high-quality food and basking sites (Lind et al. 1996, Yarnell 2005, Wheeler et al. 2006, Catenazzi and Kupferberg 2017). Habitat suitability and use vary by life stage, sex, geographic location, watershed size, and season and can generally be categorized as breeding and rearing habitat, nonbreeding season habitat, and overwintering habitat (Van Wagner 1996, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011, Hayes et al. 2016, Catenazzi and Kupferberg 2017). Yarnell (2005) located higher densities of Foothill Yellow-legged Frogs in areas with greater habitat heterogeneity and suggested that they were selecting sites that possessed the diversity of habitats necessary to support each life stage within a relatively short distance.

2.5.1 Breeding and Rearing Habitat

Suitable breeding habitat must be connected to suitable rearing habitat for metamorphosis to be successful. When this connectivity exists, as flows decline through the season, tadpoles can follow the receding shoreline into areas of high productivity and lower predation risk as opposed to becoming trapped in isolated pools with a high risk of overheating, desiccation, and predation (Kupferberg et al. 2009c).

Several studies on Foothill Yellow-legged Frog breeding habitat, carried out across the species' range in California, reported similar findings. Foothill Yellow-legged Frogs select oviposition (egg-laying) sites within a narrow range of depths, velocities, and substrates and exhibit fidelity to breeding sites that consistently possess suitable microhabitat characteristics over time (Kupferberg 1996a, Bondi et al. 2013, Lind et al. 2016). At a coarse-spatial scale, breeding sites in rivers and large streams are often located near the confluence of tributary streams in sunny, wide, shallow reaches (Kupferberg 1996a, Yarnell 2005, GANDA 2008, Peek 2010). These areas are highly productive compared to cooler, deeper, closed-canopy sites (Catenazzi and Kupferberg 2013). At a fine spatial scale, females prefer to lay eggs in low velocity areas dominated by cobble- and boulder-sized substrates, often associated with sparsely-vegetated point bars (Kupferberg 1996a, Lind et al. 1996, Van Wagner 1996, Bondi et al. 2013, Lind et al. 2016). They tend to select areas with less variable, more stable flows, and in areas with higher flows at the time of oviposition, they place their eggs on the downstream side of large cobblestones and boulders, which protects them from being washed away (Kupferberg 1996a, Wheeler et al. 2006).

Appropriate rearing temperatures are vital for successful metamorphosis. Tadpoles grow faster and larger in warmer water to a point (Zweifel 1955; Catenazzi and Kupferberg 2017,2018). Zweifel (1955) conducted experiments on embryonic thermal tolerance and determined that the critical low was approximately 43°F, and the critical high was around 79°F. Welsh and Hodgson (2011) determined that best the single variable for predicting Foothill Yellow-legged Frog presence was temperature since none were observed below 55°F, but numbers increased significantly with increasing temperature. Catenazzi and Kupferberg (2013) measured tadpole thermal preference at 61.7-72.0°F, and the distribution of Foothill Yellow-legged Frog populations across a watershed was consistent within this temperature range. When the daily average temperatures during the warmest month of the year were below 61°F, tadpoles were absent under closed canopy and scarce even with an open canopy (Ibid.). Catenazzi and Kupferberg (2017) found regional differences in apparently suitable breeding temperatures. Inland populations from primarily snowmelt-fed systems with relatively cold water were relegated to reaches that are warmer on average during the warmest 30 days of the year than coastal populations in the chiefly rainfall-fed, and thus warmer, systems (63.7-75.6°F vs. 60.3-71.6°F, respectively). However, experiments on tadpole thermal preference demonstrated that individuals from different source populations selected similar rearing temperatures, which presumably optimized development (Ibid.). In regulated systems, where water released from dams is often colder than normal, suitable rearing temperatures downstream may be limited (Wheeler et al. 2014, Catenazzi and Kupferberg 2017).

Appropriate flow velocities are also critical for survival to metamorphosis. The velocity at which Foothill Yellow-legged Frog egg masses shear away from the substrate they are adhered to varies according to factors such as depth and degree to which the eggs are sheltered (Spring Rivers Ecological Sciences 2003). This critical velocity is expected to decrease as the egg mass ages due to the reduced structural integrity of the protective jelly envelopes (Hayes et al. 2016). Short duration increases in flow velocity may be tolerated if the egg masses are somewhat protected, but sustained high velocities increase the likelihood of detachment (Kupferberg 1996a, Spring Rivers Ecological Sciences 2003). Hatchlings and tadpoles about to undergo metamorphosis are relatively poor swimmers and require especially slow, stable flows during these stages of development (Kupferberg et al. 2011b). Tadpoles respond to increasing flows by swimming against the current to maintain position for a short period of time and eventually swimming to the bottom and seeking refuge in the rocky substrate's interstitial spaces (Ibid.). When tadpoles are exposed to repeated increases in velocities, their growth and development are delayed (Ibid.). Under experimental conditions, the critical velocity at which tadpoles were swept downstream ranged between 0.66-1.31 ft/s; however, as they reach metamorphosis it decreases to as low as 0.33 ft/s (Ibid.).

2.5.2 Nonbreeding Season Habitat

Post-metamorphic Foothill Yellow-legged Frogs utilize a more diverse range of habitats and are much more dispersed during the nonbreeding season than the breeding season. Microhabitat preferences appear to vary by location and season, but some patterns are common across the species' range. Foothill Yellow-legged Frogs tend to remain close to the water's edge (average <10 ft); select sunny areas with limited canopy cover; and are often associated with riffles and pools (Zweifel 1955, Hayes and Jennings 1988, Van Wagner 1996, Welsh et al. 2005, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011). Adequate water, food resources, cover from predators, ability to thermoregulate (e.g., presence of basking sites and cool refugia), and absence of non-native predators are important components of nonbreeding season habitat (Hayes and Jennings 1988, Van Wagner 1996, Catenazzi and Kupferberg 2013).

2.5.3 Overwintering Habitat

Overwintering habitat varies depending on local conditions, but as with the rest of the year, Foothill Yellow-legged Frogs are most often found in or near water where they can forage and take cover from predators and high discharge events (Storer 1925, Zweifel 1955). In larger streams and rivers, Foothill Yellow-legged Frogs are often found along tributaries during the winter where the risk of being displaced by heavy flows is reduced (Kupferberg 1996a, Gonsolin 2010). Bourque (2008) found 36.4% of adult females used intermittent and ephemeral tributaries during the overwintering season. Van Wagner (1996) located most overwintering Foothill Yellow-legged Frogs using pools with cover such as boulders, root wads, and woody debris. During high flow events, they moved to the stream's edge and took cover under vegetation like sedges (*Carex* sp.) or leaf litter (Ibid.). Rombough (2006) found most

Foothill Yellow-legged Frogs under woody debris along the high waterline and often using seeps along the stream-edge, which provided them with moisture, a thermally stable environment, and prey.

Exceptions to the pattern of remaining near the stream's edge during winter have been reported. Cook et al. (2012) observed dozens of juvenile Foothill Yellow-legged Frogs traveling over land, as opposed to using riparian corridors. They were found using upland habitats with an average distance of 234 ft from water (range: 52-1,086 ft) (Ibid.). In another example, a single subadult that was found adjacent to a large wetland complex 2,723 ft straight-line distance from the wetted edge of the Van Duzen River, although it is possible the wetland was connected to the river via a spillway or drainage that may have served as the movement corridor (CDFW 2018a, R. Bourque pers. comm. 2019).

2.5.4 Seasonal Activity and Movements

Because Foothill Yellow-legged Frogs occupy areas with relatively mild winter temperatures, they can be active year-round, although at low temperatures (<44°F), they become lethargic (Storer 1925, Zweifel 1955, Van Wagner 1996, Bourque 2008). They are active both day and night, and during the day adults are often observed basking on warm objects such as sun-heated rocks, although this is also when their detectability is highest (Fellers 2005, Wheeler et al. 2005). For example, Gonsolin (2010) located radio-telemetered Foothill Yellow-legged Frogs under substrate a third of the time and underwater a quarter of the time, but nearly all his detections of frogs without transmitters were basking.

Adult Foothill Yellow-legged Frogs migrate from their overwintering sites to breeding habitat in the spring, often from a tributary to its confluence with a larger stream or river. In areas where tributaries dry down, juveniles also make this downstream movement (Haggarty 2006). When the tributary itself is perennial and provides suitable breeding habitat, the frogs may not undertake these long-distance movements (Gonsolin 2010). Cues for adults to initiate this migration to breeding sites are somewhat enigmatic and vary by location, elevation, and amount of precipitation (S. Kupferberg and A. Lind pers. comm. 2017). They can include day length, water temperature, and sex (GANDA 2008, Gonsolin 2010, Yarnell et al. 2010, Wheeler et al. 2018). Males initiate movements to breeding sites where they congregate in leks (areas of aggregation for courtship displays), and females arrive later and over a longer period (Wheeler and Welsh 2008, Gonsolin 2010). Most males utilize breeding sites associated with their overwintering tributaries, but some move substantial distances to other sites and may use more than one breeding site in the same season (Wheeler et al. 2006, GANDA 2008).

While the predictable hydrograph in California consists of wet winters with high spring flows and dry summers with low flows, the timing and quantity of seasonal discharge can vary significantly from year to year. The timing of oviposition can influence offspring growth and survival. Early breeders risk scouring of egg masses from their substrate by late spring storms in wet years or desiccation if waters recede rapidly, but when they successfully hatch, tadpoles benefit from a longer growing season, which can enable them to metamorphose at a larger size and increase their likelihood of survival (Railsback et al. 2016). Later breeders are less likely to have their eggs scoured away or desiccated because flows are generally more stable, but they have fewer mate choices, and their tadpoles have a shorter growing period before metamorphosis, reducing their chance of survival (Ibid.). Some evidence indicates larger females, who coincidentally lay larger clutches, breed earlier (Kupferberg et al. 2009c, Gonsolin 2010). Consequently, early season scouring or stranding of egg masses or tadpoles can disproportionately impact the population's reproductive output because later breeders produce fewer and smaller eggs per clutch (Kupferberg et al. 2009c, Gonsolin 2010).

Timing of oviposition is often a function of water temperature and flow, but it consistently occurs on the descending limb of the hydrograph, which is the period of time when high spring discharge gradually recedes toward low summer base flow (Kupferberg 1996a, GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010, Yarnell et al. 2010, Yarnell et al. 2013). Under natural conditions, the timing coincides with intermittent tributaries drying down and increases in algal blooms that provide forage for tadpoles (Haggarty 2006, Power et al. 2008). Even in regulated systems, hydrodynamic modeling indicated that managing for flow recessions with down-ramping rates similar to those observed in unregulated systems (less than 10% per day) provided the most diverse hydraulic habitat for an appropriate duration in spring to support native species and maximize aquatic biodiversity (Yarnell et al. 2013). At lower elevations, breeding can start in late March or early April, and at mid-elevations, breeding typically occurs in mid-May to mid-June (Gonsolin 2010, S. Kupferberg and A. Lind pers. comm. 2017). The time of year a population initiates breeding can vary by as much as two months among water years, occurring later at deeper sites when colder water becomes warmer (Wheeler et al. 2018, R. Peek pers. comm. 2019a). In wetter years, delayed breeding into early July can occur in some colder snowmelt systems (Yarnell et al. 2013, GANDA 2018).

A population's period of oviposition can also vary from two weeks to three months, meaning they could be considered explosive breeders at some sites and prolonged breeders at others (Storer 1925, Zweifel 1955, Van Wagner 1996, Ashton et al. 1997, Wheeler and Welsh 2008). Water temperature typically warms to over 50°F before breeding commences (GANDA 2008, Gonsolin 2010, Wheeler et al. 2018). Wheeler and Welsh (2008) observed Foothill Yellow-legged Frogs breeding when flows were below 02 ft/s, pausing during increased flows until they receded, and GANDA (2008) reported breeding initiated when flow decreased to less than 55% above base flow.

Male Foothill Yellow-legged Frogs spend more time at breeding sites during the season than females, many of whom leave immediately after laying their eggs (GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010). Daily movements are usually short (<1 ft), but some individuals travel substantial distances: median 232 ft/day in spring and 104 ft/day in fall/winter, nearly always using streams as movement corridors (Van Wagner 1996, Bourque 2008, Gonsolin 2010). The maximum reported movement rate is 0.86 mi/day, and the longest seasonal (post-breeding) daily distance reported is 4.37 mi by a female that traveled up a dry tributary and over a ridge before returning to and moving up the mainstem creek (Bourque 2008). Movements during the non-breeding season are typically in response to drying channels or during rain events (Bourque 2008, Gonsolin 2010, Cook et al. 2012).

Hatchling Foothill Yellow-legged Frogs tend to remain with what is left of the egg mass for several days before dispersing into the interstitial spaces in the substrate (Ashton et al. 1997). They often move downstream in areas of moderate flow and will follow the location of warm water in the channel throughout the day (Brattstrom 1962, Ashton et al. 1997, Kupferberg et al. 2011a). Tadpoles usually

metamorphose in late August or early September (S. Kupferberg and A. Lind pers. comm. 2017). Twitty et al. (1967) reported that newly metamorphosed Foothill Yellow-legged Frogs mostly migrated upstream, which may be an evolutionary mechanism to return to their natal site after being washed downstream (Ashton et al. 1997).

2.5.5 Home Range and Territoriality

Foothill Yellow-legged Frogs exhibit a lek-type mating system in which males aggregate at the breeding site and establish calling territories (Wheeler and Welsh 2008, Bondi et al. 2013). The species has a relatively large calling repertoire for western North American ranids with seven unique vocalizations recorded (Silver 2017). Some of these can be reasonably attributed to territory defense and mate attraction communications (MacTeague and Northen 1993, Silver 2017). Physical aggression among males during the breeding season has been reported (Rombough and Hayes 2007, Wheeler and Welsh 2008, Wilcox and Alvarez 2019). In addition, Wheeler and Welsh (2008) observed a non-random mating pattern in which males engaged in amplexus with females were larger than males never seen in amplexus, suggesting either physical competition or female preference for larger individuals. Very little information has been published on Foothill Yellow-legged Frog home range size. Wheeler and Welsh (2008) studied males during a 17-day period during breeding season and classified some of them as "site faithful" based on their movements and calculated their home ranges. Two-thirds of males tracked were site faithful, and their mean home range size was 6.24 ft^2 (SE = 1.08 ft^2) (Ibid.). In contrast, perhaps because the study took place over a longer time period, Bourque (2008) reported approximately half of the males he tracked during the spring were mobile, and the other half were sedentary. The median distances traveled along the creek (a proxy for home range size since they rarely leave the riparian corridor) for mobile and sedentary males were 489 ft and 18 ft, respectively.

2.6 Diet and Predators

Foothill Yellow-legged Frog diet varies by life stage and likely body size. Tadpoles graze on periphyton (algae growing on submerged surfaces) scraped from rocks and vegetation and grow faster, and to a larger size, when it contains a greater proportion of epiphytic diatoms with nitrogen-fixing endosymbionts (*Epithemia* spp.), which are high in protein and fat (Kupferberg 1997b, Fellers 2005, Hayes et al. 2016, Catenazzi and Kupferberg 2017). Tadpoles may also forage on necrotic tissue from dead bivalves and other tadpoles, or more likely the algae growing on them (Ashton et al. 1997, Hayes et al. 2016). Post-metamorphic Foothill Yellow-legged Frogs primarily feed on a wide variety of terrestrial arthropods but also some aquatic invertebrates (Fitch 1936, Van Wagner 1996, Haggarty 2006). Most of their diet consists of insects and arachnids (Van Wagner 1996, Haggarty 2006, Hothem et al. 2009). Haggarty (2006) did not identify any preferred taxonomic groups, but she noted larger Foothill Yellow-legged Frogs consumed a greater proportion of large prey items compared to smaller individuals, suggesting the species may be gape-limited generalist predators. Hothem et al. (2009) found mammal hair and bones in a Foothill Yellow-legged Frog stomach. Adult Foothill Yellow-legged Frogs, like many other ranids, also cannibalize conspecifics (Wiseman and Bettaso 2007). In the fall when young-of-year are abundant, they may provide an important source of nutrition for adults prior to overwintering (Ibid.).

Foothill Yellow-legged Frogs are preyed upon by several native and introduced species, including each other as described above. Some predators target specific life stages, while others may consume multiple stages. Several species of gartersnakes (genus *Thamnophis*) are the primary and most widespread group of native predators on Foothill Yellow-legged Frog tadpoles through adults (Fitch 1941, Fox 1952, Zweifel 1955, Lind and Welsh 1994, Ashton et al. 1997, Wiseman and Bettaso 2007, Gonsolin 2010). Table 1 lists other known and suspected predators of Foothill Yellow-legged Frogs.

3.0 STATUS AND TRENDS IN CALIFORNIA

3.1 Administrative Status

3.1.1 Sensitive Species

The Foothill Yellow-legged Frog is listed as a Sensitive Species by the U.S. Bureau of Land Management (BLM) and USDA Forest Service (Forest Service). These agencies define Sensitive Species as those species that require special management consideration to promote their conservation and reduce the likelihood and need for future listing under the ESA.

3.1.2 California Species of Special Concern

The Department's Species of Special Concern (SSC) designation is similar to the federal Sensitive Species designation. It is administrative, rather than regulatory in nature, and intended to focus attention on animals at conservation risk. The designation is used to stimulate needed research on poorly known species and to target the conservation and recovery of these animals before they meet the CESA criteria for listing as threatened or endangered (Thomson et al. 2016). The Foothill Yellow-legged Frog is listed as a Priority 1 (highest risk) SSC (Ibid.).

3.2 Trends in Distribution and Abundance

3.2.1 Range-wide in California

Range is the general geographical area in which an organism occurs. For purposes of CESA and this Status Review, the range is the species' California range (*Cal. Forestry Assn. v. Cal. Fish and Game Com.* (2007) 156 Cal.App.4th 1535, 1551). Historical documentation of Foothill Yellow-legged Frog distribution and abundance is somewhat haphazard. However, systematic range-wide assessments of Foothill Yellow-legged Frog distribution were conducted relatively recently. Estimates of relative abundance or population trends are less common at both local and range-wide scales. This makes assessing trends in distribution and abundance difficult despite a relatively large number of observations compared to many other species tracked by the California Natural Diversity Database (CNDDB). A detailed account of what has been documented within the National Parks and National Forests in California can be found in Appendix 3 of the *Foothill Yellow-legged Frogs Conservation Assessment in California* (Hayes et al. 2016). The CNDDB contained 2,411 Foothill Yellow-legged Frog occurrences in its August 2019 edition, at least 529 (22%) of which were observed in 2014 or more recently.

Table 1. Confirmed and potential Foothill Yellow-legged Frog predators in California in addition to gartersnakes (*Thamnophis* spp.)

Common Name	Scientific Name	Classification	Native	Prey Life Stage(s)	Sources
Caddisfly (larva)	*Dicosmoecus gilvipes*	Insect	Yes	Embryos (eggs)	Rombough and Hayes 2005
Dragonfly (nymph)	*Aeshna walker*	Insect	Yes	Larvae	Catenazzi and Kupferberg 2018
Waterscorpion	*Ranatra brevicollis*	Insect	Yes	Larvae	Catenaazi and Kupferberg 2018
Signal Crayfish	*Pacifastacus leniusculus*	Crustacean	No	Embryos (eggs) and Larvae	Rombough and Hayes 2005; Wiseman et al. 2005
Speckled Dace	*Rhinichthys osculus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Reticulate Sculpin	*Cottus perplexus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Sacramento Pikeminnow	*Ptychocheilus grandis*	Fish	Yes*	Embryos (eggs) to Adults	Corum 2003; Ashton and Nakamoto 2007
Sunfishes	Family Centrachidae	Fish	No	Larvae	Moyle 1973; Hayes and Jennings 1986
Catfishes	Family Ictaluridae	Fish	No	Larvae	Moyle 1973; Hayes and Jennings 1986
Rough-skinned Newt	*Taricha granulosa*	Amphibian	Yes	Embryos (eggs)	Evenden 1948
California Giant Salamander	*Dicamptodon ensatus*	Amphibian	Yes	Larvae	Fidenci 2006
American Bullfrog	*Rana catesbeiana*	Amphibian	No	Larvae to Adults	Crayon 1998; Hothem et al. 2009
California Red-legged Frog	*Rana draytonii*	Amphibian	Yes	Larvae to Adults	Gonsolin 2010
American Robin	*Turdus migratorius*	Bird	Yes	Larvae	Gonsolin 2010
Common Merganser	*Mergus merganser*	Bird	Yes	Larvae	Gonsolin 2010
American Dipper	*Cinclus mexicanus*	Bird	Yes	Larvae	Ashton et al. 1997
Mallard	*Anas platyrhynchos*	Bird	Yes	Adults	Rombough et al. 2005
Raccoon	*Procyon lotor*	Mammal	Yes	Larvae to Adults	Zweifel 1955; Ashton et al. 1997
River Otter	*Lontra canadensis*	Mammal	Yes	Larvae to Adults	S. Kupferberg pers. comm. 2019; T. Rose pers. comm. 2014

* Introduced to the Eel River, location of documented predation; Foothill Yellow-legged Frogs are extirpated from most areas of historical range overlap

A few wide-ranging historical survey efforts that included Foothill Yellow-legged Frogs exist. Reports from early naturalists suggest Foothill Yellow-legged Frogs were relatively common in the Coast Ranges as far south as central Monterey County, in eastern Tehama County, and in the foothills in and near Yosemite National Park (Grinnell and Storer 1924, Storer 1925, Grinnell et al. 1930, Martin 1940). In addition to these areas, relatively large numbers of Foothill Yellow-legged Frogs (17-35 individuals) were collected at sites in the central and southern Sierra Nevada and the San Gabriel Mountains between 1911 and 1950 (Hayes et al. 2016). Widespread disappearances of Foothill Yellow-legged Frog populations were documented as early as the 1970s and 80s in southern California, the southern Coast Range, and the central and southern Sierra Nevada foothills (Moyle 1973, Sweet 1983).

Twenty-five years ago, the Department published the first edition of *Amphibians and Reptile Species of Special Concern in California* (Jennings and Hayes 1994). The authors revisited hundreds of localities between 1988 and 1991 that had historically been occupied by Foothill Yellow-legged Frogs and consulted local experts to determine presumed extant or extirpated status. Based on these survey results and stressors observed on the landscape, they considered Foothill Yellow-legged Frogs endangered in central and southern California south of the Salinas River in Monterey County. They considered the species threatened in the west slope drainages of the Cascade Mountains and Sierra Nevada east of the Central Valley, and they considered the remainder of the range to be of special concern (Ibid.).

Fellers (2005) and his field crews conducted surveys for Foothill Yellow-legged Frogs throughout California. They visited 804 sites across 40 counties with suitable habitat within the species' historical range. They detected at least one individual at 213 sites (26.5% of those surveyed) over 28 counties. They located Foothill Yellow-legged Frogs in approximately 40% of streams in the North Coast, 30% in the Cascade Mountains and south of San Francisco in the Coast Range, and 12% in the Sierra Nevada. Fellers estimated population abundance was 20 or more adults at only 14% of the sites where the species was found and noted the largest and most robust populations occurred along the North Coast. In addition, to determine status of Foothill Yellow-legged Frogs across the species' range and potential causes for declines between 2000 and 2002, Lind (2005) used previously published status accounts, species expert and local biologist professional opinions, and field visits to historically occupied sites. She determined that Foothill Yellow-legged Frogs had disappeared from 201 of 394 of the sites, representing just over 50%. The coarse-scale trend of Foothill Yellow-legged Frog populations in California is one of greater declines and extirpations in lower elevations and latitudes (Davidson et al. 2002).

Few site-specific population trend data are available from which to evaluate status. However, some long-term monitoring efforts have used egg mass counts as a proxy to estimate adult breeding female abundance. The results of these studies revealed extreme interannual variability in number of egg masses laid (Ashton et al. 2010, S. Kupferberg and M. Power pers. comm. 2015, Peek and Kupferberg 2016). In a meta-analysis of egg mass count data collected across the species' range in California over the past 25 years, Peek and Kupferberg (2016) reported declines in two unregulated rivers and an increase in another. Their models did not detect any significant trends in abundance across different locations or regulation type (dammed or undammed); however, high interannual variability can render trend detection difficult. Interannual variability was substantially greater in regulated rivers vs.

unregulated; the median coefficients of variation were 66.9% and 41.6%, respectively (Ibid.). The greater variability in regulated rivers decreases the probability of identifying significant declines, and coupled with low abundance, it can lead to populations dropping below a density necessary for persistence undetected, resulting in extirpation.

Regional differences in Foothill Yellow-legged Frog persistence across its range have been recognized for nearly 50 years (i.e., more extirpations documented in the south than other parts of the range). Because of these differences and the recent availability of new landscape genomic data, more detailed descriptions of trends in Foothill Yellow-legged Frog population distribution and abundance in California are evaluated by clade below. Figure 5 depicts Foothill Yellow-legged Frog localities across all clades in California by the most recent confirmed sighting in the datasets available to the Department within a Public Land Survey System (PLSS) section. “Transition Zones” are those areas where the exact clade boundaries are unknown due to a lack of samples. In addition, while not depicted as an area of uncertainty, no genetic samples have been evaluated from south of the extant population in northern San Luis Obispo County, in the Sutter Buttes in Sutter County, or northeastern Plumas County. It is possible there were historically more clades than is currently understood. For management purposes and the Department’s listing recommendation using the best available science, clade boundaries were delineated along commonly recognized geographic features like county lines, watershed subbasin (HU8) boundaries, and anthropogenic linear features that coincide as closely as possible with what is known about Foothill Yellow-legged Frog genetic population structure (Figure 6).

Caution should be exercised in comparing the following observation data across the species’ range and across time since survey effort and reporting are not standardized. These data can be useful for making some general inferences about distribution, abundance, and trends. For instance, the species was present at a location at least as recently as the date of the record, assuming the species was correctly identified. However, this only works in the affirmative. For example, at a site where the last time the species was seen was 75 years ago, the species may continue to persist there if no one surveyed it adequately since the original observation. CNDDB staff use information on land use conversion, subsequent survey results, and biological reports to categorize an occurrence location as “extirpated” or “possibly extirpated”.

3.2.2 Northwest/North Coast Clade

The current known range of Northwest/North Coast clade extends from north of San Francisco Bay through the Coast Range and Klamath Mountains to the northern limit of the Foothill Yellow-legged Frog’s range and east through the Cascade Range. For management purposes and the Department’s listing recommendation, and based on the best available science, the boundaries of the Northwest/North Coast clade include the following whole counties: Colusa, Del Norte, Glenn, Humboldt, Lake, Marin, Mendocino, Napa, Shasta, Solano, Sonoma, Tehama, Trinity, and Yolo. Portions of Butte, Lassen, Modoc, and Siskiyou counties are also included in this clade and are delineated by the following watershed subbasins: Applegate, Big-Chico Creek-Sacramento, Lower Klamath, Lower Pit, McCloud, Sacramento Headwaters, Salmon, Scott, Shasta, and Upper Klamath (Figure 6). This clade covers the largest geographic area and contains the greatest amount of genetic diversity

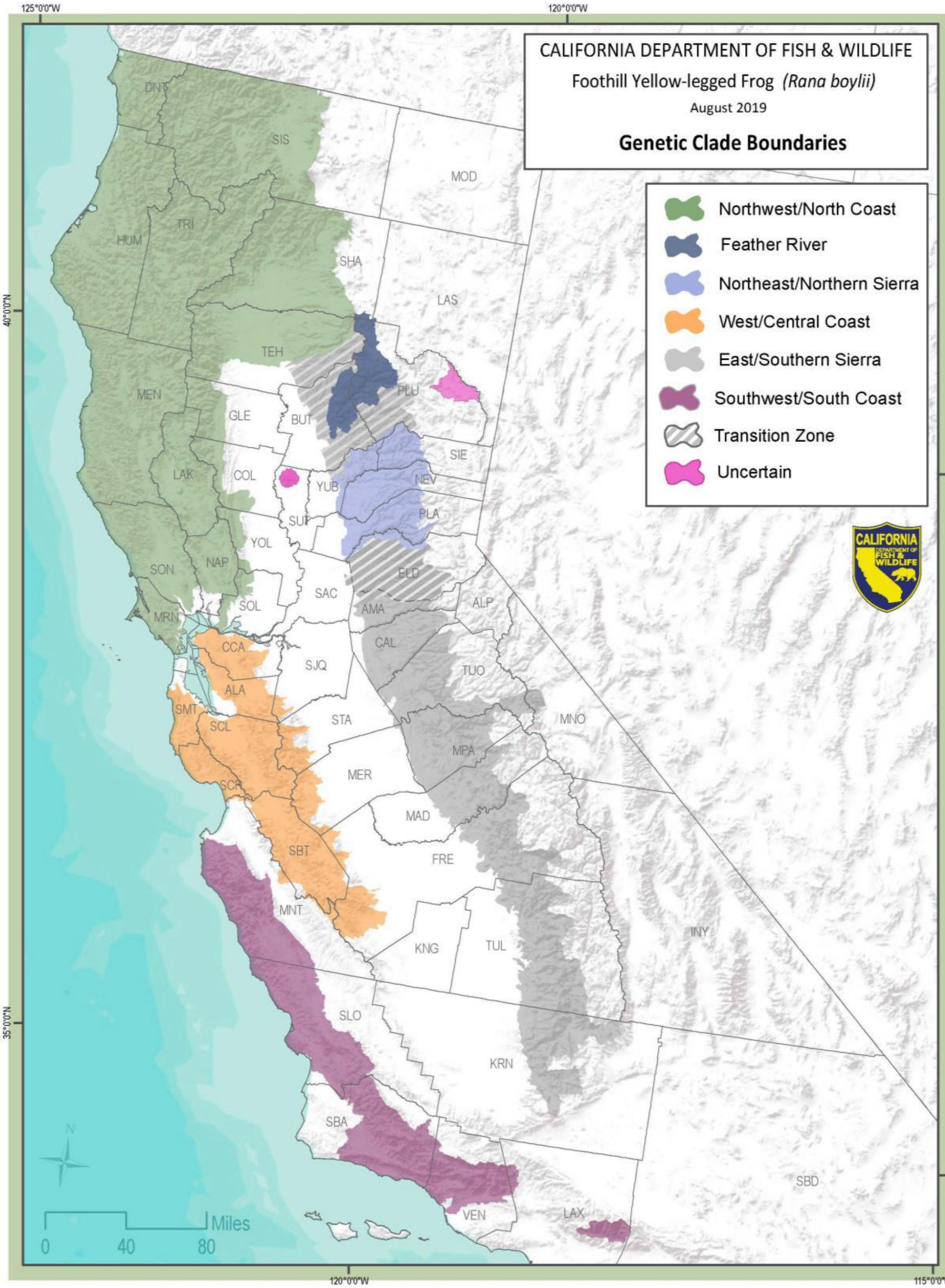

Figure 5. California Foothill Yellow-legged Frog occurrences from 1889-2019 overlaying the species' range and clade boundaries by most recent sighting in a Public Land Survey System section (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

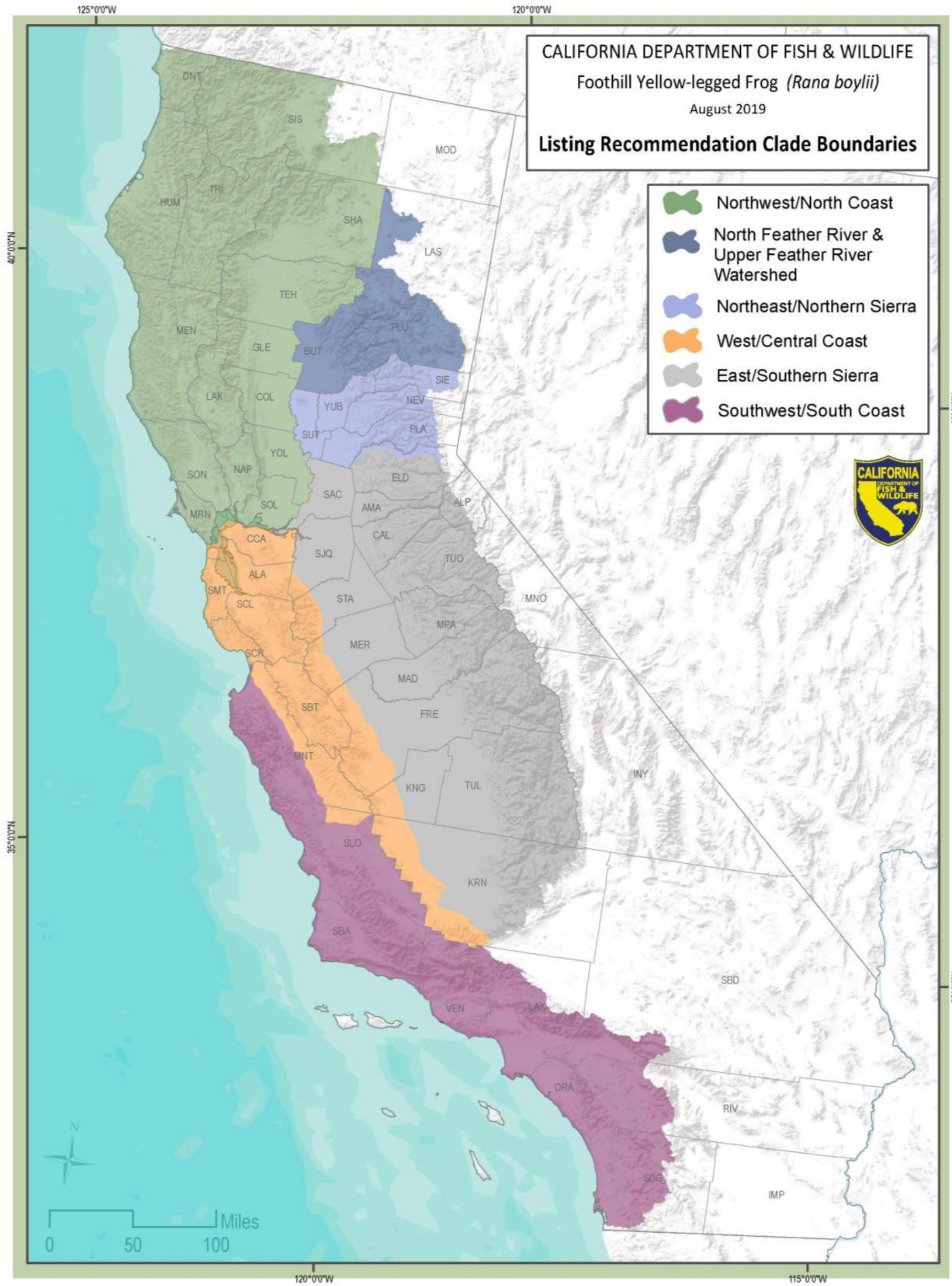

Figure 6. Foothill Yellow-legged Frog clade boundaries for management purposes and the Department's listing recommendation

(McCartney-Melstad et al. 2018, Peek 2018). In addition, it is the only clade with an increasing trend in genetic diversity (Peek 2018).

Early records note the comparatively high abundance of Foothill Yellow-legged Frogs in this area. Storer (1925) described Foothill Yellow-legged Frogs as very common in many of Coast Range streams north of San Francisco Bay, and Cope (1879,1883 as cited in Hayes et al. 2016) noted they were "rather abundant in the mountainous regions of northern California." In addition, relatively large collections occurred over short periods of time in this region in the late 1800s and the first half of the 20th century (Hayes et al. 2016). Nineteen were taken over two weeks in 1893 along Orrs Creek, a tributary to the Russian River, and 40 from near Willits (both in Mendocino County) in 1911; 112 were collected over three days at Skaggs Spring (Sonoma County) in 1911; 57 were taken in one day along Lagunitas Creek (Marin County) in 1928; and 50 were collected in one day near Denny (Trinity County) in 1955 (Ibid.).

A few long-term Foothill Yellow-legged Frog egg mass monitoring efforts undertaken within this clade's boundaries found densities vary significantly, often based on river regulation type, and documented several robust populations. The Green Diamond Resources Company has monitored a stretch of the Mad River near Blue Lake (Humboldt County) since 2008 (GDRC 2018). The greatest published density of Foothill Yellow-legged Frog egg masses was documented here in 2009 at 520.7 egg masses/mi (Bourque and Bettaso 2011). However, in 2017, surveyors counted 1,006 egg masses/mi along the same reach (GDRC 2018). At its lowest during this period, egg mass density was calculated at 115.1/mi in 2010, although this count occurred after a flooding even that likely scoured over half of the egg masses laid that season (GDRC 2018, R. Bourque pers. comm. 2019). During a single day survey in 2017 along approximately 1.3 mi of Redwood Creek in Redwood National Park (Humboldt County), 2,009 young and 126 adult Foothill Yellow-legged Frogs were found (D. Anderson pers. comm. 2017). Some reaches of the South Fork Eel River (Mendocino County) also support high densities of Foothill Yellow-legged Frogs. Kupferberg (pers. comm. 2018) recorded 333 and 171 egg masses/mi along two stretches in 2016, and 324 and 189 egg masses/mi in 2017. However, other reaches yielded counts as low as 9.8 and 13.5 egg masses/mi (Ibid.). In the Angelo Reserve (an unregulated reach), the 24-year mean density was 175.4/mi (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015). In contrast, a 10-year mean density of egg masses below Lewiston Dam on the Trinity River (Trinity County) was 1.43/mi (Ibid.).

Figure 7 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, Biological Information Observation System (BIOS) datasets, and personal communications that are color coded by the most recent date of detection. Nearly 65% of Foothill Yellow-legged Frog CNDDB records (1,558) occur within this clade, and recent observations (2014 and later) were made in at least 366 areas (CNDDB 2019). The species remains widespread within many watersheds, although most observations only verify presence, or fewer than ten individuals or egg masses are recorded (Ibid.). Documented extirpations are comparatively rare (Figure 8), and nearly all occurred just north of the high-populated San Francisco Bay area (Ibid.).

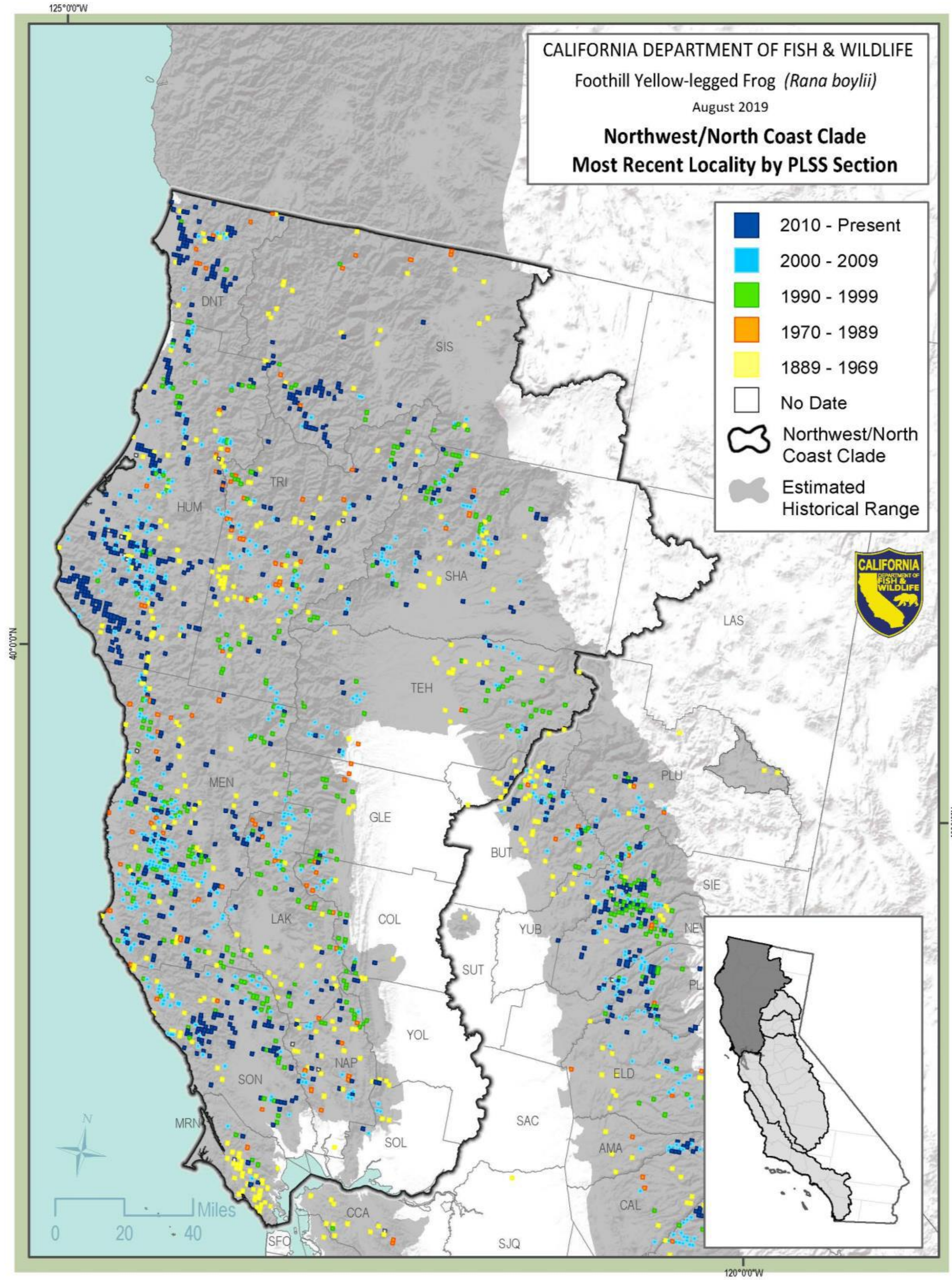

Figure 7. Northwest/North Coast Foothill Yellow-legged Frog clade observations from 1889-2019 by most recent sighting in a Public Land Survey System section (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

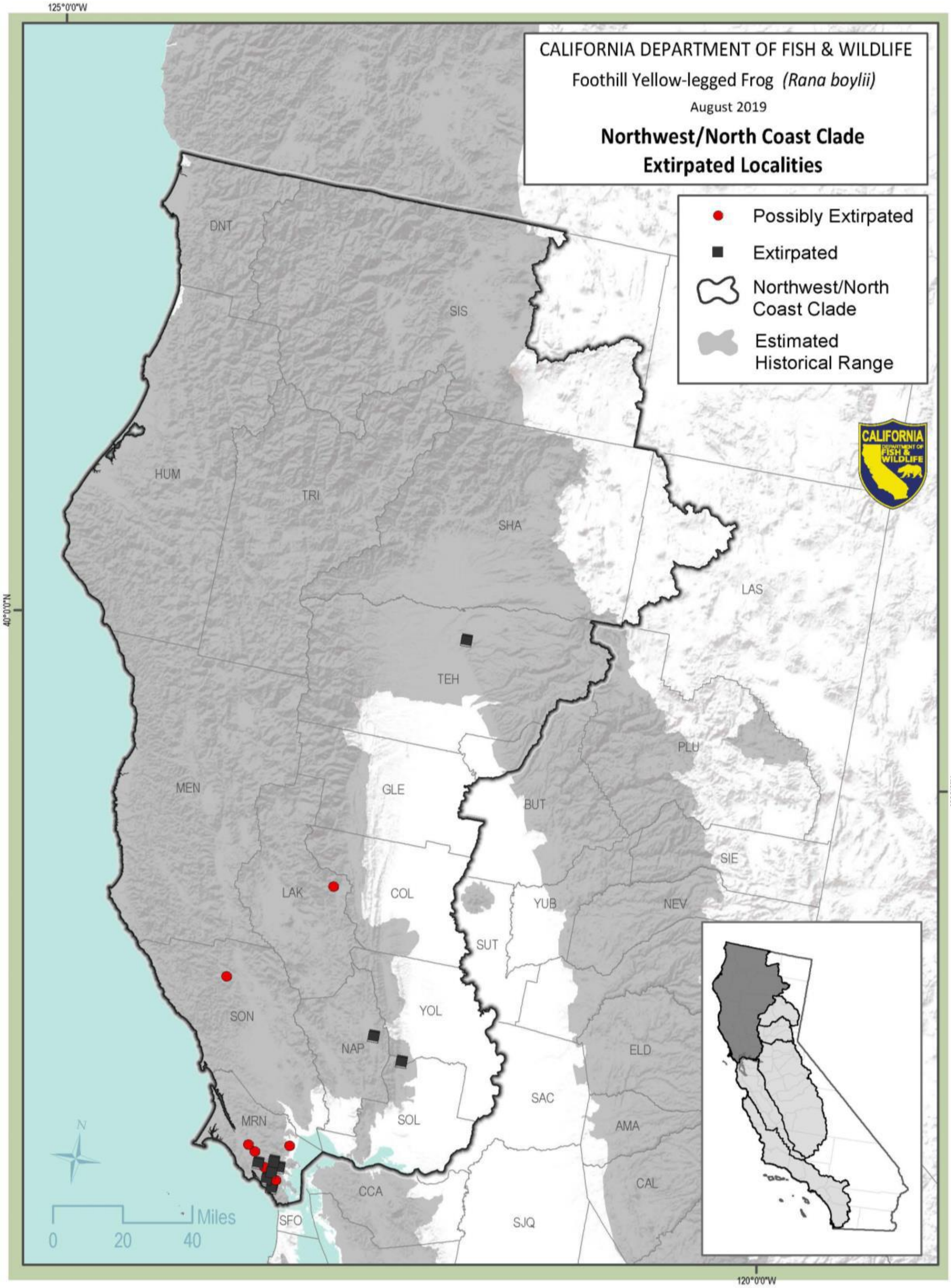

Figure 8. Possibly extirpated and extirpated Northwest/North Coast Foothill Yellow-legged Frog clade occurrences (CNDDB)

3.2.3 Feather River Clade

The Feather River clade was included in the Northeast clade as defined by McCartney-Melstad et al. (2018), but according to Peek (2018), it is very distinct and located primarily in Plumas and Butte counties. No genetic samples were available for testing from the disjunct population in northeastern Plumas County before it was extirpated. If these were correctly identified Foothill Yellow-legged Frogs, as opposed to Sierra Nevada Yellow-legged Frogs, they may have belonged to a separate clade. However, for management purposes and the Department's listing recommendation, and based on the best available science, the boundaries of the Feather River clade include the following subbasins in Butte, Lassen, Plumas, and Sierra counties: Butte Creek, East Branch of North Fork Feather, Honcut Headwaters-Lower Feather, Middle Fork Feather, and North Fork Feather (Figure 6).

In general, there is a paucity of historical Foothill Yellow-legged Frog data for west-slope Sierra Nevada streams, particularly in the lower elevations of the Sacramento Valley, and no quantitative abundance data exist prior to major changes in the landscape (i.e., mining, dams, and diversions) or the introduction of non-native species (Hayes et al. 2016). Foothill Yellow-legged Frogs were collected frequently from the Plumas National Forest area in small numbers from the turn of the 20th century through the 1970s (Ibid.). Estimates of relative abundance are not clear from the records, but they suggest the species was somewhat widespread in this area.

More recently, Foothill Yellow-legged Frog populations in the Sierra Nevada have been the subject of a focused surveys and research associated with relicensing of hydropower generating dams by the Federal Energy Regulatory Commission (FERC). Foothill Yellow-legged Frogs have been observed in at least 110 locations within this clade, 24 (22%) of which were in 2014 or later (CNDDB 2019). As with the rest of the range, most records are observations of only a few individuals; however, many observations occurred over multiple years, and in some cases all life stages were observed over multiple years (Ibid). The populations appear to persist even with the small numbers reported. Figure 9 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, BIOS, and personal communications that are color coded by the most recent date of detection. Documented extirpations are shown in Figure 10 and occur in lower elevation sites closer to the Sacramento Valley (Ibid.).

The only long-term consistent survey effort in this area has been occurring on the North Fork Feather River along the Cresta and Poe reaches (GANDA 2018). The Cresta reach's subpopulation declined significantly in 2006 and never recovered despite modification of the flow regime to reduce egg mass and tadpole scouring and some habitat restoration (Ibid.). A pilot project to augment the Cresta reach's subpopulation through in situ captive rearing was initiated in 2017 (Dillingham et al. 2018). It resulted in the highest number of young-of-year Foothill Yellow-legged Frogs recorded during fall surveys since researchers started keeping count (Ibid.). The number of egg masses laid in the Poe reach varies substantially year-to-year, from a low of 26 in 2001 to a high of 154 in 2015 and back down to 36 in 2017 (GANDA 2018).

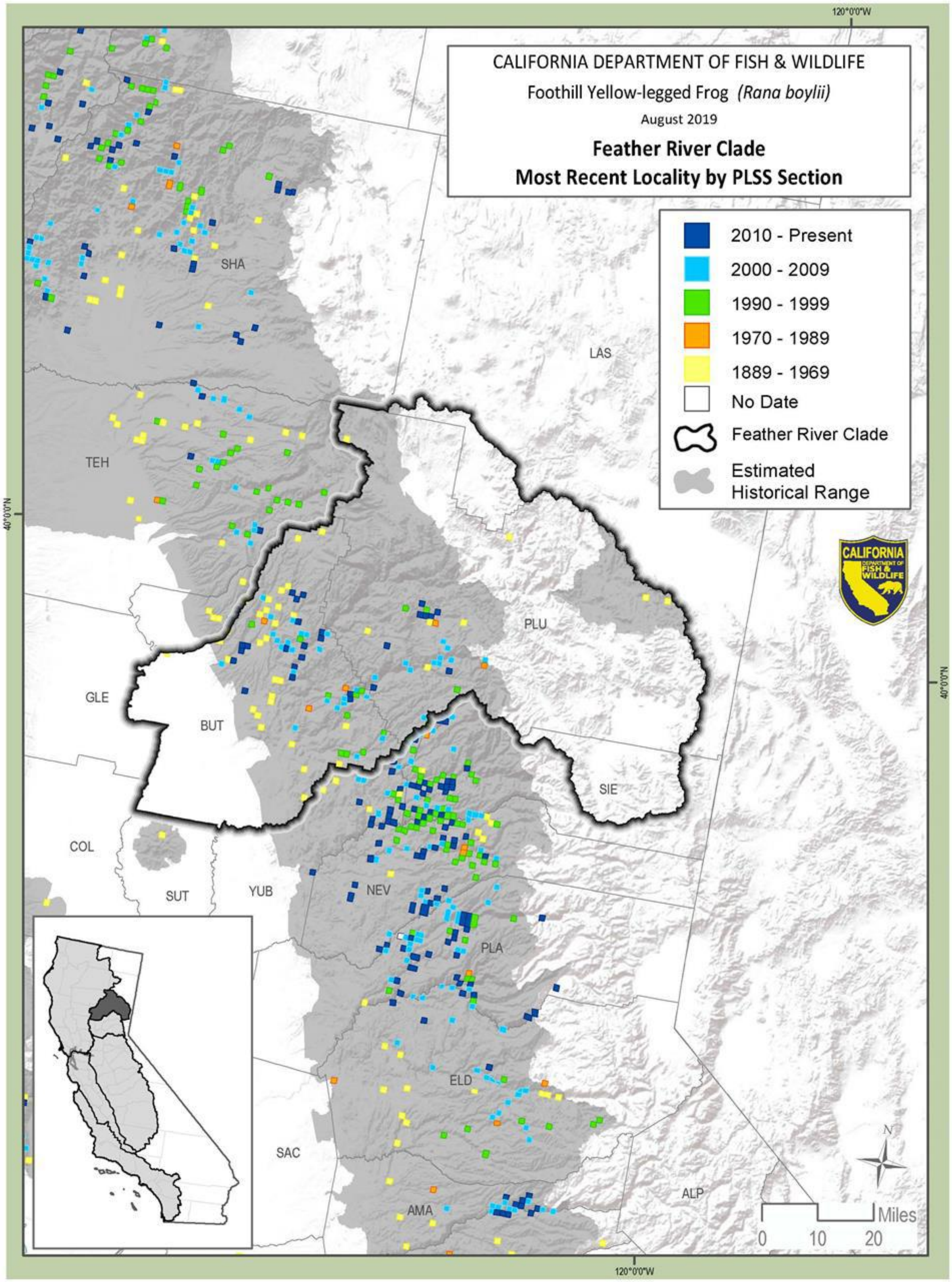

Figure 9. Feather River Foothill Yellow-legged Frog clade observations from 1889-2019 by most recent sighting in a Public Land Survey System section (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

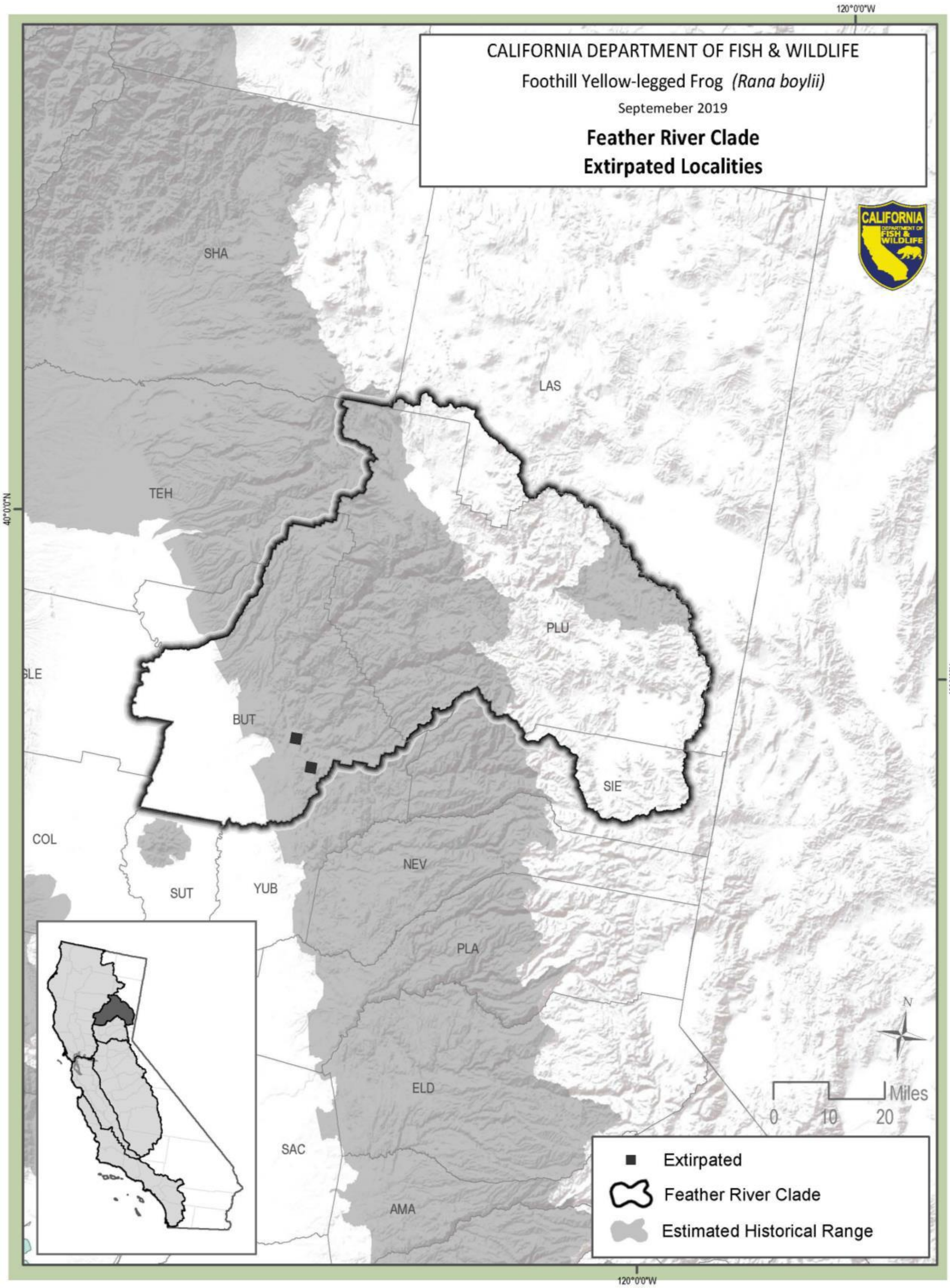

Figure 10. Extirpated Feather River Foothill Yellow-legged Frog clade occurrences (CNDDB)

3.2.4 Northeast/Northern Sierra Clade

The current known range of the Northeast/Northern Sierra clade roughly extends from the Upper Yuba Subbasin south through the North Fork American River Subbasin. No genetic samples were available to test in the Sutter Buttes to determine which clade it belonged to before it was extirpated (Figure 5; Olson et al. 2016). However, for management purposes and the Department's listing recommendation, and based on the best available science, the boundaries of the Northeast/Northern Sierra clade include Sutter County and the following watershed subbasins in Nevada, Placer, Sierra, and Yuba counties: Lower American, North Fork American, Upper Bear, Upper Coon-Upper Auburn, and Upper Yuba (Figure 6).

As described above, little historical data exist for the Foothill Yellow-legged Frog's distribution along west-slope Sierra Nevada streams, and no abundance data exist prior to major changes in the landscape. Foothill Yellow-legged Frogs have been observed in at least 231 locations within this clade, 76 (33%) of which were in 2014 or later (CNDDB 2019). The general pattern in this clade, and across the range, is that unregulated rivers or reaches have more areas that are occupied more consistently over time and in larger numbers than regulated rivers or reaches (CNDDB 2019, S. Kupferberg pers. comm. 2019).

Foothill Yellow-legged Frogs were rarely observed in the hydropeaking reach of the Middle Fork American River and were observed in low numbers in the bypass reach, but they were present and breeding in small tributary populations (PCWA 2008). Relatively robust populations appear to inhabit the North Fork American River and Lower Rubicon River, both in Placer County (Gaos and Bogan 2001, PCWA 2008, Hogan and Zuber 2012, K. Kundargi pers. comm. 2014, S. Kupferberg pers. comm. 2019). Additional apparently sufficiently large and relatively stable populations occur on Clear Creek, South Fork Greenhorn Creek, and Shady Creek (Nevada County) and the North and Middle Yuba River (Sierra County), but the remaining observations are of small numbers in tributaries with minimal connectivity among them (CNDDB 2019, S. Kupferberg pers. comm. 2019).

Figure 11 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, BIOS, and personal communications that are color coded by the most recent date of detection. Only one extirpation has been documented within this clade (Figure 12), but due to the lack of distribution data on the species prior to the Gold Rush in this area, there were undoubtedly others (CNDDB 2019).

3.2.5 East/Southern Sierra Clade

The current known range of the East/Southern Sierra clade extends from the South Fork American River Subbasin (the northernmost area where individuals from this clade were sampled) south to where the Sierra Nevada meets the Tehachapi Mountains. The Central Valley is not considered suitable habitat, and specimens collected from the Mokelumne River in northern San Joaquin County were likely waifs that washed down in a flood (CNDDB 2019). Because some of the San Joaquin Valley counties span both this clade and the West/Central Coast clade, the California Aqueduct was selected as geographic boundary between the two (Figure 6). This is an imperfect boundary because some east-draining creeks from the Coast Range flow into the San Joaquin Valley under the aqueduct. Therefore, for management

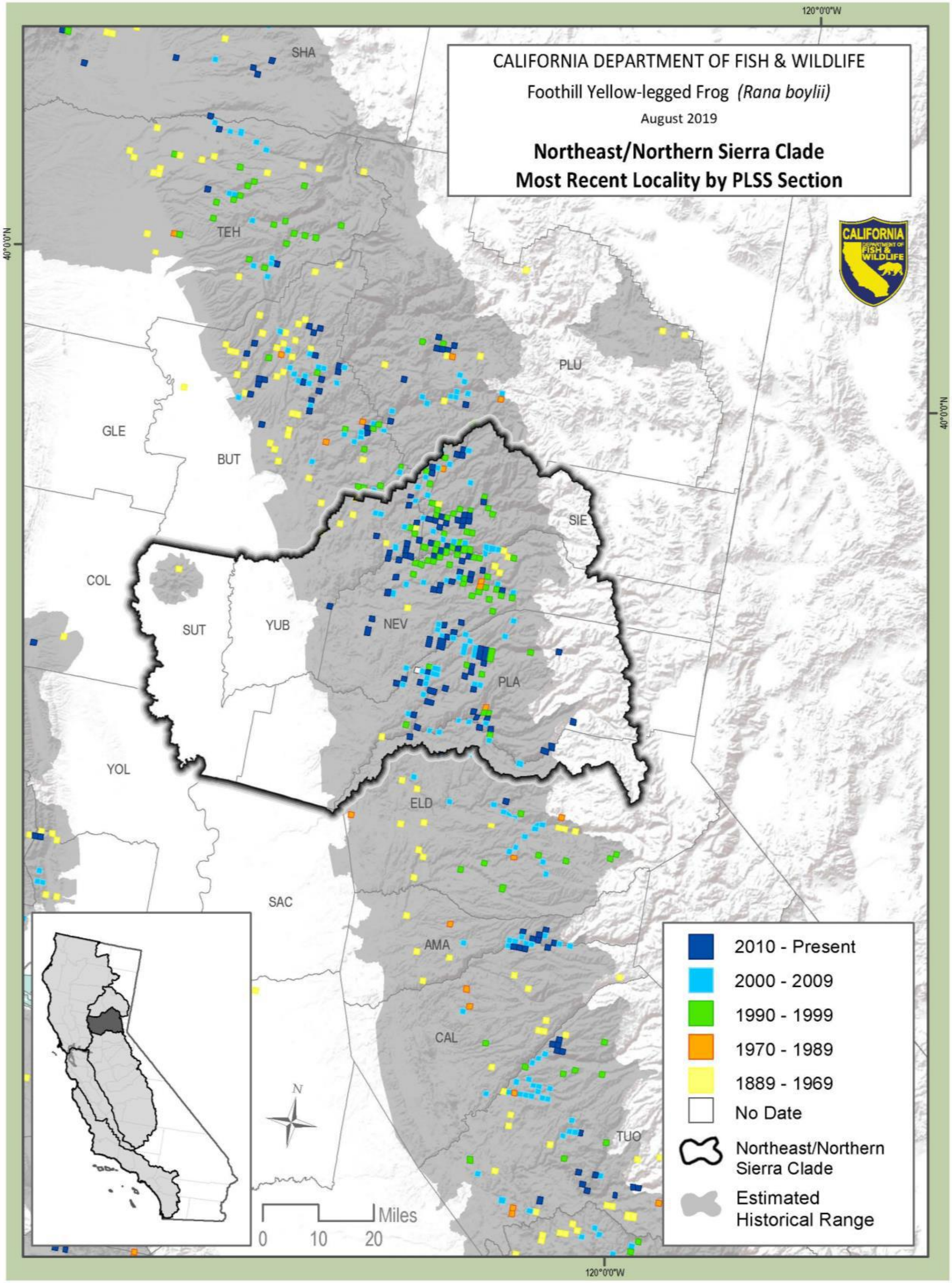

Figure 11. Northeast/Northern Sierra clades observations from 1889-2019 by most recent sighting in a Public Land Survey System section (ARSSC, BIOS, CNDDB)

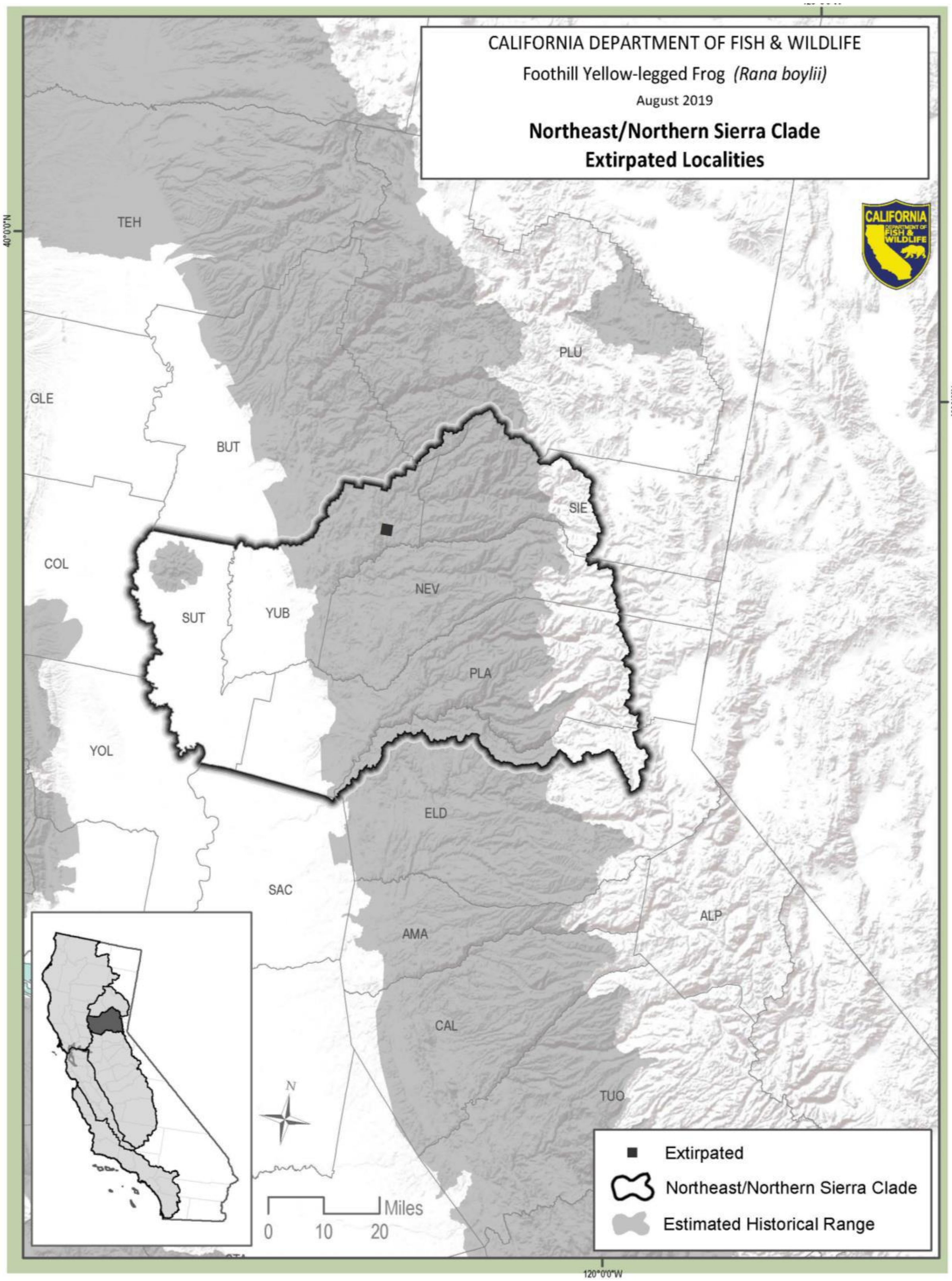

Figure 12. Extirpated Northeast/Northern Sierra Foothill Yellow-legged Frog clades occurrences (CNDDB)

purposes and the Department's listing recommendation, and based on the best available science, the boundaries of the East/Southern Sierra clade include the following whole counties: Amador, Calaveras, Madera, Mariposa, Sacramento, Tulare, and Tuolumne. The portion of Kern County within this clade is bounded on the west by the California Aqueduct and by the following subbasins in the east: Middle Kern-Upper Tehachapi-Grapevine, South Fork Kern, and Upper Kern. The following subbasins in El Dorado and Alpine counties are included in this clade: South Fork American, Upper Cosumnes, and Upper Mokelumne. A small area where the estimated historical range spans into Mono County is also included in this clade. The following counties east of the California Aqueduct are included in this clade: Fresno, Kings, Merced, San Joaquin, and Stanislaus.

Historical collections of small numbers of Foothill Yellow-legged Frogs occurred in every major river system within this clade beginning as early as the turn of the 20th century, indicating widespread distribution, but little information on abundance exists (Hayes et al. 2016). By the early 1970s, declines in Foothill Yellow-legged Frog populations from this area were already apparent; Moyle (1973) found them at 30 of 95 sites surveyed in 1970. Notably bullfrogs inhabited the other 65 sites formerly occupied by Foothill Yellow-legged Frogs, and they co-occurred at only three sites (Ibid.). In 1992, Drost and Fellers (1996) revisited the sites around Yosemite National Park (Tuolumne and Mariposa counties) that Grinnell and Storer (1924) surveyed in 1915 and 1919. Foothill Yellow-legged Frogs had disappeared from all seven historically occupied sites and were not found at any new sites surveyed surrounding the park (Ibid.). Resurveys of previously occupied (pre-1990) sites on the Stanislaus (Tuolumne County), Sierra (Fresno County), and Sequoia (Tulare County) National Forests, six sites per forest, were also undertaken (Lind et al. 2003b). Two of the previously occupied sites on the Stanislaus were still occupied, and 19 new populations were found with evidence of breeding at seven of them (Ibid.). Foothill Yellow-legged Frogs were absent from all of the previously occupied sites in Sierra National Forest, but one new population discovered (Ibid.) Similarly, Foothill Yellow-legged Frogs were absent from all of the previously occupied sites in the Sequoia National Forest, but two new populations were discovered (Ibid.). These populations remain extant but are small and isolated (CNDDB 2019). Twenty of the 24 populations extant at the time inhabited unregulated waterways (Ibid.). Most of the CNDDB (2019) records of Foothill Yellow-legged Frogs on the Stanislaus are at least a decade old and are represented by low numbers.

More recently, surveys for Foothill Yellow-legged Frogs were conducted along the South Fork American River as part of the El Dorado Hydroelectric Project's FERC license amphibian monitoring requirements (GANDA 2017). Between 2002 and 2016, counts of different life stages varied significantly by year, but the trend for every life stage was a decline over that period (Ibid.). Foothill Yellow-legged Frogs have been observed in at least 260 locations within this clade, 34 (13%) of which were in 2014 or later (CNDDB 2019). There appears to be a small population persisting along the North Fork Mokelumne River (Amador and Calaveras counties), but it was only productive during the 2012-2014 drought years (Ibid.). Small numbers have also been observed recently in several locations on private timberlands in Tuolumne County (CNDDB 2019).

Figure 13 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, BIOS, and personal communications that are color coded by the most recent date of detection. The proportion of extirpated sites in this clade is second only to the Southwest/South Coast and follows the pattern of greater losses in the south (Figure 14). Like the southern coastal clade, the southern Sierra clade has low genetic variability and a trajectory of continued loss of diversity (Peek 2018).

3.2.6 West/Central Coast Clade

The current known range of the West/Central Coast clade extends south from the San Francisco Bay through the Diablo Range and down the peninsula through the Santa Cruz and Gabilan Mountains in the Coast Range east of the Salinas Valley. No Foothill Yellow-legged Frogs belonging to this clade are expected south of Monterey and Fresno counties (Figure 5), and whether the species ever occurred in San Francisco County is unknown. For management purposes and the Department's listing recommendation, and based on the best available science, the West/Central Coast clade includes the following whole counties: Alameda, Contra Costa, San Benito, San Francisco, San Mateo, Santa Clara, and Santa Cruz. It includes the following counties west of the California Aqueduct: Fresno, Kern, Kings, Merced, San Joaquin, and Stanislaus, as well as portions of the east-draining creeks from the Coast Range that flow under the California Aqueduct. Monterey County east of Highway 101 is also included in this clade as well as the northeastern portion of San Luis Obispo County bounded by Highways 101 and 46 (Figure 6). Like the California Aqueduct, the highways represent imperfect boundaries, but they are intended to approximate the Salinas Valley separating the Sierra de Salinas and Santa Lucia Range to the west (in the Southwest/South Coast clade) from the Gabilan and Diablo ranges in this clade.

Records of Foothill Yellow-legged Frogs occurring south of San Francisco Bay did not exist until specimens were collected in 1918 around what is now Pinnacles National Park in San Benito County, and little information exists on historical distribution and abundance within this clade (Storer 1923, Hayes et al. 2016). Figure 15 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, BIOS, and personal communications that are color coded by the most recent date of detection. Foothill Yellow-legged Frogs have been observed in at least 174 locations within this clade, 27 (15.5%) of which were in 2014 or later (CNDDB 2019).

The San Francisco Bay Area is heavily urbanized. Documented and possible extirpations are concentrated around the San Francisco Bay and sites at the southern portion of the clade's range (Figure 16); however, the latter may not have been resurveyed since their original observations in the 1940s through 1960s, with the exception of a 1994 survey conducted in Pinnacles National Park (Ibid.). Foothill Yellow-legged Frogs may be gone from Contra Costa County; eight of the nine CNDDB records from the county are museum specimens collected between 1891 and 1953. The most recent observation was two adults in a plunge pool in an intermittent tributary to Moraga Creek in 1997, but its veracity is dubious (CNDDB 2019, S. Kupferberg pers. comm. 2019). No recent (2010 or later) observations exist from San Mateo County (Ibid.). In addition, although not depicted, two populations south of Livermore (Alameda County) are also likely extirpated (M. Grefsrud pers. comm. 2019).

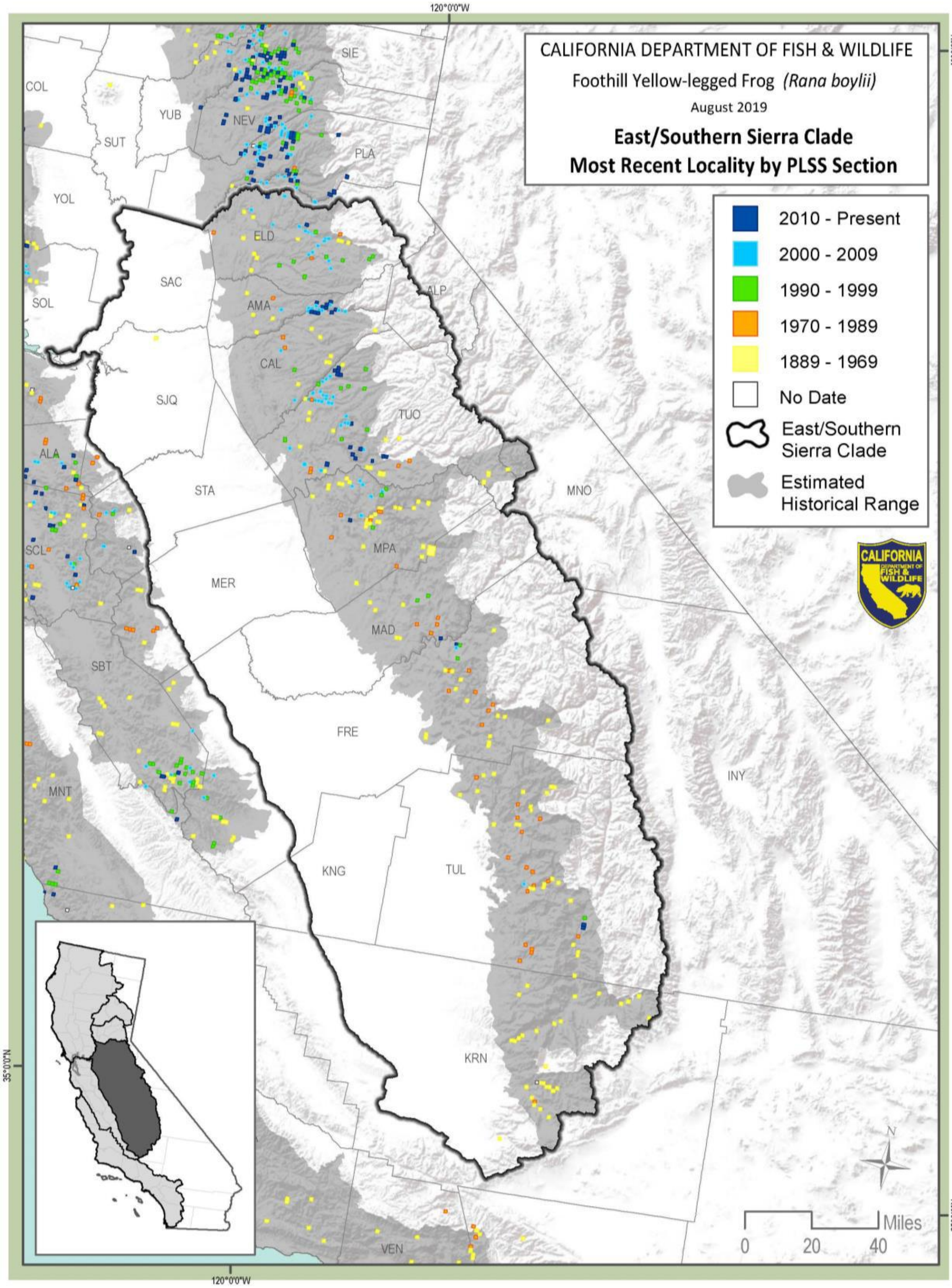

Figure 13. East/Southern Sierra clade observations from 1889-2019 by most recent sighting in a Public Land Survey System section (ARSSC, BIOS, CNDDB)

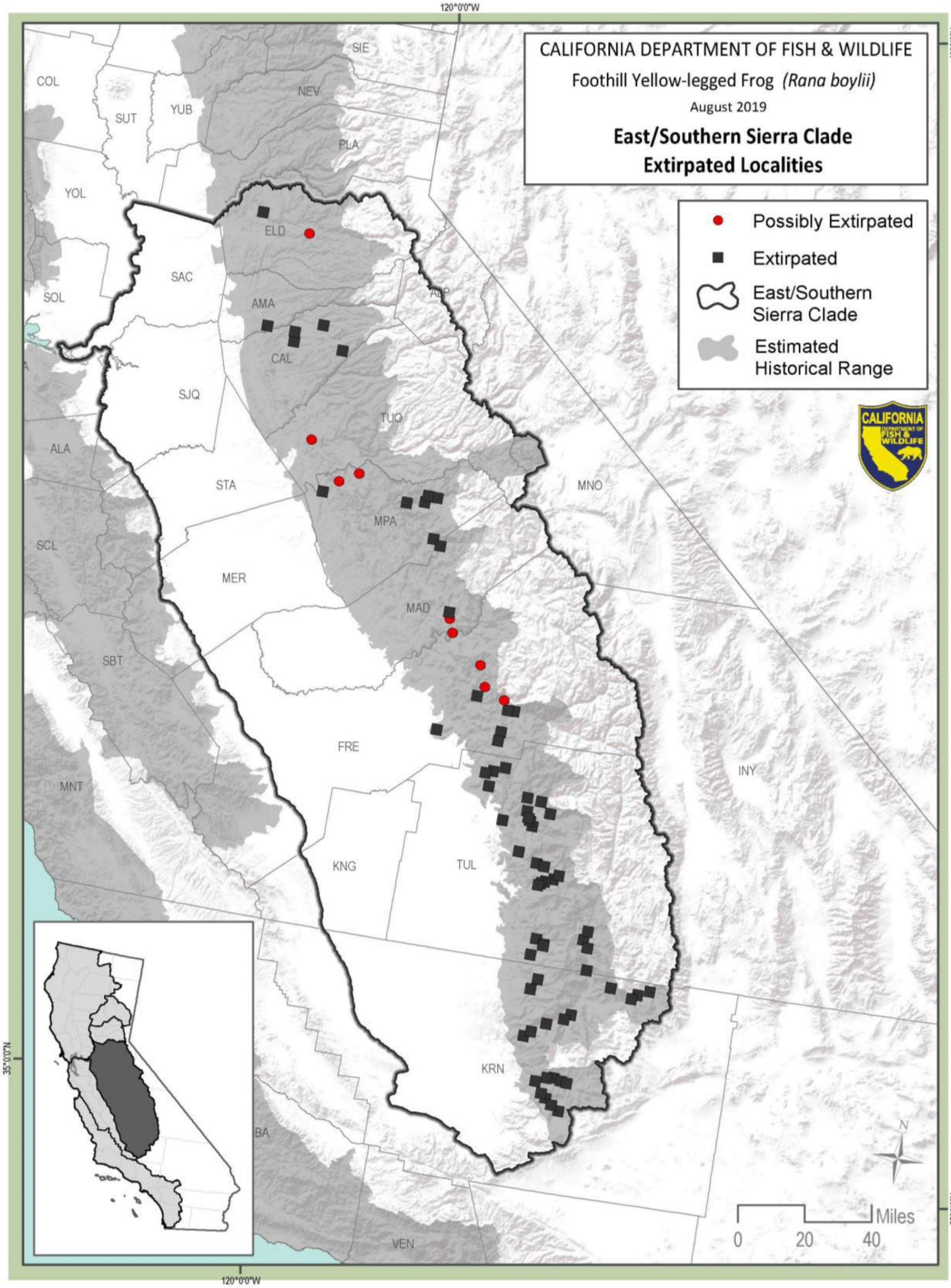

Figure 14. Possibly extirpated and extirpated East/Southern Sierra Foothill Yellow-legged Frog clade occurrences (CNDDB)

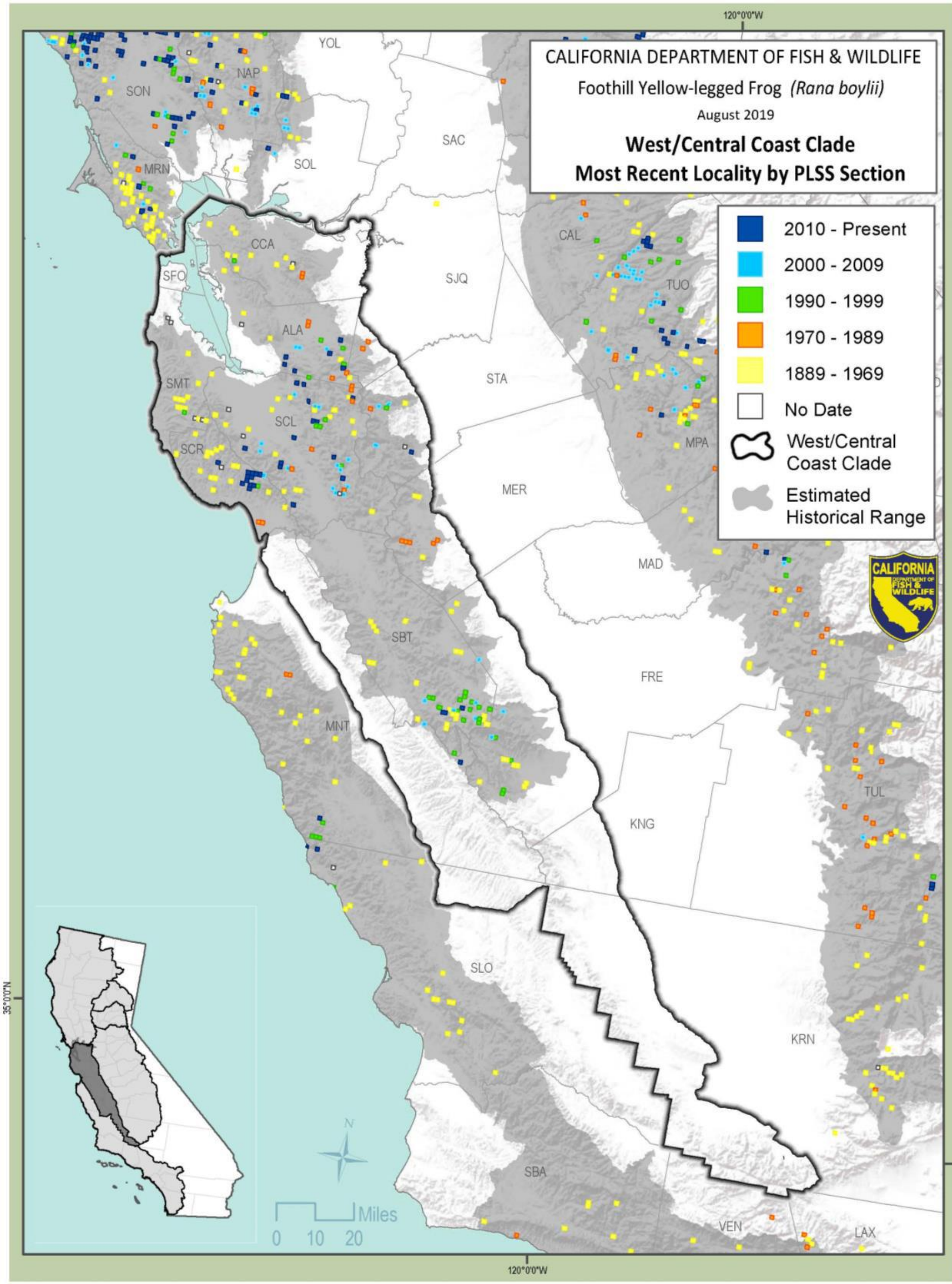

Figure 15. West/Central Coast clade observations from 1889-2019 by most recent sighting in a Public Land Survey System section (ARSSC, BIOS, CNDDB)

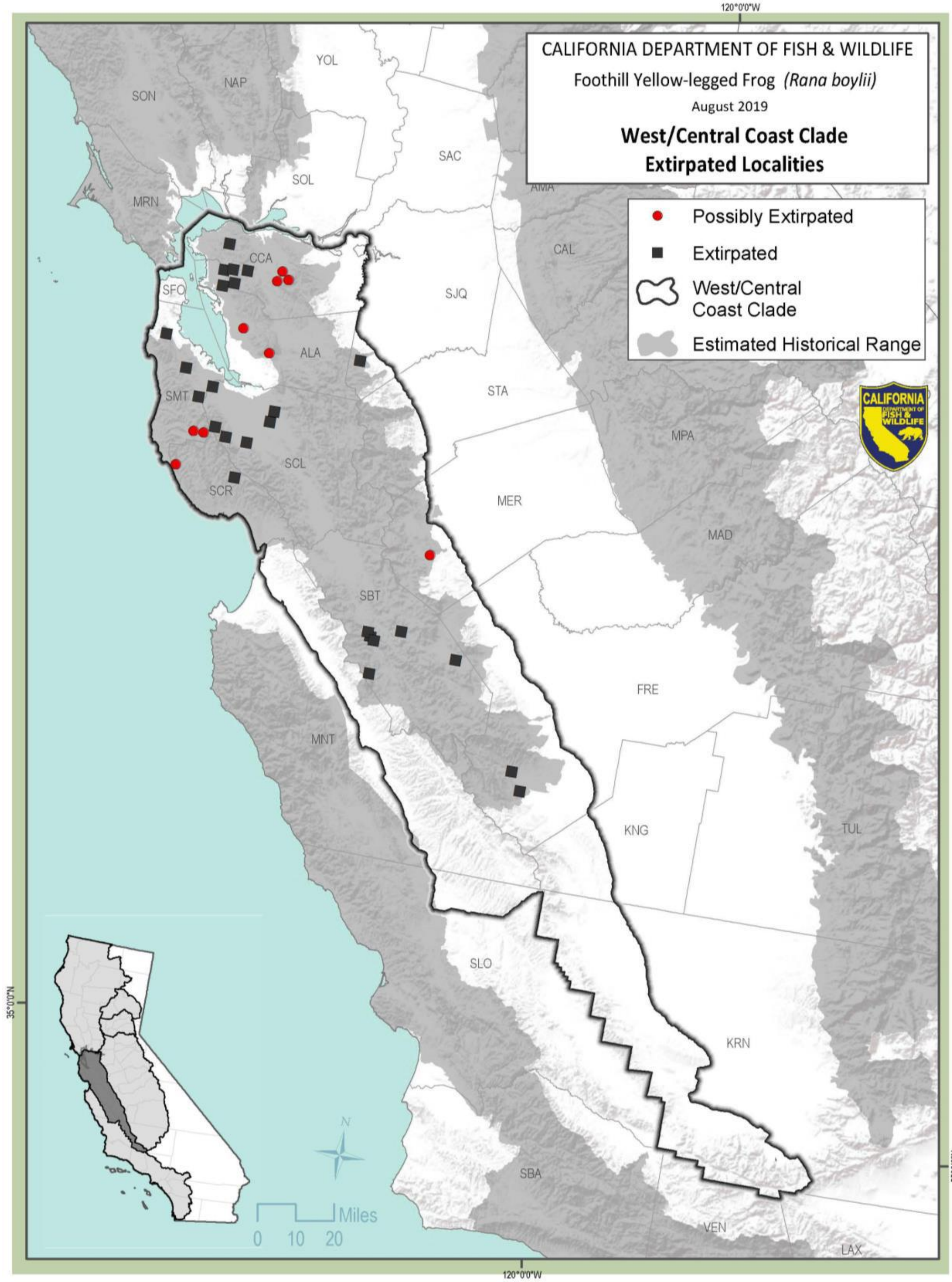

Figure 16. Possibly extirpated and extirpated West/Central Coast Foothill Yellow-legged Frog clade occurrences (CNDDB)

While historically-occupied lower elevation sites surrounding the San Francisco Bay and inland appear to be extirpated, there are (or were) some moderately abundant breeding populations remaining at higher elevations in Arroyo Hondo (Alameda County), Alameda Creek (Alameda and Santa Clara counties), Coyote and Upper Llagas creeks (Santa Clara County), and Soquel Creek (Santa Cruz County) with some scattered smaller populations also persisting in these counties (J. Smith pers. comm. 2016, 2017; CNDDB 2019). The Arroyo Hondo population is expected to lose approximately 1 mi of prime breeding habitat (i.e., supporting the highest density of egg masses on the creek) as the Calaveras Reservoir is refilled following its dam replacement project in 2019 (M. Grefsrud pers. comm. 2019). The Alameda Creek and Coyote Creek populations recently underwent large-scale mortality events, so their numbers may be lower than what is currently reported in the CNDDB (Adams et al. 2017a, Kupferberg and Catenazzi 2019). However, during 2019 surveys, Foothill Yellow-legged Frog egg mass density along Coyote Creek, including the location of the 2018 die-off, was comparable to those reported 15 years ago, although there may be a time lag before population-level effects are detected (S. Kupferberg pers. comm. 2019). Foothill Yellow-legged Frogs may be extirpated from Corral Hollow Creek in San Joaquin County, but a single individual was observed five years ago further up the drainage in Alameda County within an Off-Highway Vehicle park (CNDDB 2019). Few recent sightings of Foothill Yellow-legged Frogs in the east-flowing creeks are documented. They may still be extant in the headwaters of Del Puerto Creek (western Stanislaus County), but the records further downstream indicate bullfrogs (known predators and disease reservoirs) are moving up the system (Ibid.). Several locations in southern San Benito, western Fresno, and eastern Monterey counties have relatively recent (2000 and later) detections (Ibid.). However, while many of these sites supported somewhat large populations in the 1990s, the more recent records report fewer than ten individuals (Ibid.). The exception is a Monterey County site where 25 to 30 juveniles were observed in 2012 (Ibid.).

3.2.7 Southwest/South Coast Clade

Few early records exist for the Southwest/South Coast clade. Storer (1923) reported that Foothill Yellow-legged Frogs were collected for the first time in Monterey County in 1919 and that a specimen collected by Cope in 1889 in Santa Barbara and listed as *Rana temporaria pretiosa* may refer to the Foothill Yellow-legged Frog because as previously mentioned, the taxonomy of this species changed several times over the first century after it was named. Widespread extirpations occurred decades ago, detected primarily in the 1960s and 1970s, in southern California (Adams et al. 2017b). As a result, genetic samples were largely unavailable; nevertheless, the current known range of this clade is presumed to include the Coast Range west of the Salinas River from Monterey Bay in Monterey County south to the Transverse Range across to the San Gabriel Mountains in Los Angeles County. The Petition included references to museum specimens, collected below the putative elevation range of the Southern Mountain Yellow-legged Frog in Orange, San Bernardino, and San Diego counties, that should be examined to determine a conclusive identification. If the specimens from México were indeed Foothill Yellow-legged Frogs, additional historical populations in southern California cannot be completely ruled out. For management purposes and the Department’s listing recommendation, and based on the best available science, the boundaries of the Southwest/South Coast clade include the following whole counties: Orange, Santa Barbara, and Ventura. The eastern extent of this clade in Los

Angeles, Riverside, San Bernardino, and San Diego is bounded by the following subbasins: Los Angeles, San Diego, San Gabriel, San Jacinto, San Luis Rey-Escondido, Santa Ana, Santa Clara, and Santa Margarita. Monterey County west of Highway 101 and San Luis Obispo County south and west of Highways 101 and 46 are also part of this clade (Figure 6).

Figure 17 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, BIOS, and personal communications that are color coded by the most recent date of detection. Foothill Yellow-legged Frogs had been widespread and fairly abundant in this area until the late 1960s but were rapidly extirpated throughout the southern Coast Ranges and western Transverse Ranges by the mid-1970s (Sweet 1983, Adams et al. 2017b). Now the species has disappeared from nearly all know historically occupied locations (Figure 18), and only two populations from this clade are known to be extant, both located near the border of Monterey and San Luis Obispo counties (S. Sweet pers. comm. 2017, McCartney-Melstad et al. 2018, Peek 2018, CNDDB 2019). These populations appear to be extremely small and rapidly losing genetic diversity, making them at high risk of extirpation (McCartney-Melstad et al. 2018, Peek 2018).

4.0 FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE

"The fortunes of the boylii *population fluctuate with those of the stream"* - Tracy I. Storer, 1925

Several past and ongoing activities have changed the watersheds upon which Foothill Yellow-legged Frogs depend, and many interact with each other exacerbating their adverse impacts. With such an expansive range in California, the degree and severity of these impacts on the species often vary by location. To the extent feasible, based on the best scientific information available, those differences are discussed below.

4.1 Dams, Diversions, and Water Operations

Foothill Yellow-legged Frogs evolved in a Mediterranean climate with predictably cool wet winters and hot dry summers; their life cycle is adapted to these conditions. In California and other areas with a Mediterranean climate, human demands for water are at the highest when runoff and precipitation are lowest, and annual water supply varies significantly but always follows the general pattern of peak discharge declining to base flow in the late spring or summer (Grantham et al. 2010). The Foothill Yellow-legged Frog's life cycle depends on this flow pattern and the specific habitat conditions it produces (see the Breeding and Rearing Habitat section). Dams are ubiquitous, but not evenly distributed, in California. Figure 19 depicts the locations of dams under the jurisdiction of the Army Corps of Engineers (ACOE) and the California Department of Water Resources (DWR). Figure 20 depicts the number of surface diversions per PLSS section within the Foothill Yellow-legged Frog's range (eWRIMS 2019).

Dam operations frequently change the amount, timing, and frequency of water availability; water temperature, depth, and velocity; the downstream capacity to transport sediment; and channel morphology, all of which can result in dramatic consequences for the Foothill Yellow-legged Frog's ability to survive and successfully reproduce. Several studies comparing Foothill Yellow-legged Frog

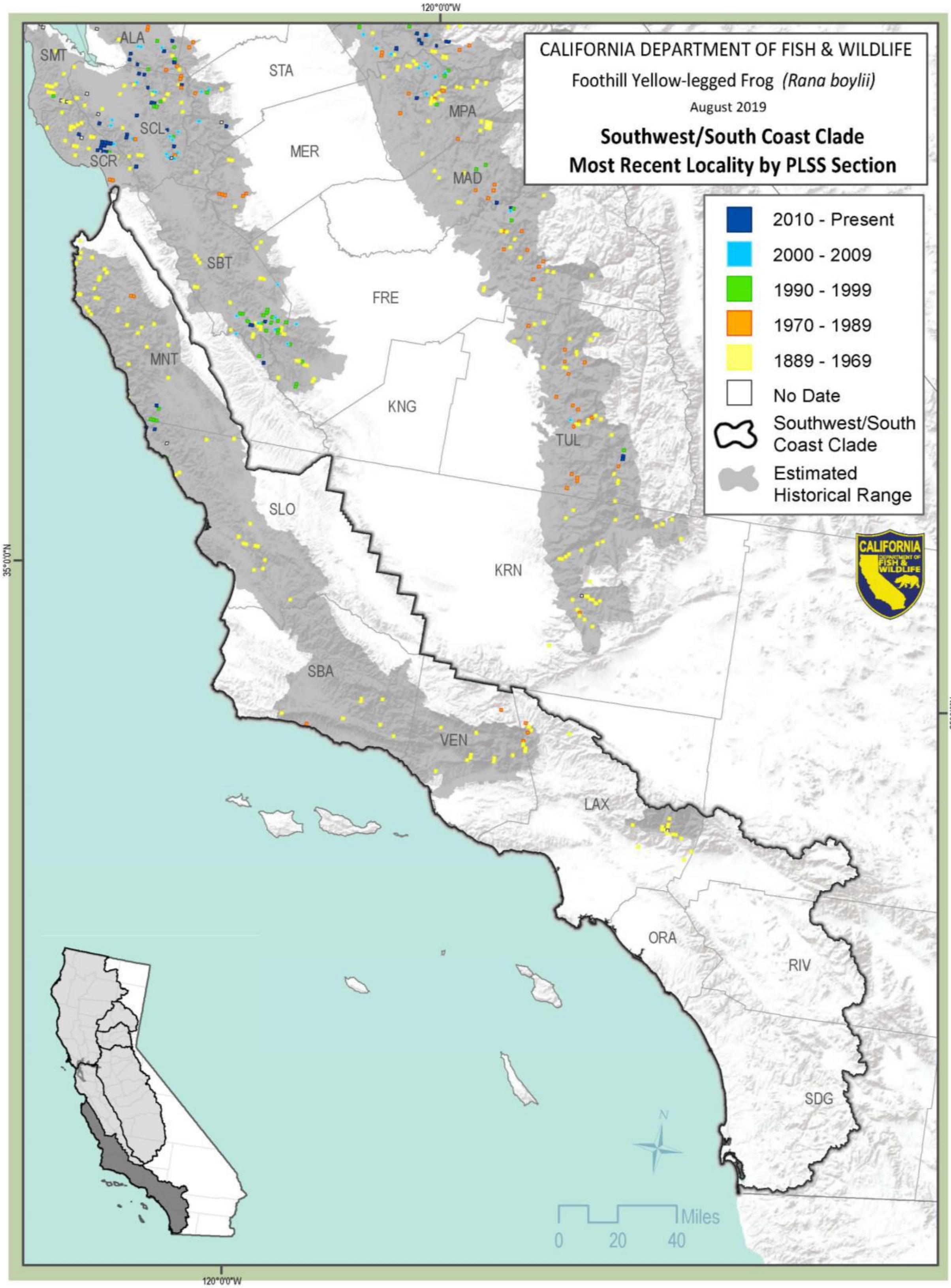

Figure 17. Southwest/South Coast clade observations from 1889-2019 by most recent sighting in a Public Land Survey System section (ARSSC, BIOS, CNDDB)

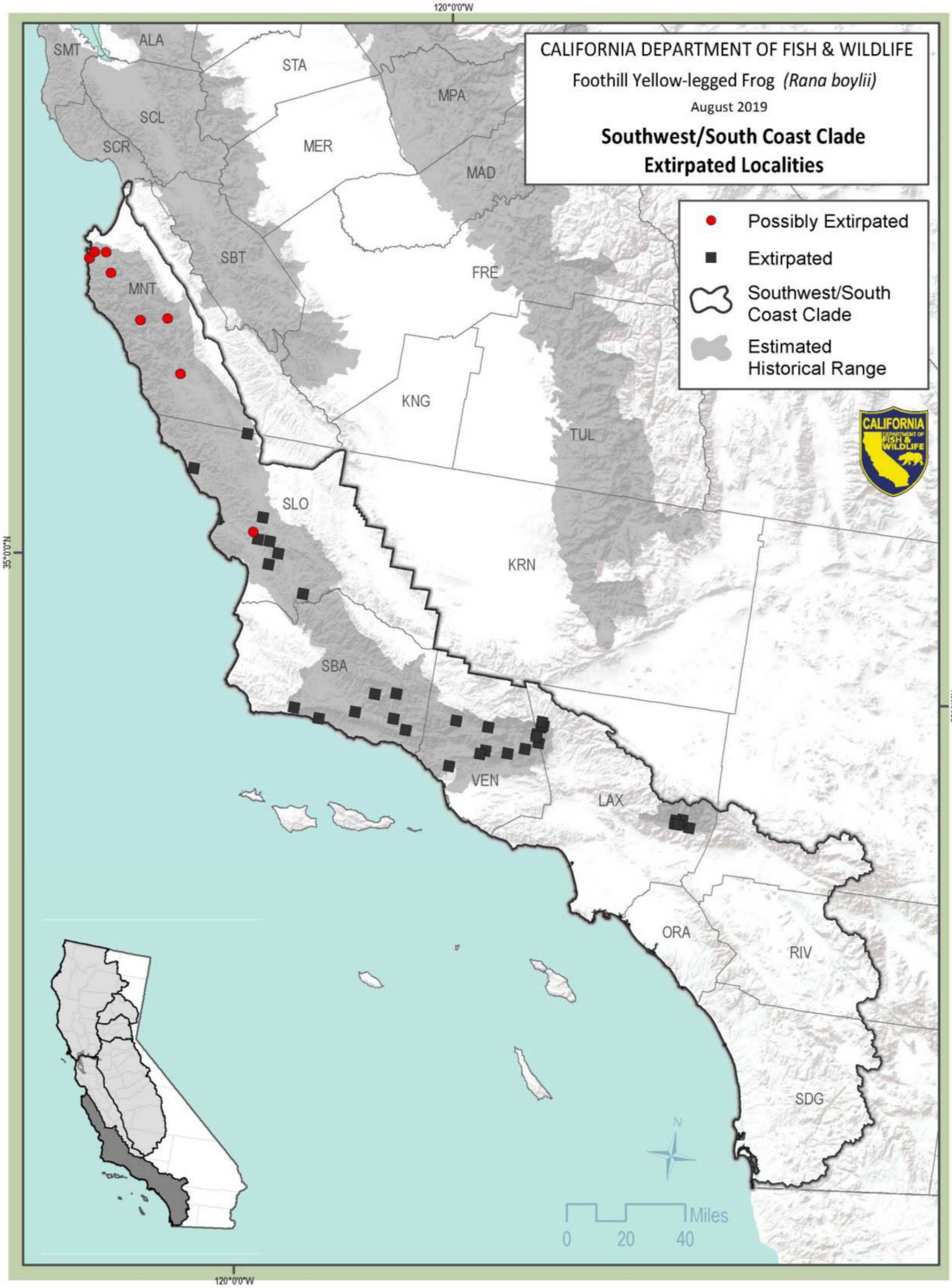

Figure 18. Possibly extirpated and extirpated Southwest/South Coast Foothill Yellow-legged Frog clade occurrences (CNDDB)

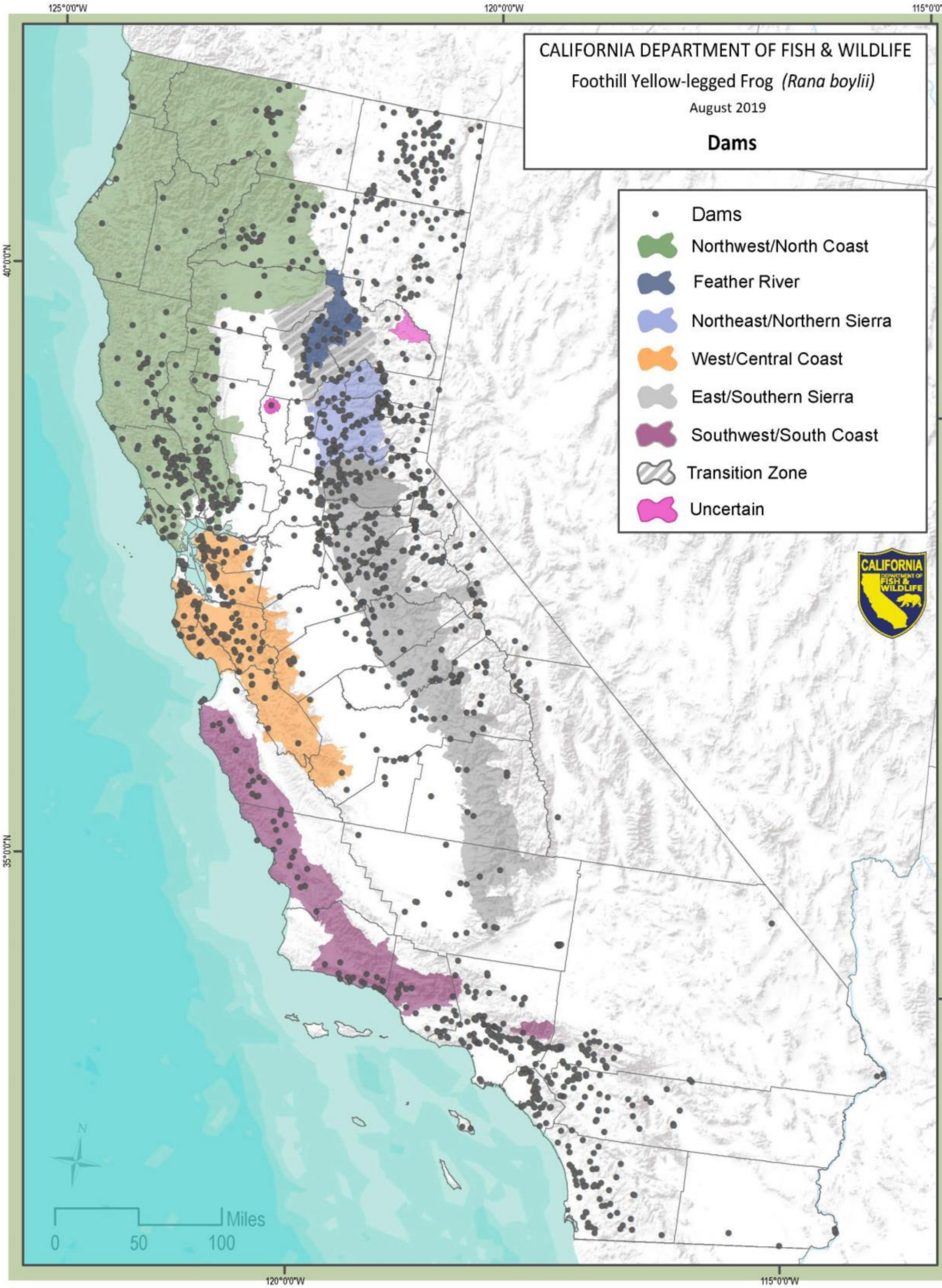

Figure 19. Locations of dams under the jurisdiction of the U.S. Army Corps of Engineers and the California Department of Water Resources in California (DWR, FRS)

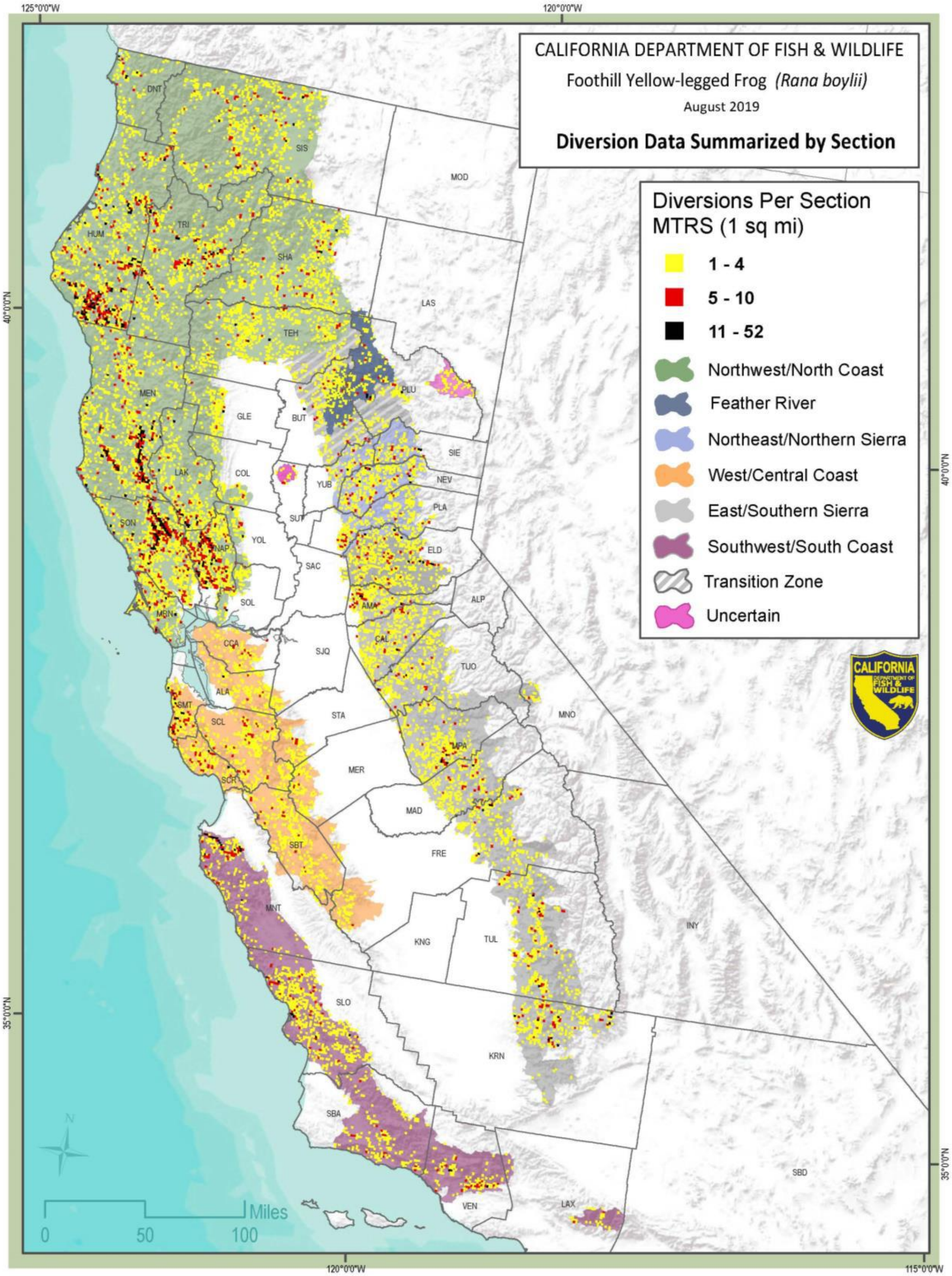

Figure 20. Number of surface water diversions per Public Land Survey System section within the Foothill Yellow-legged Frog's range in California (eWRIMs)

populations in regulated and unregulated reaches within the same watershed investigated potential dam-effects. These studies demonstrated that dams and their operations can result in several factors that contribute to population declines and possible extirpation. These factors include confusing breeding cues, scouring and stranding of egg masses and tadpoles, reducing the quality and quantity of breeding and rearing habitat, diminishing tadpole growth rate, creating barriers to gene flow, and supporting the establishment and spread of non-native species (Hayes et al. 2016). In addition, as previously discussed in the Population Structure and Genetic Diversity section, subpopulations of Foothill Yellow-legged Frogs on regulated rivers are more genetically isolated, and the type of water operations (hydropeaking vs. bypass flows) significantly affects the degree of connectivity and associated gene flow among them (Peek 2010, 2018; R. Peek pers. comm. 2019b). Both the Middle Fork of the American River and the Tuolumne River have hydropeaking reaches, and the Foothill Yellow-legged Frogs occupying them show marked genetic divergence and evidence of genetic bottlenecking (Peek 2018, R. Peek pers. comm. 2019b). Figure 21 depicts the locations of hydropower generating dams within and around the Foothill Yellow-legged Frog's range in California.

As discussed in the Seasonal Activity and Movements section, cues for Foothill Yellow-legged Frogs to start breeding include water temperature and velocity, two features altered by dams. Some dam operations result in reduced flows that are more stable over the course of a year than under unimpaired conditions, while others can result elevated and highly variable flows (R. Peek pers. comm. 2019a). In addition, dam operators are frequently required to maintain thermally appropriate water temperatures and flows for cold water adapted salmonids (USFWS and Hoopa Valley Tribe 1999, Wheeler et al. 2014). For example, late-spring and summer water temperatures on the mainstem Trinity River below Lewiston Dam have been reported to be up to 20°F cooler than average pre-dam temperatures, while average winter temperatures are slightly warmer (USFWS and Hoopa Valley Tribe 1999). As a result, Foothill Yellow-legged Frogs breed later in the season on the mainstem Trinity River compared to six nearby tributaries, and some mainstem reaches may never attain the minimum temperature required for successful breeding (Wheeler et al. 2014, Snover and Adams 2016). In addition, annual discharges past Lewiston Dam have been 10-30% of pre-dam flows and do not mimic the natural hydrograph (Lind et al. 1996). In other regulated rivers like the Middle Fork American, the water level can fluctuate nearly 3 ft in several hours, and higher than natural flows may be released for extended periods of time before returning to base flows (Peek 2010).

Aseasonal discharges from dams occur for several reasons including increased flow in late-spring and early summer to facilitate outmigration of salmonids, channel maintenance pulse flows, short-duration releases for recreational whitewater boating, rapid reductions after a spill (uncontrolled flows released down a spillway when reservoir capacity is exceeded) to retain water for power generation or water supply later in the year, peaking flows for hydropower generation, and sustained releases to maintain the seismic integrity of the dam (Lind et al. 1996, Jackman et al. 2004, Kupferberg et al. 2011b, Kupferberg et al. 2012, Snover and Adams 2016). The results of a Foothill Yellow-legged Frog population viability analysis (PVA) suggest that the likelihood a population will persist is very sensitive to early life stage mortality; the 30-year probability of extinction increases significantly with high levels of egg or tadpole scouring or stranding (Kupferberg et al. 2009c). For instance, in 1991 and 1992, all egg masses

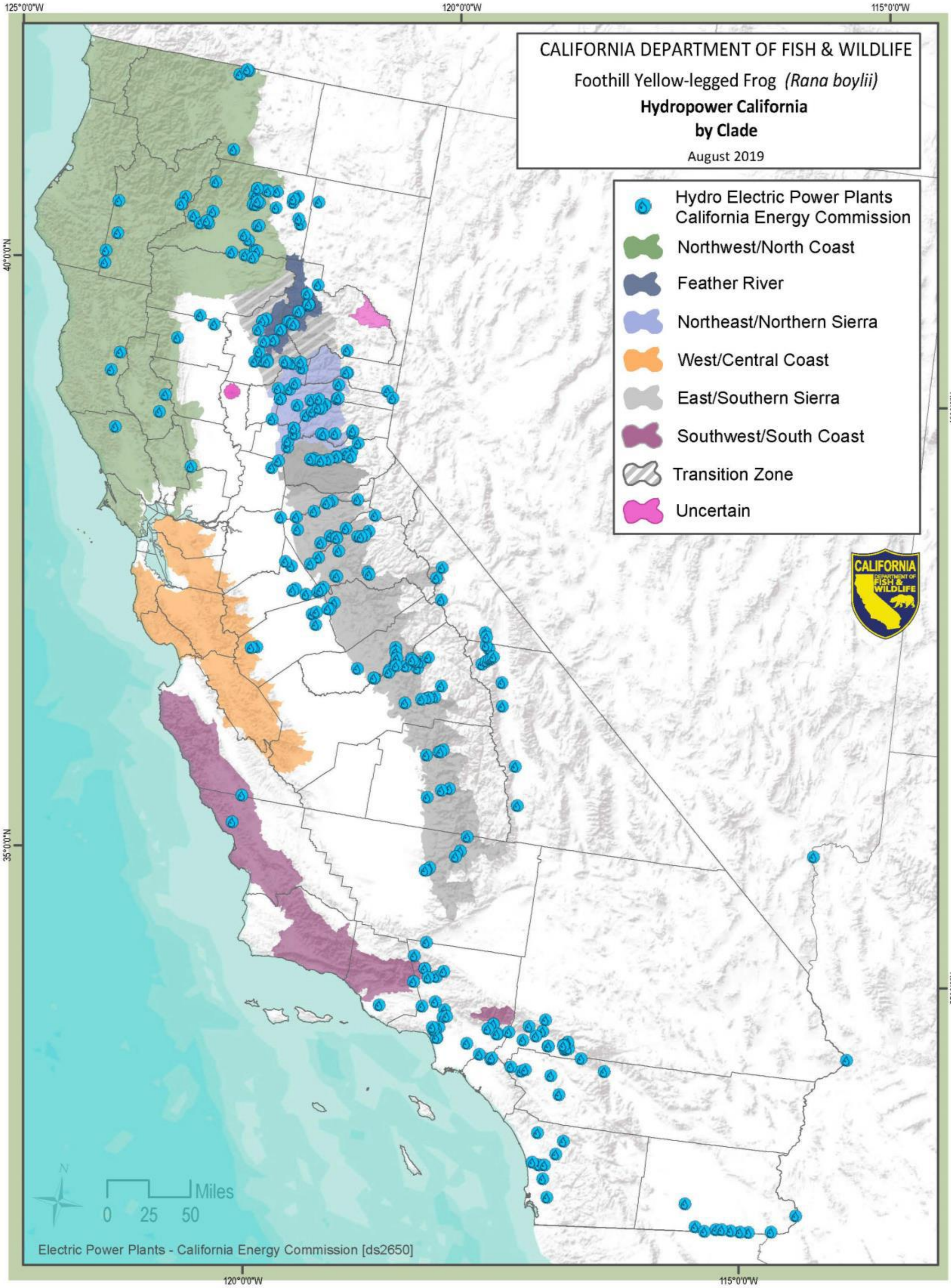

Figure 21. Locations of hydropower generating dams (BIOS)

laid before high flow releases to encourage outmigration of salmonids on the Trinity River were scoured away (Lind et al. 1996). According to the PVA, even a single annual pulse flow such as this, or for recreational boating, can result in a three- to five-fold increase in the 30-year extinction risk based on amount of tadpole mortality experienced (Kupferberg et al. 2009c). Management after natural spills can also lead to substantial mortality. For example, in 2006, Foothill Yellow-legged Frogs on the North Fork Feather River bred during a prolonged spill, and the rapid recession below Cresta Dam that followed stranded and desiccated all the eggs laid (Kupferberg et al. 2009b). Rapid flows can also increase predation risk if tadpoles are forced to seek shelter under rocks where crayfish and other invertebrate predators are more common or if they are displaced into the water column where their risk of predation by fish is greater (Ibid.).

The overall decrease in flows and frequency of large winter floods below dams can produce extensive changes to Foothill Yellow-legged Frog habitat quality. They reduce the formation of river bars that are regularly used as breeding habitat, and they create deeper and steeper channels with less complexity and fewer warm, calm, shallow edgewater habitats for tadpole rearing (Lind et al. 1996, Wheeler and Welsh 2008, Kupferberg et al. 2011b, Wheeler et al. 2014). For example, 26 years after construction of the Lewiston Dam on the Trinity River, habitat changes for 39 mi immediately downstream of the dam were evaluated (Lind et al. 1996). Riparian vegetation went from covering 30% of the riparian area pre-dam to 95% (Ibid.). Additionally, river bars made up 70% of the pre-dam riparian area compared to 4% post-dam, amounting to a 94% decrease in available Foothill Yellow-legged Frog breeding habitat (Ibid.).

Several features of riverine habitat below dams can decrease tadpole growth rate and other measures of fitness. As ectotherms, Foothill Yellow-legged Frogs require temperatures that support their metabolism, food conversion efficiency, growth, and development, and these temperatures may not be reached until late in the season, or not at all, when the water released is colder than their lower thermal limit (Kupferberg et al. 2011a, Catenazzi and Kupferberg 2013, Wheeler et al. 2014). Colder temperatures and higher flows reduce time spent feeding and food assimilation efficiency, resulting in slower growth and development (Kupferberg et al. 2011a,b; Catenazzi and Kupferberg 2018). Large bed-scouring winter floods promote greater *Cladophora glomerata* blooms, the filamentous green alga that dominates primary producer biomass during the tadpole rearing season (Power et al. 2008, Kupferberg et al. 2011a). The period of most rapid tadpole growth often coincides with blooms of highly nutritious and more easily assimilated epiphytic diatoms, so reduced flows can have food-web impacts on tadpole growth and survival (Power et al. 2008, Kupferberg et al. 2011a, Catenazzi and Kupferberg 2018). In addition, colder temperatures and fluctuating summer flows, such as those released for hydropower generation, can reduce the amount of algae available for grazing and can change the algal assemblage to one dominated by mucilaginous stalked diatoms like *Didymosphenia geminata* that have low nutritional value (Spring Rivers Ecological Sciences 2003, Kupferberg et al 2011a, Yarnell et al. 2013, Furey et al. 2014). Altered temperatures, flows, and food quality can contribute to slower growth and development, longer time to metamorphosis, smaller size at metamorphosis, and reduced body condition, which adversely impact fitness (Kupferberg et al. 2011b, Catenazzi and Kupferberg 2018).

As previously discussed, genetic divergence and diversity are strongly affected by river regulation (Peek 2010, 2018; Stillwater Sciences 2012). Foothill Yellow-legged Frogs primarily use watercourses as movement corridors, so the reservoirs created behind dams are often uninhabitable and represent barriers to gene flow (Bourque 2008; Peek 2010, 2018). This decreased connectivity can lead to loss of genetic diversity, which can reduce a species' ability to adapt to changing conditions (Palstra and Ruzzante 2008).

Decreased winter discharge below dams facilitates establishment and expansion of invasive bullfrogs, whose tadpoles require overwintering and are not well-adapted to flooding events (Lind et al. 1996, Doubledee et al. 2003). Where they occur, bullfrogs tend to dominate areas more altered by dam operations than less impaired areas, which support a higher proportion of native species (Moyle 1973, Fuller et al. 2011). In addition to downstream effects, the reservoirs created behind dams directly inundate and eliminate lotic (flowing) Foothill Yellow-legged Frog habitat, typically do not retain natural riparian communities due to fluctuating water levels, are often managed for human activities not compatible with the species' needs, and act as a source of introduced species upstream and downstream (Brode and Bury 1984, PG&E 2018). Moyle and Randall (1998) identified characteristics of sites with low native biodiversity in the Sierra Nevada foothills; they were often drainages that had been dammed and diverted in lower- to middle-elevations and dominated by introduced fishes and bullfrogs. Even small-scale operations can have significant effects. Some farming operations divert water during periods of high flows and store it in small impoundments for use during low flow-high demand times; these ponds can serve as sources for introduced species like bullfrogs to spread into areas where the habitat would otherwise be unsuitable (Kupferberg 1996b).

The mechanisms described above result in the widespread pattern of greater Foothill Yellow-legged Frog density in unregulated rivers and in reaches far enough downstream of a dam to experience minimal effects from it (Lind et al. 1996, Kupferberg 1996a, Bobzien and DiDonato 2007, Peek 2010). Foothill Yellow-legged Frog abundance in unregulated rivers averages five times greater than population abundance downstream of large dams (Kupferberg et al. 2012). Figure 22 depicts a comprehensive collection of egg mass density data, where at least four years of surveys have been undertaken, showing much lower abundance in regulated rivers (Peek and Kupferberg 2016). In California, Foothill Yellow-legged Frog presence is associated with an absence of dams or with only small dams far upstream (Lind 2005, Kupferberg et al. 2012). Hydropower generation from Sierra Nevada rivers accounts for nearly half its statewide production and about 9% of all electrical power used in California (Dettinger et al. 2018). Every major stream below approximately 2,000 ft in the Sierra Nevada has at least one large reservoir (≥100,000 ac-ft), and many have multiple medium and small ones (Hayes et al. 2016). Because of this, Catenazzi and Kupferberg (2017) posit that the dam-effect on Foothill Yellow-legged Frog populations is likely greater in the Sierra Nevada than the Coast Range because in the former dams are more often constructed in a series along a river and spaced close enough together that suitable breeding temperatures may never be attained in the intervening reaches.

4.2 Pathogens and Parasites

Perhaps the most widely recognized amphibian disease is chytridiomycosis, which is caused by the fungal pathogen *Batrachochytrium dendrobatidis* (Bd). Implicated in the decline of over 500 amphibian species, including 90 presumed extinctions, it represents the greatest recorded loss of biodiversity

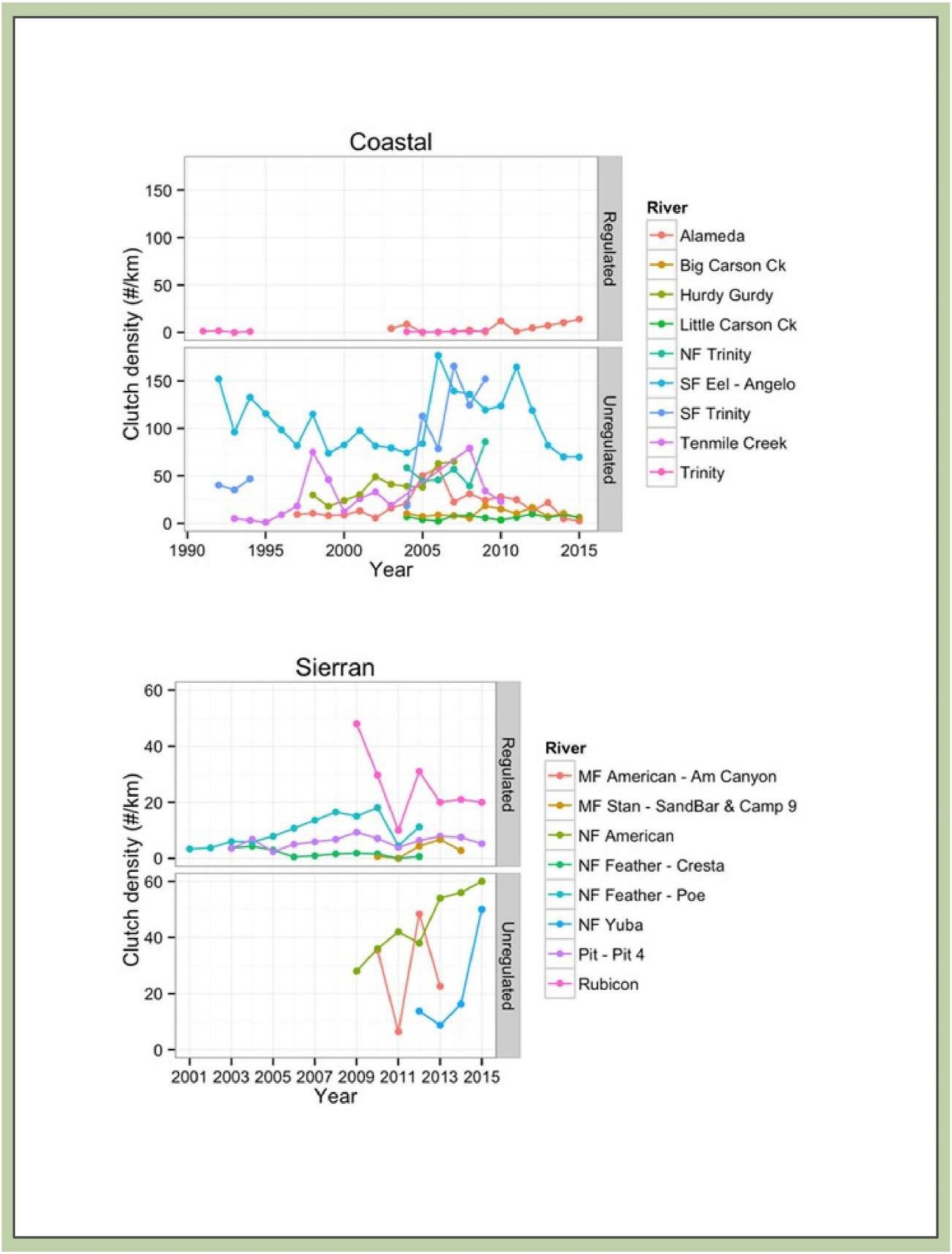

Figure 22. Foothill Yellow-legged Frog Egg mass density estimates along the coast from 1990-2015 and the Sierra Nevada from 2001-2015 (Peek and Kupferberg 2016)

attributable to a disease (Scheele et al. 2019). The global trade in American Bullfrogs (primarily for food) is connected to the disease's spread because the species can persist with low-level Bd infections without developing chytridiomycosis (Yap et al. 2018). Previous studies suggested Foothill Yellow-legged Frogs may not be susceptible to Bd-associated mass mortality; skin peptides strongly inhibited growth of the fungus in the lab, and the only detectable difference between Bd+ and Bd- juvenile Foothill Yellow-legged Frogs was slower growth (Davidson et al. 2007). At Pinnacles National Park in 2006, 18% of post-metamorphic Foothill Yellow-legged Frogs tested positive for Bd; all were asymptomatic and at least one Bd+ Foothill Yellow-legged Frog subsequently tested negative, demonstrating an ability to shed the fungus (Lowe 2009). However, recent studies have found historical evidence of Bd contributing to the extirpation of Foothill Yellow-legged Frogs in southern California, an acute die-off in 2013 in the Alameda Creek watershed, and another in 2018 in Coyote Creek (Adams et al. 2017a,b; Kupferberg and Catenazzi 2019). Evaluation of museum specimens indicated a lower Bd prevalence (proportion of individuals infected) in Foothill Yellow-legged Frogs than most other co-occurring amphibians in southern California in the first part of the 20th century, but it spiked in the 1970s just prior to the last observation of an individual in 1977 (Adams et al. 2017b). Two museum specimens collected in 1966, one from Santa Cruz County and the other from Alameda County, provide the earliest evidence of Bd in Foothill Yellow-legged Frogs in central California (Padgett-Flohr and Hopkins 2009). In contrast to the southern California results, Foothill Yellow-legged Frogs possessed the highest Bd prevalence among all amphibians tested in coastal Humboldt County in 2013 and 2014; however, zoospore (the aquatic dispersal agent) loads were well below the presumed lethal density threshold (Ecoclub Amphibian Group et al. 2016).

In addition to bullfrogs, the native Pacific Treefrog (*Pseudacris regilla*) seems immune to the lethal effects of chytridiomycosis, and owing to its broad ecological tolerances, more terrestrial lifestyle, and relatively large home range size and dispersal ability, the species is ubiquitous across California (Padgett-Flohr and Hopkins 2009). In a laboratory experiment, Bd-infected Pacific Treefrogs shed an average of 68 zoospores/min, making them the prime candidate for spreading and maintaining Bd in areas where bullfrogs do not occur (Padgett-Flohr and Hopkins 2009, Reeder et al. 2012). In the wild in Sixty Lakes Basin (Fresno County), Pacific Treefrog populations persisted at 100% of sites where the Southern Mountain Yellow-legged Frog had been extirpated from 72% of its formerly occupied sites due to a Bd outbreak (Reeder et al. 2012). This is consistent with the results of a model that incorporated Bd habitat suitability, host availability, and invasion history in North America, which concluded west coast mountain ranges were at the greatest risk from the disease (Yap et al. 2018).

Several other pathogens and parasites have been associated with Foothill Yellow-legged Frogs, but none have been ascribed to large-scale mortality events. Another fungus, a water mold (*Saprolegnia* sp.) carried by fish, is an important factor in amphibian embryo mortality in the Pacific Northwest (Blaustein et al. 1994, Kiesecker and Blaustein 1997). Fungal infections of Foothill Yellow-legged Frog egg masses, potentially from *Saprolegnia*, have been observed in the mainstem Trinity River (Ashton et al. 1997). *Saprolegnia* infection is more likely to occur in ponds and lakes, particularly if stocked by hatchery-raised fish into previously fishless areas and when frogs use communal oviposition sites, so it likely does not represent a major source of mortality in Foothill Yellow-legged Frogs (Blaustein et al. 1994, Kiesecker and Blaustein 1997). However, they may be more susceptible to *Saprolegnia* infection when exposed to other environmental stressors that compromise their immune defenses (Blaustein et al. 1994, Kiesecker and Blaustein 1997).

The trematode parasite *Ribeiroia ondatrae* is responsible for limb malformations in ranids (Stopper et al. 2002). *Ribeiroia ondatrae* was detected on a single Foothill Yellow-legged Frog during a study on malformations, but its morphology was normal (Kupferberg et al. 2009a). The results of the study instead linked malformations in Foothill Yellow-legged Frog tadpoles and young-of-year to the Anchor Worm (*Lernaea cyprinacea*), a parasitic copepod from Eurasia (Ibid.). Prevalence of malformations was low, under 4% of the population in both years of study, but there was a pattern of infected individuals metamorphosing at a smaller size, which as previously mentioned can have implications on fitness (Ibid.). Three other species of helminths (parasitic worms) were encountered during the study (*Echinostoma* sp., *Manodistomum* sp., and *Gyrodactylus* sp.); their relative impact on their hosts is unknown, but at least one Foothill Yellow-legged Frog had 700 echinostome cysts in its kidney (Ibid.). Bursey et al. (2010) discovered 13 species of helminths in and on Foothill Yellow-legged Frogs from Humboldt County. Most are common in anurans, and some are generalists with multiple possible hosts, but studies on their impact on Foothill Yellow-legged Frogs are lacking (Ibid.).

4.3 Introduced Species

Species not native to an area, but introduced, can alter food webs and ecosystem processes through predation, competition, hybridization, disease transmission, and habitat modification. Native species lack evolutionary history with introduced species, and early life stages of native anurans are particularly susceptible to predation by aquatic non-native species (Kats and Ferrer 2003). Because introduced species often establish in highly modified habitats, it can be difficult to differentiate between impacts from habitat degradation and the introduced species (Fisher and Shaffer 1996). However, native amphibians have been frequently found successfully reproducing in heavily altered habitats when introduced species were absent, suggesting introduced species themselves can impose an appreciable adverse effect (Ibid.). Numerous introduced species have been documented to adversely impact Foothill Yellow-legged Frogs or are suspected of doing so.

American Bullfrogs were introduced to California from the eastern U.S. around the turn of the 20th century, likely in response to overharvest of native ranids by the frog-leg industry that accompanied the Gold Rush (Jennings and Hayes 1985). Nearly 50 years ago, Moyle (1973) reported that distributions of Foothill Yellow-legged Frogs and bullfrogs in the Sierra Nevada foothills were nearly mutually exclusive. He speculated that bullfrog predation and competition may be causal factors in their disparate distributions in addition to the habitat degradation from dams and diversions that facilitated the bullfrog invasion in the first place. In a study along the South Fork Eel River and one of its tributaries, Foothill Yellow-legged Frog abundance was nearly an order of magnitude (10 times) lower in reaches where bullfrogs were well established (Kupferberg 1997a). At a site in Napa Valley, after bullfrogs were eradicated, Foothill Yellow-legged Frogs, among other native species, recolonized the area (Wilcox and Alvarez 2019). In a mesocosm experiment, Foothill Yellow-legged Frog tadpole survival in the presence of bullfrog tadpoles was half that of control enclosures containing only Foothill Yellow-legged Frogs, and they weighed approximately one-quarter less at metamorphosis (Kupferberg 1997a). The mechanism for these declines appeared to be the reduction of high-quality algae by bullfrog tadpole grazing, as opposed to any behavioral or chemical interference (Ibid.). Adult bullfrogs, which can get very large (3.5-6.0 inches), also directly consume Foothill Yellow-legged Frogs, including adults (Moyle 1973, Crayon 1998, Powell et al. 2016).

As discussed briefly in the Pathogens and Parasites section, American Bullfrogs act as reservoirs and vectors of the lethal chytrid fungus. In museum specimens from both southern and central California, Bd was detected in bullfrogs before it was detected in Foothill Yellow-legged Frogs in the same area (Padgett-Flohr and Hopkins 2009, Adams et al. 2017b). During a die-off from chytridiomycosis that commenced in 2013, Bd prevalence and load in Foothill Yellow-legged Frogs was positively predicted by bullfrog presence (Adams et al. 2017a). A similar die-off in 2018 from a nearby county appears to be related to transmission by bullfrogs as well (Kupferberg and Catenazzi 2019). In addition, male Foothill Yellow-legged Frogs have been observed amplexing female bullfrogs, which may not only constitute wasted reproductive effort but could serve to increase their likelihood of contracting Bd (Lind et al. 2003a). In fact, adult males were more likely to be infected with Bd than females or juveniles during the recent die-off in Alameda Creek (Adams et al. 2017a). African Clawed Frogs (*Xenopus laevis*) have also been implicated in the spread of Bd in California because, like bullfrogs, they are asymptomatic carriers (Padgett-Flohr and Hopkins 2009). However, African Clawed-Frog distribution only minimally overlaps with the Foothill Yellow-legged Frog's range unlike the widespread bullfrog (Stebbins and McGuinness 2012).

Hayes and Jennings (1986) observed a negative association between the abundance of introduced fish and Foothill Yellow-legged Frogs. Rainbow trout (*Onchorynchus mykiss*) and green sunfish (*Lepomis cyanellus*) are suspected of destroying egg masses (Van Wagner 1996). Bluegill sunfishes (*L. macrochirus*) are likely predators; in captivity when offered eggs and tadpoles of two ranid species, they consumed both life stages but a significantly greater number of tadpoles (Werschkul and Christensen 1977). Common hatchery-stocked fish like brook (*Salvelinus fontinalis*) and rainbow trout commonly carry *Saprolegnia* (Blaustein et al. 1994). In addition, presence of non-native fish can facilitate bullfrog invasions by reducing the density of macroinvertebrates that prey on their tadpoles (Adams et al. 2003). Foothill Yellow-legged Frog tadpoles raised from eggs from sites with and without smallmouth bass (*Micropterus dolomieu*) did not differ in their responses to exposure to the non-native, predatory bass and a native, non-predatory fish (Paoletti et al. 2011). This result suggests that Foothill Yellow-legged Frogs have not yet evolved a recognition of bass as a threat, which makes them more vulnerable to predation (Ibid.).

Introduced into several areas within the Coast Range and Sierra Nevada, signal crayfish have been recorded preying on Foothill Yellow-legged Frog egg masses and are suspected of preying on their tadpoles based on observations of tail injuries that looked like scissor snips (Riegel 1959, Wiseman et al. 2005). The introduced red swamp crayfish (*Procambarus clarkii*) likely also preys on Foothill Yellow-legged Frogs. Because Foothill Yellow-legged Frogs evolved with the native Shasta Crayfish (*Pacifastacus fortis*) in some parts of northern California, frogs from those areas may more effectively avoid crayfish predation than in other parts of the state where they are not native (Riegel 1959, USFWS 1998, Kats and

Ferrer 2003). The Foothill Yellow-legged Frog's naiveté to crayfish was demonstrated in a study that showed they did not change behavior when exposed to signal crayfish chemical cues; however, once the crayfish was released and consuming Foothill Yellow-legged Frog tadpoles, the survivors, likely reacting to chemical cues from dead tadpoles, exhibited a predator-avoidance behavior (Kerby and Sih 2015).

4.4 Sedimentation

Several anthropogenic activities, some of which are described in greater detail below, can artificially increase sedimentation into waterways occupied by Foothill Yellow-legged Frogs and adversely impact biodiversity (Moyle and Randall 1998). These activities include but are not limited to mining, agriculture, overgrazing, timber harvest, and poorly constructed roads (Ibid.). Increased fine sediments can substantially degrade Foothill Yellow-legged Frog habitat quality. Heightened turbidity decreases light penetration that phytoplankton and other aquatic plants require for photosynthesis (Cordone and Kelley 1961). When silt particles fall out of the water column, they can destroy algae by covering the bottom of the stream (Ibid.). Algae are not only important for Foothill Yellow-legged Frog tadpoles as forage but also for oxygen production (Ibid.). Sedimentation may impede attachment of egg masses to substrate (Ashton et al. 1997). The effect of silt accumulation on embryonic development is unknown, but it does make them less visible, which could decrease predation risk (Fellers 2005). Fine sediments can fill interstitial spaces between rocks that tadpoles use for shelter from high velocity flows and cover from predators and that serve as sources for aquatic invertebrate prey for post-metamorphic Foothill Yellow-legged Frogs (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b).

4.5 Mining

Current mining practices, as well as legacy effects from historical mining operations, may adversely impact Foothill Yellow-legged Frogs through contaminants, direct mortality, habitat destruction and degradation, and behavioral disruption. While mercury in streams can result from atmospheric deposition, storm-induced runoff of naturally occurring mercury, agricultural runoff, and geothermal springs, runoff from historical mine sites mobilizes a significant amount of mercury (Foe and Croyle 1998, Alpers et al. 2005, Hothem et al. 2010). Beginning in the mid-1800s, extensive mining occurred in the Coast Range to supply mercury for gold mining in the Sierra Nevada, causing widespread contamination of both mountain ranges and the rivers in the Central Valley (Foe and Croyle 1998). Studies on Foothill Yellow-legged Frog tissues collected from the Cache Creek (Coast Ranges) and Greenhorn Creek (Sierra Nevada) watersheds revealed mercury bioaccumulation concentrations as high as 1.7 and 0.3 ppm, respectively (Alpers et al. 2005, Hothem et al. 2010). For context, the U.S. Environmental Protection Agency's mercury criterion for issuance of health advisories for fish consumption is 0.3 ppm; concentrations exceeded this threshold in Foothill Yellow-legged Frog tissues at 62% of sampling sites in the Cache Creek watershed (Hothem et al. 2010). Bioaccumulation of this powerful neurotoxin can cause deleterious impacts on amphibians including inhibited growth, decreased survival to metamorphosis, increased malformations, impaired reproduction, and other sublethal effects (Zillioux et al. 1993, Unrine et al. 2004). In a study measuring Sierra Nevada watershed health, Moyle and Randall (1998) reportedly found very low biodiversity in streams that were heavily polluted by acidic water leaching from historical mines. Acidic drainage measured as low as pH 3.4 from some mined areas in the northern Sierra Nevada (Alpers et al. 2005).

Widespread suction dredging for gold occurred in the Foothill Yellow-legged Frog's California range until enactment of a moratorium on issuing permits in 2009 (Hayes et al. 2016). Suction dredging vacuums up the contents of the streambed, passes them through a sluice box to separate the gold, and then deposits the tailings on the other side of the box (Harvey and Lisle 1998). While most habitat disturbance is localized and minor, it can be especially detrimental if it degrades or destroys breeding and rearing habitat through direct disturbance or sedimentation (Ibid.). In addition, this activity can lead to direct mortality of early life stages through entrainment, and those eggs and tadpoles that do survive passing through the suction dredge may experience greater mortality due to subsequent unfavorable physiochemical conditions and possible increased predation risk (Ibid.). Suction dredging can also reduce the availability of invertebrate prey, although this impact is typically short-lived (Ibid.). Suction dredging alters stream morphology, and relict tailing ponds can serve as breeding habitat for bullfrogs in areas that would not normally support them (Fuller et al. 2011). However, in some areas these mining holes have reportedly benefited Foothill Yellow-legged Frogs by creating cool persistent pools through the summer at one Sierra Nevada site that adult females appeared to prefer (Van Wagner 1996). Senate Bill 637 (2015) directs the Department to work with the State Water Resources Control Board (SWRCB) to develop a statewide water quality permit that would authorize the use of vacuum or suction dredge equipment in California under conditions set forth by the two agencies. SWRCB staff, in coordination with Department staff, are in the process of collecting additional information to inform the next steps that will be taken by the SWRCB (SWRCB 2019).

Instream aggregate (gravel) mining continues today and can have similar impacts to suction dredge mining by removing, processing, and relocating stream substrates (Olson and Davis 2009). This type of mining typically removes bars used as Foothill Yellow-legged Frog breeding habitat and reduces habitat heterogeneity by creating flat wide channels (Kupferberg 1996a, Yarnell 2005). When listed salmonids are present, typically mining must be conducted above the wetted edge, but this practice can create perennial off-channel bullfrog breeding ponds (M. van Hattem pers. comm. 2018).

4.6 Agriculture

California is the nation's largest agricultural producer and exporter (CDFA 2018a). Direct loss of Foothill Yellow-legged Frog habitat from wildland conversion to agriculture is likely rare overall because the typically rocky riparian areas they inhabit are usually not conducive to farming, but removal of riparian vegetation directly adjacent to streams for agriculture is more common and widespread. The U.S. Department of Agriculture classifies 9.6 million ac in California as cropland, which amounts to less than 10% of the state's land area, and 70% of this occurs in the Central Valley between Redding and Bakersfield (Martin et al. 2018). In addition, several indirect impacts can adversely affect Foothill Yellow-legged Frogs at substantial distances from agricultural operations such as effects from runoff (sediments and agrochemicals), drift and deposition of airborne pollutants, water diversions, and creation of novel habitats like impoundments that facilitate spread of detrimental non-native species. As sedimentation and introduced species impacts were previously discussed, this section instead focuses on the other possible adverse impacts.

4.6.1 Agrochemicals

Many species of amphibians, particularly ranids, have experienced declines throughout California, but the most dramatic declines have occurred in the Sierra Nevada east of the San Joaquin Valley where 60% of the total pesticide usage in the state was sprayed (Sparling et al. 2001). Agrochemicals applied to crops in the Central Valley can volatilize, travel through the atmosphere, and deposit in higher elevations (LeNoir et al. 1999). Pesticide concentrations diminish as elevations increase in the lower foothills but change little from 1,750 to 6,300 ft, which coincides with the Foothill Yellow-legged Frog's elevational range (Ibid). Foothill Yellow-legged Frog absence at historically occupied sites in California significantly correlated with agricultural land use within 3.1 mi (Davidson et al. 2002). Figure 23 depicts the positive relationship between Foothill Yellow-legged Frog declines and the amount of upwind agriculture, suggesting airborne agrochemicals may be a contributing factor (Ibid.). Cholinesterase-inhibitors (most organophosphates and carbamates), which disrupt nerve impulse transmission, were more strongly associated with population declines than other pesticide types (Davidson 2004). Olson and Davis (2009) and Lind (2005) also reported a negative correlation between Foothill Yellow-legged Frog presence and proximity and quantity of nearby agriculture in Oregon and across the species' entire range, respectively.

Lethal and sublethal effects of agrochemicals on amphibians can take two general forms: direct toxicity and food-web effects. Sublethal doses of agrochemicals can interact with other environmental stressors to reduce fitness. Foothill Yellow-legged Frog tadpoles showed significantly greater vulnerability to the lethal and sublethal effects of carbaryl than Pacific Treefrogs (Kerby and Sih 2015). An inverse relationship exists between carbaryl concentration and Foothill Yellow-legged Frog activity, and their 72-hr LC_{50} (concentration at which 50% die) measured one-fifth that of Pacific Treefrogs (Ibid.). Carbaryl slightly decreased Foothill Yellow-legged Frog development rate, but it significantly increased susceptibility to predation by signal crayfish despite nearly no mortality in the pesticide- and predator-only treatments (Ibid.). Sparling and Fellers (2009) also found Foothill Yellow-legged Frogs were significantly more sensitive to pesticides (chlorpyrifos and endosulfan in this study) than Pacific Treefrogs; their 96-hr LC_{50} was nearly five-times less than for treefrogs. Endosulfan was nearly 121 times more toxic to Foothill Yellow-legged Frogs than chlorpyrifos, and water samples from the Sierra Nevada have contained endosulfan concentrations greater than the LC_{50} for the species in some parts of the species' range (Ibid.). Sublethal effects included smaller body size, slower development rate, and increased time to metamorphosis (Ibid.). Sparling and Fellers (2007) determined the organophospates chlorpyrifos, malathion, and diazinon can harm Foothill Yellow-legged Frog populations, and their oxon derivatives (the resultant compounds once they begin breaking down in the body) were 10 to 100 times more toxic than their respective parental forms.

Extrapolating the results of studies on other ranids to Foothill Yellow-legged Frogs should be undertaken with caution; however, those studies can demonstrate additional potential adverse impacts of exposure to agrochemicals. Relyea (2005) discovered that Roundup®, a common herbicide, could cause rapid and

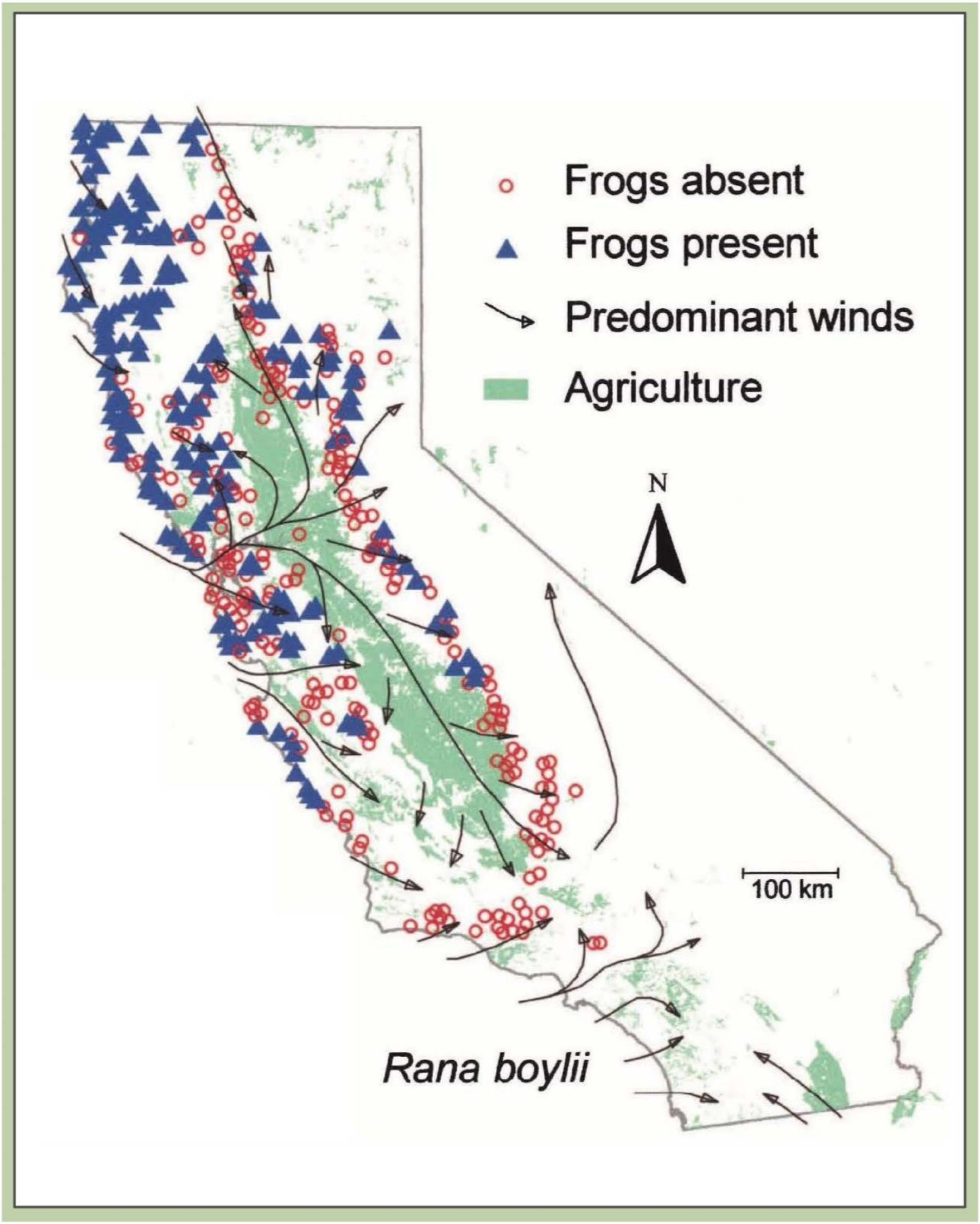

Figure 23. Relationship of Foothill Yellow-legged Frog occupancy to agriculture and prevailing winds from Davidson et al. (2002)

widespread mortality in amphibian tadpoles through direct toxicity, and overspray at the manufacturer's recommended application concentrations would be highly lethal. Atrazine, another common herbicide, has been implicated in disrupting reproductive processes in male Northern Leopard Frogs (Rana pipiens) by slowing gonadal development, inducing hermaphroditism, and even producing oocytes (eggs) (Hayes et al. 2003). However, recent research on sex reversal in wild populations of Green Frogs (R. clamitans) suggests the phenomenon may be a relatively common natural process unrelated to environmental contaminants, requiring more research (Lambert et al. 2019). Malathion, a common organophosphate insecticide, that rapidly breaks down in the environment, applied at low concentrations caused a trophic cascade that resulted in reduced growth and survival of two species of ranid tadpoles (Relyea and Diecks 2008). Malathion caused a reduction in the amount of zooplankton, which resulted in a bloom of phytoplankton and an eventual decline in periphyton, an important food source for tadpoles (Ibid.). In contrast, Relyea (2005) found that some insecticides increased amphibian tadpole survival by reducing their invertebrate predators. Runoff from agricultural areas can contain fertilizers that input nutrients into streams and increase productivity, but they can also result in harmful algal blooms (Cordone and Kelley 1961). In addition, exposure to pesticides can result in immunosuppression and reduce resistance to the parasites that cause limb malformations (Kiesecker 2002, Hayes et al. 2006).

4.6.2 Cannabis

An estimated 60-70% of the cannabis (*Cannabis indica* and *C. sativa*) used in the U.S. from legal and illegal sources is grown in California, and most comes from the Emerald Triangle, an area comprised of Humboldt, Mendocino, and Trinity counties (Ferguson 2019). Small-scale illegal cannabis farms have operated in this area since at least the 1960s but have expanded rapidly since the passage of the Compassionate Use Act in 1996, particularly trespass grows on public land primarily by Mexican cartels (Mallery 2010, Bauer et al. 2015). Like other forms of agriculture, it involves clearing the land, diverting water, and using herbicides and pesticides; however, in addition, many of these illicit operations use large quantities of fertilizers and highly toxic banned pesticides to kill anything that may threaten the crop, and they leave substantial amounts of non-biodegradable trash and human excrement (Mallery 2010, Thompson et al. 2014, Carah et al. 2015).

Measurements of environmental impacts of illegal cannabis grows have been hindered by the difficult and dangerous nature of accessing many of these sites; however, some analyses have been conducted, often using aerial images and GIS. An evaluation of 54% of watersheds within and bordering Humboldt County revealed that while cannabis grow sites are generally small (<1.2 ac) and comprised a tiny fraction of the study area (301 ac), they were widespread (present in 83% of watersheds) but unevenly distributed, indicating impacts are concentrated in certain watersheds (Butsic and Brenner 2016, Wang et al. 2017). The results also showed that 68% of grows were ≤0.3 mi from developed roads, 23% were located on slopes steeper than 30%, and 5% were within 328 ft of critical habitat for threatened salmonids (Butsic and Brenner 2016). These characteristics suggest wildlands adjacent to cannabis cultivations are at heightened risk of habitat fragmentation, erosion, sedimentation, landslides, and impacts to waterways critical to imperiled species (Ibid.).

A separate analysis in the same general area estimated potentially significant impacts from water diversions alone. Cannabis requires a substantial amount of water during the growing season, so it is often cultivated near sources of perennial surface water for irrigation, commonly diverting from springs and headwater streams (Bauer et al. 2015). In the least impacted of the study watersheds, Bauer et al. (2015) calculated that diversions for cannabis cultivation could reduce the annual seven-day low flow by up to 23%, and in some of the heavily impacted watersheds, water demands for cannabis could exceed surface water availability. If not regulated carefully, cannabis cultivation could have substantial impacts on sensitive aquatic species like Foothill Yellow-legged Frogs in watersheds in which it is concentrated.

For context, cannabis cultivation was responsible for approximately 1.1% of forest cover lost within study watersheds in Humboldt County from 2000 to 2013, while timber harvest accounted for 53.3% (Wang et al. 2017). Cannabis requires approximately two times as much water per day as wine grapes, the other major irrigated crop in the region (Bauer et al. 2015). Impacts from cannabis cultivation have been observed by Foothill Yellow-legged Frog researchers working on the Trinity River and South Fork Eel River in the form of lower flows in summer, increased egg stranding, and more algae earlier in the season in recent years (S. Kupferberg and M. Power pers. comm. 2015; D. Ashton pers. comm. 2017; S. Kupferberg, M. van Hattem, and W. Stokes pers. comm. 2017). In addition, Gonsolin (2010) reported illegal cannabis cultivations on four headwater streams that drained into his study area along Coyote Creek, three of which were occupied by Foothill Yellow-legged Frogs. The cultivators had removed vegetation adjacent to the creeks, terraced the slopes, diverted water, constructed small water impoundments, poured fertilizers directly into the impoundments, and applied herbicides and pesticides, as evidenced by leftover empty containers littering the site.

Commercial sale of cannabis for recreational use became legal in California on January 1, 2018, through passage of the Control, Regulate and Tax Adult Use of Marijuana Act (2016), and with it an environmental permitting system and habitat restoration fund was established. The number of applications for temporary licenses per watershed is depicted in Figure 24. Two of the expected outcomes of passage of this law were that the profit-margin on growing cannabis would fall to the point that it would discourage illegal trespass grows and move the bulk of the cultivation out of remote forested areas into existing agricultural areas like the Central Valley (CSOS 2016). However, until cannabis is legalized at the federal level, these results may not occur since banks are reluctant to work with growers due to federal prohibitions subjecting them to prosecution for money laundering (ABA 2019). Additional details on cannabis permitting at the state level can be found under the Existing Management section.

4.6.3 Vineyards

Vineyard operators historically built on-stream dams and removed almost all the surrounding riparian vegetation to make room for vines and for ease of irrigation (M. van Hattem pers. comm. 2019). They still divert a substantial amount of water for irrigation, and they build on- and off-stream impoundments that support bullfrogs (Ibid.). The acreage of land planted in wine grapes in California began rising dramatically in the 1970s and now accounts for 90% of wine produced in the U.S. (Geisseler and Horwath 2016, Alston et al. 2018). The number of wineries in California rose from approximately 330 to

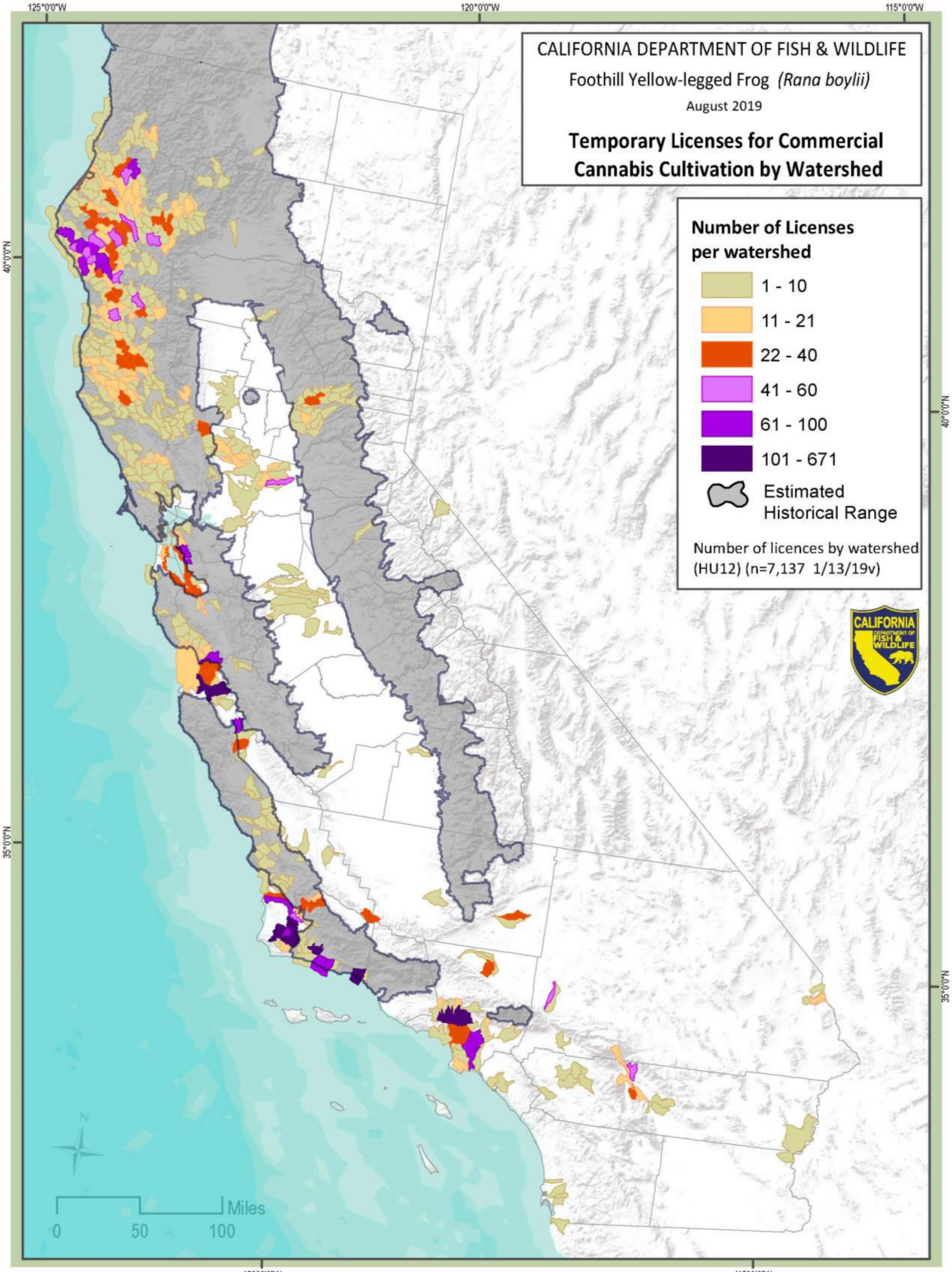

Figure 24. Cannabis cultivation temporary licenses by watershed in California (CDFA, NHD)

nearly 2,500 between 1975 and 2006; however, expansion slowed and has reversed slightly recently with 60,000 ac, or 6.5% of total area planted, removed between 2015 and 2017 (Volpe et al. 2010, CDFA 2018b). In 2015, 857,000 ac were planted in grapes with 70% located in the San Joaquin Valley; 66%, 21%, and 13% were planted in wine, raisin, and table grapes, respectively (Alston et al. 2018).

Expansion of wineries in the coastal counties converted natural areas such as oak woodlands and forests to vineyards (Merenlender 2000, Napa County 2010). The area of Sonoma County covered in grapes increased by 32% from 1990 to 1997, and 42% of these new vineyards were planted above 328 ft with 25% on slopes greater than 18% (Merelender 2000). For context, only 18% of vineyards planted before 1990 occurred above 328 ft and less than 6% on slopes greater than 18% (Ibid.). This conversion took place on approximately 1,909 ac of conifer and dense hardwood forest, 7,229 ac of oak grassland savanna, and 367 ac of shrubland (Ibid.). Recent expansion of oak woodland conversion to vineyards in Napa County was highest in its eastern hillsides (Napa County 2010). Napa County estimates that between 2,682 and 3,065 ac of woodlands will be converted to vineyards between 2005 and 2030 (Ibid.). For context, 733 ac were converted from 1992 to 2003 (Ibid.). In addition, wine grapes were second only to almonds in terms of overall quantity of pesticides applied in California in 2016, but the quantity per unit area 2.6 lb/ac was 160% greater for the wine grapes (CDPR 2018). Vineyard expansion into hillsides has continued into sensitive headwater areas, and like cannabis cultivation, even small vineyards can have substantial impacts on Foothill Yellow-legged Frog habitat through sedimentation, water diversions, spread of harmful non-native species, and agrochemical contamination (Merelender 2000, K. Weiss pers. comm. 2018).

4.6.4 Livestock Grazing

Livestock grazing can be an effective habitat management tool, including control of riparian vegetation encroachment into important Foothill Yellow-legged Frog breeding habitat, but overgrazing can significantly degrade the environment (Siekert et al. 1985). Cattle display a strong preference for riparian areas and have been implicated as a major source of habitat damage in the western U.S., where the adverse impacts of overgrazing on riparian vegetation are intensified by arid and semi-arid climates (Behnke and Raleigh 1978, Kauffman and Krueger 1984, Belsky et al. 1999). The severity of grazing impacts on riparian systems can be influenced by the number of animals, duration and time of year, substrate composition, and soil moisture (Benhke and Raleigh 1978, Kauffman et al. 1983, Marlow and Pogacnik 1985, Siekert et al. 1985). In addition to habitat damage, cattle can directly trample any life stage of Foothill Yellow-legged Frog.

Signs of overgrazing include impacts to the streambanks such as increased slough-offs and cave-ins that collapse undercuts used as refuge by Foothill Yellow-legged Frogs (Kauffman et al. 1983). Overgrazing reduces riparian cover and increases erosion and sedimentation, which as described above can result in silt degradation of breeding, rearing, and invertebrate food-producing areas (Cordone and Kelley 1961, Behnke and Raleigh 1978, Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). Loss of streamside and instream vegetative cover and changes to channel morphology can increase water temperatures and velocities (Behnke and Raleigh 1978). Water quality can be affected by increased turbidity and nutrient input from excrement, and seasonal water quantity can be impacted through changes to channel morphology (Belsky et al. 1999). In addition, increased nutrients and temperatures can promote blooms of harmful cyanobacteria like *Microcystis aeruginosa*, which releases a toxin when it expires that can cause liver damage to amphibians as well as other animals including humans (Bobzien and DiDonato 2007, Zhang et al. 2013).

While some recent studies indicate livestock grazing continues to damage stream and riparian ecosystems, its impact on Foothill Yellow-legged Frogs in California is unknown (Belsky et al. 1999, Hayes et al. 2016). In Oregon, the species' presence was correlated with significantly less grazing than where they were absent according to Borisenko and Hayes's 1999 report (as cited in Olson and Davis 2009). However, Fellers (2005) reported that apparently some Coast Range foothill populations occupying streams draining east into the San Joaquin Valley were doing well at the time of publication despite being heavily grazed.

4.7 Urbanization and Road Effects

Habitat conversion and fragmentation combined with modified environmental disturbance regimes can substantially jeopardize biological diversity (Tracey et al. 2018). This threat is most severe in areas like California with Mediterranean-type ecosystems that are biodiversity hot spots, fire-prone, and heavily altered by human land use (Ibid.). From 1990 to 2010, the fastest-growing land use type in the conterminous U.S. was new housing construction, which rapidly expanded the wildland-urban interface (WUI), where houses and natural vegetation meet or intermix on the landscape (Radeloff et al. 2018).

Of several variables tested, proportion of urban land use within a 3.1 mi radius of a site was associated with Foothill Yellow-legged Frog declines (Davidson et al. 2002). Lind (2005) also found significantly less urban development nearby and upwind of sites occupied by Foothill Yellow-legged Frogs, suggesting pollutant drift may be a contributing factor. Changes in wildfires may also contribute to the species' declines; 95% of California's fires are human-caused, and wildfire issues are greatest at the WUI (Syphard et al. 2009, Radeloff et al. 2018). Population density, intermix WUI (where wildland and development intermingle as opposed to an abrupt interface), and distance to WUI explained the most variability in fire frequency (Syphard et al. 2007). In addition to wildfires, habitat loss, and fragmentation, urbanization can impact adjacent ecosystems through non-native species introduction, native predator subsidization, and disease transmission (Bar-Massada et al. 2014).

Projections show growth in California's population to 51 million people by 2060, from approximately 40 million currently (PPIC 2019). This will increase urbanization, the WUI, and habitat fragmentation. The Department of Finance projects the Inland Empire, the San Joaquin Valley, and the Sacramento metropolitan area will be the fastest-growing regions of the state over the next several decades (Ibid.). This puts the greatest pressure in areas outside of the Foothill Yellow-legged Frog's range; however, because the environmental stressors associated with urbanization can span far beyond its physical footprint, they may still adversely affect the species.

Highways are frequently recognized as barriers to dispersal that fragment habitats and populations; however, single-lane roads can pose significant risks to wildlife as well (Cook et al. 2012, Brehme et al. 2018). Foothill Yellow-legged Frogs are at risk of being killed by vehicles when roads are located near their habitat (Cook et al. 2012, Brehme et al. 2018). Fifty-six juvenile Foothill Yellow-legged Frogs were found on a road adjacent to Sulphur Creek (Mendocino County), seven of which had been struck and killed (Cook et al. 2012). When fords (naturally shallow areas) are used as vehicle crossings, they can create sedimentation and poor water quality, and when the fords are gravel or cobble bars used by Foothill Yellow-legged Frogs for breeding, their use could result in direct mortality (K. Blanchard pers. comm. 2018, R. Bourque pers. comm. 2018).

Construction of culverts under roads to keep vehicles out of the streambed can result in varying impacts. In some cases, they can impede dispersal, trap frogs, and create deep scoured pools that support predatory fish and frogs, but when properly constructed, they can facilitate frog movement up and down the channel with reduced road mortality (Van Wagner 1996, GANDA 2008, C. Dillingham pers. comm. 2019). In addition, those scoured pools can provide habitat for Foothill Yellow-legged Frogs in areas where premature drying is a threat and non-native species are absent (M. Grefsrud pers. comm. 2019). Culverts can also act in a similar way to a natural waterfall and impede upstream migration of non-native fish and crayfish (Kerby et al. 2005). An evaluation of the relative impact of roads on 166 native California amphibians and reptiles, through barriers to movement and direct mortality, concluded that Foothill Yellow-legged Frogs, at individual and population levels, were at moderate risk in aquatic habitat but very low risk of impacts in terrestrial habitat (Brehme et al. 2018). For context, all chelonids (turtles and tortoises), 72% of snakes, 50% of anurans, 18% of lizards, and 17% of salamander species in California were ranked as having a high or very high risk of negative road impacts in the same evaluation (Ibid.).

Poorly constructed roadways near rivers and streams can result in substantial erosion and sedimentation, leading to reduced amphibian densities (Welsh and Ollivier 1998). Proximity of roads to Foothill Yellow-legged Frog habitat contributes to petrochemical runoff and poses the threat of spills (Ashton et al. 1997). A diesel spill on Hayfork Creek (Trinity County) resulted in mass mortality of Foothill Yellow-legged Frog tadpoles and partial metamorphs (Bury 1972). Roads have also been implicated in the spread of disease and may have aided in the spread of Bd in California (Adams et al. 2017b).

Frogs use auditory and visual cues to defend territories and attract mates, and some studies reveal that realistic levels of traffic noise can impede transmission and reception of these signals (Bee and Swanson 2007). Some male frogs have been observed changing the frequency of their calls to increase the distance they can be heard over traffic noise, but if females have evolved to recognize lower pitched calls as signs of superior fitness, this potential trade-off between audibility and attractiveness could have implications for reproductive success (Parris et al. 2009). In a separate study, traffic noise caused a change in male vocal sac coloration and an increase in stress hormones, which changed sexual selection processes and suppressed immunity (Troïanowski et al. 2017). Because Foothill Yellow-legged Frogs mostly call underwater and are not known to use color displays, communication cues may not be adversely affected by traffic noise, but their stress response is unknown.

4.8 Timber Harvest

Because Foothill Yellow-legged Frogs tend to remain close to the water channel (i.e., within the riparian corridor) and current timber harvest practices minimize disturbance in riparian areas for the most part, adverse effects from timber harvest are expected to be relatively low (Hayes et al. 2016, CDFW 2018b). However, some activities have a potential to negatively impact Foothill Yellow-legged Frogs or their habitat, including direct mortality and increased sedimentation during construction and decommissioning of watercourse crossings and infiltration galleries, tree felling, log hauling, and entrainment by water intakes or desiccation of eggs and tadpoles through stranding from dewatering during drafting operations (CDFW 2018b,c). In addition to impacts previously described under the Sedimentation and Urbanization and Road Effects sections, when silt runoff into streams is accompanied by organic materials, such as logging debris, impaired water quality can result, including reduced dissolved oxygen, which is important in embryonic and tadpole development (Cordone and Kelley 1961).

Because Foothill Yellow-legged Frogs are heliotherms (i.e, they bask in the sun to raise their body temperature) and sensitive to thermal extremes, some moderate timber harvest may benefit the species (Zweifel 1955, Fellers 2005). Ashton (2002) reported 85% of his Foothill Yellow-legged Frog observations occurred in second-growth forests (37-60 years post-harvest) as opposed to late-seral forests and postulated that the availability of some open canopy areas played a major part in this disparity. Foothill Yellow-legged Frogs are typically absent in areas with closed canopy (Welsh and Hodgson 2011). Reduced canopy also raises stream temperatures, which could improve tadpole development and promote algal and invertebrate productivity in otherwise cold streams (Olson and Davis 2009; Catenazzi and Kupferberg 2013,2017).

4.9 Recreation

Several types of recreation can adversely impact Foothill Yellow-legged Frogs, and some are more severe and widespread than others. Increased and intensified recreation in streams was one of the main potential factors identified by herpetologists as contributing to disappearance of Foothill Yellow-legged Frogs in southern California (Adams et al. 2017b). The greater number of people traveling into the backcountry may have facilitated the spread Bd to these areas, and while no evidence shows stress from disturbance or other environmental pressures increases susceptibility to Bd, the stress hormone corticosterone has been implicated in immunosuppression (Hayes et al. 2003, Adams et al. 2017b).

The amount of Foothill Yellow-legged Frog habitat disturbed by off-highway motor vehicles (OHV) throughout its range in California is unknown, but its impacts can be significant, particularly in areas with small isolated populations (Kupferberg et al. 2009c, Kupferberg and Furey 2015). An example is the Carnegie State Vehicular Recreation Area (CSVRA), located in the hills southwest of Tracy in the Corral Hollow Creek watershed (Alameda and San Joaquin counties). The above-described road effects apply: sedimentation, crushing along trail crossings, and potential noise effects (Ibid.). In addition, dust suppression activities employed by CSVRA use magnesium chloride, which has the potential to harm developing embryos and tadpoles (Karraker et al. 2008, Hopkins et al. 2013, OHMVRC 2017). Based on museum records, Foothill Yellow-legged Frogs were apparently abundant in Corral Hollow Creek, but they are extremely rare now and are already extirpated or at risk of extirpation (Kupferberg et al. 2009c, Kupferberg and Furey 2015).

Motorized and non-motorized recreational boating can also impact Foothill Yellow-legged Frogs. The impacts of jet boat traffic were investigated in Oregon; in areas with frequent use and high wakes breaking on shore, Foothill Yellow-legged Frogs were absent (Borisenko and Hayes 1999 as cited in Olson and Davis 2009). This wake action had the potential to dislodge egg masses, strand tadpoles, disrupt adult basking behavior, and erode shorelines (Ibid.). Jet boat tours and races on the Klamath River (Del Norte and Humboldt counties) may have an impact on Foothill Yellow-legged Frog use of the mainstem (M. van Hattem pers. comm. 2019). In addition, using gravel bars as launch and haul out sites for boat trailers, kayaks, or river rafts can result in direct loss of egg masses and tadpoles or damage to breeding and rearing habitat and can disrupt post-metamorphic frog behavior (Ibid.). As described above, pulse flows released for whitewater boating in the late spring and summer can result in scouring and stranding of egg masses and tadpoles (Borisenko and Hayes 1999 as cited in Olson and Davis 2009, Kupferberg et al. 2009b). The nearshore velocities of these pulse flows are greater than those that resulted in stunted growth and increased vulnerability to predation in Foothill Yellow-legged Frog tadpoles under experimental conditions (Kupferberg et al. 2011b).

Hiking, horse-riding, camping, fishing, and swimming, particularly in sensitive breeding and rearing habitat, can also adversely impact Foothill Yellow-legged Frog populations (Borisenko and Hayes 1999 in Olson and Davis 2009). Because Foothill Yellow-legged Frog breeding activity was being disturbed and egg masses were being trampled by people and dogs using Carson Falls (Marin County), the land manager established an educational program, including employing docents on weekends that remind people to stay on trails and tread lightly to try to reduce the loss of Foothill Yellow-legged Frog reproductive effort (Prado 2005). In addition, within his study site, Van Wagner (1996) reported that a property owner moved rocks that were being used as breeding habitat to create a swimming hole. The extent to which this is more than a small, local problem is unknown, but as the population of California increases, recreational pressures in Foothill Yellow-legged Frog habitat are likely to increase commensurately.

4.10 Drought

Drought is a common phenomenon in California and is characterized by lower than average precipitation. Lower precipitation in general results in less surface water, and water availability is critical for obligate stream-breeding species. Even in the absence of drought, a positive relationship exists between precipitation and latitude within the Foothill Yellow-legged Frog's range in California, and mean annual precipitation has a strong influence on Foothill Yellow-legged Frog presence at historically occupied sites (Davidson et al. 2002, Lind 2005). Figure 25 depicts the recent historical annual average precipitation across the state as well as during the most recent drought and how they differ. Southern California is normally drier than northern California, but the severity of the drought was even greater in the south.

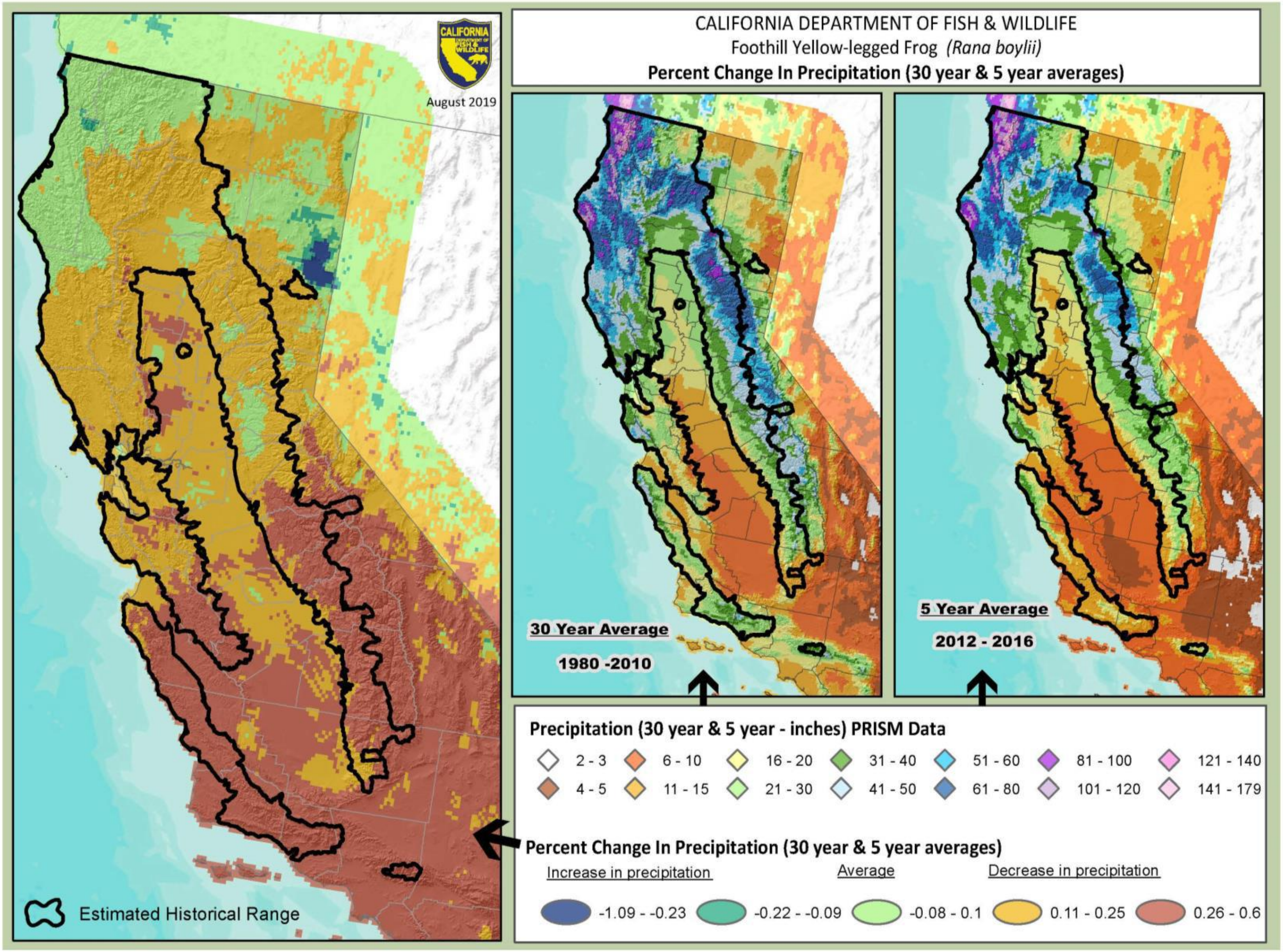

Figure 25. Change in precipitation from recent 30-year average and 5-year drought (PRISM)

Reduced precipitation can result in deleterious effects to Foothill Yellow-legged Frogs beyond the obvious premature drying of aquatic habitat. When stream flows recede during the summer and fall, sometimes the isolated pools that stay perennially wet are the only remaining habitat. This phenomenon concentrates aquatic species, resulting in several potentially significant adverse impacts. Stream flow volume was negatively correlated with Bd load during a recent chytridiomycosis outbreak in the Alameda Creek watershed (Adams et al. 2017a). The absence of high peak flows in winter coupled with wet years allowed bullfrogs to expand their distribution upstream, and the drought-induced low flows in the fall concentrated them with Foothill Yellow-legged Frogs in the remaining drying pools (Ibid.). This mass mortality event appeared to have been the result of a combination of drought, disease, and dam effects (Ibid.). This die-off occurred in a regulated reach that experiences heavy recreational use, and crayfish and bass are present (Ibid.). Despite these threats, the density of breeding females in this reach was greater in 2014 and 2015 than in the unregulated reach upstream because the latter dried completely before tadpoles could metamorphose during the preceding drought years (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015).

In addition to increasing the spread of pathogens, drought-induced stream drying can increase predation and competition by introduced fish and frogs in the pools they are forced to share (Moyle 1973, Hayes and Jennings 1988, Drost and Fellers 1996). This concentration in isolated pools can also result in increased native predation as well as facilitate spread of Bd. An aggregation of six adult Foothill Yellow-legged Frogs was observed perched on a rock above an isolated pool in the summer where a gartersnake was foraging on tadpoles; this close contact may reduce evaporative water loss when they are forced out of the water during high temperatures, but it can also increase disease transmission risk (Leidy et al. 2009.). Gonsolin (2010) also documented a late summer aggregation of juvenile Foothill Yellow-legged Frogs out of water during extremely high temperatures. In addition, drought-induced low flow, high water temperatures, and high densities of tadpoles were associated with outbreaks of malformation-inducing parasitic copepods (Kupferberg et al. 2009a).

Premature stream drying caused or worsened by drought can result in stranding egg masses and tadpoles, but in some situations, it can also benefit Foothill Yellow-legged Frogs. For example, if pools stay wet long enough to support metamorphosis, complete drying at the end of the season may eliminate introduced species like warm water fish and bullfrogs (Bogan et al. 2019). Foothill Yellow-legged Frogs adapted to drought conditions by initiating breeding earlier and shortening the period over which they oviposit (Kupferberg 1996a, Yarnell et al. 2013). Moyle (1973) noted that the only intermittent streams occupied by Foothill Yellow-legged Frogs in the Sierra Nevada foothills had no bullfrogs. At a long-term study site in upper Coyote Creek in early fall 2014, at the height of the most severe drought in over a millennium, remnant pools in the upper watershed provided important refuge for native species (Griffin and Anchokaitis 2014, Bogan et al. 2019). Foothill Yellow-legged Frogs were widely distributed and relatively abundant in the remnant pools, and non-native species were absent in all but one (Bogan et al. 2019). The Foothill Yellow-legged Frog abundance was much lower than reported a decade earlier; it appeared to have never recovered from the 2007-2009 drought (Gonsolin 2010, J. Smith pers. comm. 2015). However, in 2016 after a relatively wet winter, Foothill Yellow-legged

Frogs bred en masse, and only a single adult bullfrog was detected, which was an unusually low number for that area (CDWR 2016, J. Smith pers. comm. 2016).

Drought can also exacerbate the effects of other environmental stressors. During the most recent severe drought, tree mortality increased dramatically from 2014 to 2017 and reached approximately 129 million dead trees (OEHHA 2018). Multiple years of high temperatures and low precipitation left them weakened and more susceptible to pathogens and parasites (Ibid.). Vast areas of dead and dying trees are more prone to severe wildfires, and they lose their carbon sequestration function while also emitting methane, which is an extremely damaging greenhouse gas (CNRA 2016). Post-wildfire storms can result in erosion of fine sediments from denuded hillsides into the stream channel (Florsheim et al. 2017). If the storms are short in duration and peak discharges are low magnitude, as happens during droughts, flows may be insufficient to transport the material downstream, extending the duration of habitat degradation (Ibid.). Reduced rainfall may also infiltrate the debris leading to subsurface flows rather than the surface water Foothill Yellow-legged Frogs require (Ibid.). Extended droughts increase risk of the stream being uninhabitable or inadequate for breeding for multiple years, which would result in population-level impacts and possible extirpation (Ibid.).

4.11 Wildland Fire and Fire Management

Fire is an important element for shaping and maintaining the species composition and integrity of many California ecosystems (Syphard et al. 2007, SBFFP 2018). Prior to European settlement, an estimated 4.5 to 12 million ac burned annually (4-11% of total area of the state), ignited both deliberately by Native Americans and through lightning strikes (Keeley 2005, SBFFP 2018). The impacts of wildland fires on Foothill Yellow-legged Frogs are poorly understood and likely vary significantly across the species' range with differences in climate, vegetation, soils, stream-order, slope, frequency, and severity (Olson and Davis 2009). Mortality from direct scorching is unlikely because Foothill Yellow-legged Frogs are highly aquatic, and most wildfires occur during the dry period of the year when the frogs are most likely to be in or near the water (Pilliod et al. 2003, Bourque 2008). Field observations support this presumption; sightings of post-metamorphic Foothill Yellow-legged Frogs immediately after fires in the northern Sierra Nevada and North Coast indicate they are not very vulnerable to the direct effects of fire (S. Kupferberg and R. Peek pers. comm. 2018). Similarly, Foothill Yellow-legged Frogs were observed two months, and again one year, after a low- to moderate-intensity fire burned an area in the southern Sierra Nevada in 2002, and the populations were extant and breeding as recently as 2017 (Lind et al. 2003b, CNDDB 2019). While water may provide a refuge from fire, it is also possible for temperatures during a fire, or afterward due to increased solar exposure, to near or exceed a threshold that results in lethal or sublethal harm; this would likely impact embryos and tadpoles with limited dispersal abilities (Pilliod et al. 2003).

Intense fires remove overstory canopy, which provides insulation from extreme heat and cold, and woody debris that increases habitat heterogeneity (Pilliod et al. 2003, Olson and Davis 2009). If this happens frequently enough, it can permanently change the landscape. For example, frequent high-severity burning of crown fire-adapted ecosystems can prevent forest regeneration since seeds require sufficient time between fires to mature, and repeated fires can deplete the seed bank (Stephens et al.

2014). Smoke and ash change water chemistry through increased nutrient and heavy metal inputs that can reach concentrations harmful to aquatic species during the fire and for days, weeks, or years thereafter (Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Erosion rates on granitic soils, which make up a large portion of the Foothill Yellow-legged Frog's range, can be over 60 times greater in burned vs. unburned areas and can increase sedimentation for over 10 years (Megahan et al. 1995, Hayes et al. 2016). In some cases, post-fire nutrient inputs into streams could benefit Foothill Yellow-legged Frogs through increased productivity and more rapid growth and development (Pilliod et al. 2003). While the loss of leaf litter that accompanies fire alters the food web, insects are expected to recolonize rapidly, and the lack of cover could increase their vulnerability to predation by Foothill Yellow-legged Frogs (Ibid.).

Low-intensity fires likely have no adverse effect on Foothill Yellow-legged Frogs (Olson and Davis 2009). If they occur in areas with dense canopy, wildfires can improve habitat quality for Foothill Yellow-legged Frogs by reducing riparian cover, providing areas to bask, and increasing habitat heterogeneity, which is likely to outweigh any adverse effects from some fire-induced mortality (Russell et al. 1999, Olson and Davis 2009). In a preliminary analysis of threats to Foothill Yellow-legged Frogs in Oregon, proximity to stand-replacing fires was not associated with absence (Olson and Davis 2009).

Euro-American colonization of California significantly altered the pattern of periodic fires with which California's native flora and fauna evolved through fire exclusion, land use practices, and development (OEHHA 2018). Fire suppression can lead to canopy closure, which reduces habitat quality by limiting thermoregulatory opportunities (Olson and Davis 2009). In addition, fire suppression and its subsequent increase in fuel loads combined with expanding urbanization and rising temperatures have resulted in a greater likelihood of catastrophic stand-replacing fires that can significantly alter riparian systems for decades (Pilliod et al. 2003). Firebreaks, in which vegetation is cleared from a swath of land, can result in similar impacts to roads and road construction (Ibid.). Fire suppression can also include bulldozing within streams to create temporary reservoirs for pumping water, which can cause more damage than the fire itself to Foothill Yellow-legged Frogs in some cases (S. Kupferberg and R. Peek pers. comm. 2018). In addition, fire suppression practices can involve applying hundreds of tons of ammonia-based fire retardants and surfactant-based fire suppressant foams from air tankers and fire engines (Pilliod et al. 2003). Some of these chemicals are highly toxic to some anurans (Little and Calfee 2000).

Fire suppression has evolved into fire management with a greater understanding of its importance in ecosystem health (Keeley and Syphard 2016). Several strategies are employed including prescribed burns, mechanical fuels reduction, and allowing some fires to burn instead of extinguishing them (Pilliod et al. 2003). Like wildfires themselves, fire management strategies have the potential to benefit or harm Foothill Yellow-legged Frogs. Prescribed fires and mechanical fuels removal lessen the likelihood of catastrophic wildfires, but they can also result in loss of riparian vegetation, excessive sedimentation, and increased water temperatures (Ibid.). Salvage logging after a fire may result in similar impacts to timber harvest but with higher rates of erosion and sedimentation (Ibid.). A balanced approach to wildland fires is likely to have the greatest beneficial impact on species and ecosystem health (Stephens et al. 2012).

4.12 Floods and Landslides

As previously described, Foothill Yellow-legged Frog persistence is highly sensitive to early life stage mortality (Kupferberg et al. 2009c). While aseasonal dam releases are a major source of egg mass and tadpole scouring, storm-driven floods are also capable of inducing the same effects (Ashton et al. 1997). Van Wagner (1996) concluded that the high discharge associated with heavy rainfall could account for a significant source of mortality in post-metamorphic Foothill Yellow-legged Frogs as well as eggs and tadpoles; he observed two adult females and several juveniles swept downstream with fatal injuries post-flooding. Severe flooding, specifically two 500-year flood events in early 1969 in Evey Canyon (Los Angeles County), resulted in massive riparian habitat destruction (Sweet 1983). Prior to the floods, Foothill Yellow-legged Frogs were widespread and common, but only four subsequent sightings were documented between 1970 and 1974 and none since (Sweet 1983, Adams 2017b). Sweet (1983) speculates that because Foothill Yellow-legged Frogs overwinter in the streambed in that area, the floods may have reduced the population's abundance below an extinction threshold. Four other herpetologists interviewed about Foothill Yellow-legged Frog extirpations in southern California listed severe flooding as a likely cause (Adams et al. 2017b).

As mentioned above, landslides are a frequent consequence of post-fire rainstorms and can result in lasting impacts to stream morphology, water quality, and Foothill Yellow-legged Frog populations. On the other hand, Olson and Davis (2009) suggest that periodic landslides can have beneficial effects by transporting woody debris into the stream that can increase habitat complexity and replace sediments that are typically washed downstream over time. Whether a landslide is detrimental or beneficial is likely heavily influenced by amount of precipitation and the underlying system. As previously described, too little precipitation could lead to prolonged loss of habitat through failure to transport material downstream, and too much precipitation can result in large-scale habitat destruction and direct mortality.

4.13 Climate Change

Foothill Yellow-legged Frogs evolved over millions of years through repeated droughts, flooding, and fires, but relatively recent anthropogenic habitat fragmentation and degradation have reduced the species' ability to recolonize sites where they have been extirpated by these events. Cumulatively, the threats and stressors Foothill Yellow-legged Frogs encounter over much of their range in California jeopardize their persistence in currently occupied areas. Climate change is expected to exacerbate many of these impacts.

Global climate change threatens biodiversity and may lead to increased frequency and severity of drought, wildfires, flooding, and landslides (Williams et al. 2008, Keely and Syphard 2016). Data show a consistent trend of warming temperatures in California and globally; 2014 was the warmest year on record, followed by 2015, 2017, and 2016 (OEHHA 2018). Climate model projections for annual temperature in California in the 21st century range from 2.7 to 8.1°F greater than the 1961-1990 mean (Cayan et al. 2008). Precipitation change projections are less consistent than those for temperature, but recent studies indicate increasing variability in precipitation and increasingly dry conditions in California resulting from increased evaporative water loss primarily due to rising temperatures (Cayan et al. 2005, Williams et al. 2015, OEHHA 2018). Precipitation variability and proportion of dry years were negatively associated with Foothill Yellow-legged Frog presence in a range-wide analysis (Lind 2005). In addition, low precipitation intensified the adverse effects of dams on the species (Ibid.).

California recently experienced the longest drought since the U.S. Drought Monitor began reporting in 2000 (NIDIS 2019). Figure 26 depicts that California experienced drought effects in at least a portion of the state for 376 consecutive weeks until it broke on March 5, 2019 (Ibid.). The most intense period occurred during the week of October 28, 2014 when D4 (the most severe drought category) affected 58.4% of California's land area (Ibid.). A recent modeling effort using data on historical droughts, including the Medieval megadrought between 1100 and 1300 CE, indicates the mean state of drought from 2050 to 2099 in California will likely exceed the Medieval-era drought, under both high and moderate greenhouse gas emissions models (Cook et al. 2015). The probability of a multidecadal (35 yr) drought occurring during the late 21st century is greater than 80% in all models used by Cook et al. (2015). If correct, this would represent a climatic shift that not only falls outside of contemporary variability in aridity but would also be unprecedented in the past millennium (Ibid.).

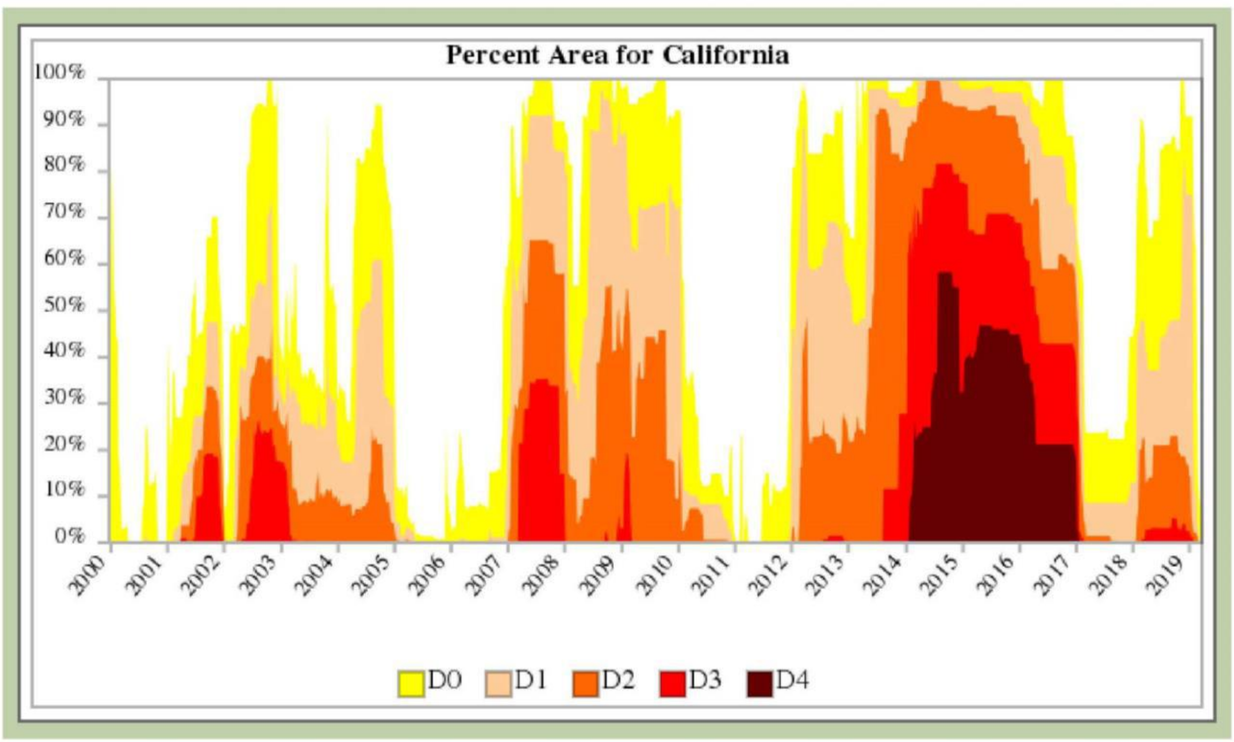

Figure 26. Palmer Hydrological Drought Indices 2000-2019 (NIDIS)

As a result of increasing temperatures, a decreasing proportion of precipitation falls as snow, resulting in more runoff from rainfall during the winter and a shallower snowpack that melts more rapidly (Stewart 2009). A combination of reduced seasonal snow accumulation and earlier streamflow timing significantly reduces surface water storage capacity and increases the risk for winter and spring floods, which may require additional and taller dams and alterations hydropower generation flow regimes

(Cayan et al. 2005, Knowles et al. 2006, Stewart 2009). The reduction in snowmelt volume is expected to impact the northern Sierra (Feather, Yuba, and American River watersheds) to a greater extent than the southern portion (Young et al. 2009). The earlier shift in peak snowmelt timing is predicted to exceed four to six weeks across the entire Sierra Nevada, depending on the amount of warming that occurs this century (Ibid.). In addition, the snow water equivalent is predicted to significantly decline by 2070-2099 over the 1961-1990 average in the Trinity, Sacramento, and San Joaquin drainages from -32% to -79%, and effectively no snow is expected to fall below 3,280 ft in the high emissions/sensitive model (Cayan et al. 2008).

The earlier shift of snowmelt and lower water content will result in lower summer flows, which will intensify the competition for water among residential, agricultural, industrial, and environmental needs (Field et al. 1999, Cook et al. 2015). In unregulated systems, as long as water is present through late summer, an earlier hydrograph recession that triggers Foothill Yellow-legged Frog breeding could result in a longer time to grow larger prior to metamorphosis, which is expected to improve survival (Yarnell et al. 2010, Kupferberg 2011b). However, if duration from peak to base flow shortens, it can result in increased sedimentation and reduced habitat complexity in addition to stranding (Yarnell et al. 2010).

Fire frequency relates to temperature, fuel loads, and fuel moisture (CCSP 2008). Therefore, increasing periods of drought combined with extreme heat and low humidity that stress or kill trees and other vegetation create ideal conditions for wildland fires (Ibid). Not surprisingly, the area burned by wildland fires over the western U.S. increased since 1950 but rose rapidly in the mid-1980s (Westerling et al. 2006, OEHHA 2018). As temperatures warmed and snow melted earlier, large-wildfire frequency and duration increased, and wildfire seasons lengthened (Westerling et al. 2006, OEHHA 2018). With increased fire frequency comes the heightened risk of landslides and extended periods of habitat unsuitability.

In California, latitude is inversely correlated with temperature and annual area burned, but the climate-fire relationship is substantially different across the state, and future wildfire regimes are difficult to predict (Keeley and Syphard 2016). For example, the relationship between spring and summer temperature and area burned in the Sierra Nevada is highly significant but not in southern California (Ibid.). Climate has a greater influence on fire regimes in mesic environments than arid, and the most influential climatological factor (e.g., precipitation, temperature, season, or their interactions) shifts over time (Ibid.). Nine of the 10 largest fires in California since 1932 have occurred in the past 20 years, four within the past two years (Figure 27; CAL FIRE 2019). However, it is possible this trend will not continue; climate- and wildfire-induced changes in vegetation could reduce wildfire severity in the future (Parks et al. 2016).

Wildfires themselves can accelerate the effects of climate change. Wildfires emit short-lived climate pollutants like black carbon (soot) and methane that are tens to thousands of times greater than carbon dioxide (the main focus of greenhouse gas reduction) in terms of warming effect and are responsible for 40% or more of global warming to date (CNRA 2016). Healthy forests can sequester large amounts of carbon from the atmosphere, but recently carbon emissions from wildfires have exceeded their uptake by vegetation in California (Ackerly et al. 2018).

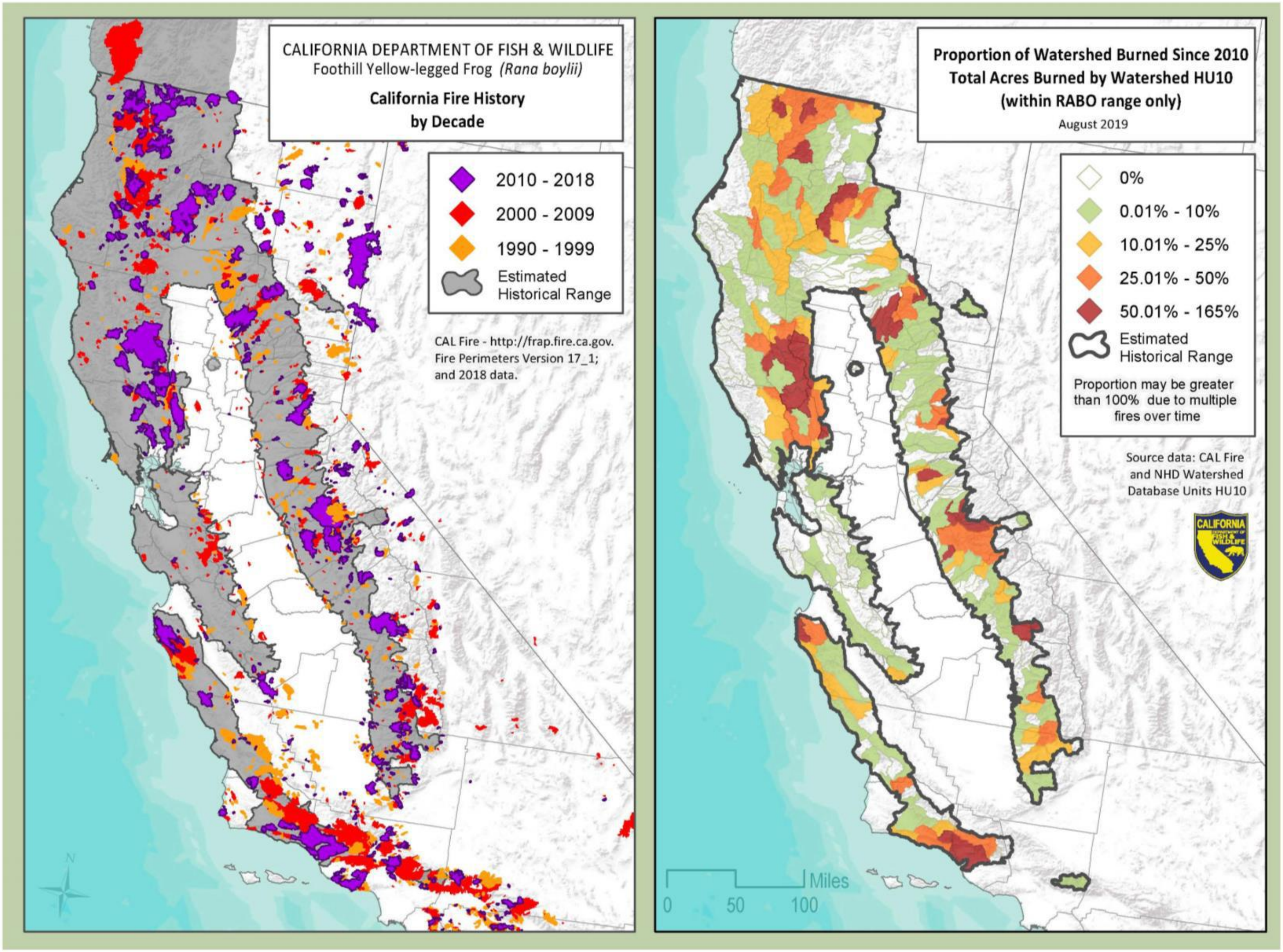

Figure 27. Fire history (1990-2018) and proportion of watershed burned (2010-2018) in California (CAL FIRE, NHD)

With increased variability and changes in precipitation type, magnitude, and timing comes more variable and extreme stream flows (Mallakpour et al. 2018). Models for stream flow in California project higher high flows, lower low flows, wetter rainy seasons, and drier dry seasons (Ibid.). The projected water cycle extremes are related to strengthening El Niño and La Niña events, and both severe flooding and intense drought are predicted to increase by at least 50% by the end of the century (Yoon et al. 2015). These changes increase the likelihood of Foothill Yellow-legged Frog egg mass and tadpole scouring and stranding. However, the severity of these phenomena will vary because an area's underlying geology and lithology affect subsurface water storage capacity, which influences base flows and the degree to which these more frequent extreme weather events will impact Foothill Yellow-legged Frogs (S. Kupferberg pers. comm. 2019). For instance, springs can provide persistent water and a buffer against some drought effects, and areas with low subsurface storage capacity are less affected by changes in rainfall (Hahm et al. 2019, S. Kupferberg pers. comm. 2019).

A species' vulnerability to climate change is a function of its sensitivity to climate change effects, its exposure to them, and its ability to adapt its behaviors to survive with them (Dawson et al. 2011). Myriad examples exist of species shifting their geographical distribution toward the poles and higher elevations as well as changing their growth and reproduction with increases in temperature over time (Parmesan and Yohe 2003, Moritz et al. 2008). However, in many places, fragmentation of suitable habitat by anthropogenic barriers (e.g., urbanization, agriculture, and reservoirs) limits a species' ability to shift its range (Pounds et al. 2007). The proportion of sites historically occupied by Foothill Yellow-legged Frogs that are now extirpated increases significantly on a north-to-south latitudinal gradient and at drier sites within California, suggesting climate change may contribute to the spatial pattern of the species' declines (Davidson et al. 2002).

An analysis of the climate change sensitivity of 195 species of plants and animals in northwestern North America revealed that, as a group, amphibians and reptiles were estimated to be the most sensitive (Case et al. 2015). Nevertheless, examples exist of amphibians adjusting their breeding behaviors (e.g., calling and migrating to breeding sites) to occur earlier in the year as global warming increases (Beebee 1995, Gibbs and Breisch 2001). Because of the rapid change in temperature, Beebee (1995) posits these are examples of behavioral and physiological plasticity rather than natural selection. However, for species with short generation times or in areas less affected by climate change, populations may be able to undergo evolutionary adaptation to the changing local environmental conditions (Hoffman and Sgrò 2011).

As previously described in the Seasonal Activity and Movements section, Foothill Yellow-legged Frog breeding is closely tied to water temperature, flow, and stage, and the species already adjusts its timing of oviposition by as much as two months in the same location during different water years, so the species may have enough inherent flexibility to reduce their vulnerability to predicted climate changes. The species appears fairly resilient to drought, fire, and flooding, at least in some circumstances. For example, after the 2012-2016 drought, the Loma Fire in late 2016, and severe winter flooding and landslides in 2016 and 2017, Foothill Yellow-legged Frog adults and metamorphs, as well as aquatic insects and rainbow trout, were abundant throughout Upper Llagas Creek in fall of 2017, and the substrate consisted of generally clean gravels and cobbles with only a slight silt coating in some pools (J.

Smith pers. comm. 2017). The frogs and fish likely took refuge in a spring-fed pool, and the heavy rains scoured the fine sediments that eroded downstream (Ibid.). These refugia from the effects of climate change reduce the species' exposure, thereby reducing their vulnerability (Case et al. 2015).

Climate change models that evaluate the Foothill Yellow-legged Frog's susceptibility from a species and habitat perspective yield mixed results. An investigation into the possible effects of climate on California's native amphibians and reptiles used ecological niche models, future climate scenarios, and general circulation models to predict species-specific climatic suitability in 2050 (Wright et al. 2013). The results suggested approximately 90-100% of localities currently occupied by Foothill Yellow-legged Frogs are expected to remain climatically suitable in that time, and the proportion of currently suitable localities predicted to change ranges from -20% to 20% (Ibid.). However, a second study, performed by the same research team using a subset of these models, found that 66.4% of currently occupied cells will experience reduced environmental suitability in 2050 (Warren et al. 2014). This analysis included 90 species of native California mammals, birds, reptiles, and amphibians. For context, over half of the taxa were predicted to experience >80% reductions, a consistent pattern reflected across taxonomic groups (Ibid.). Similarly, a third examination, using comparable methods but focusing on the Plumas National Forest (primarily Plumas County with portions of Butte and Sierra counties), found that most of the area will be of the lowest climatic suitability (least and low, in this study) for Foothill Yellow-legged Frogs by 2070 and that each future climate scenario was significantly different from the current model (Bedwell 2018).

A fourth analysis investigated the long-term risk of climate change by modeling the relative environmental stress a vegetative community would undergo in 2099 given different climate and greenhouse gas emission scenarios (Thorne et al. 2016). This model does not incorporate any Foothill Yellow-legged Frog-specific data; it strictly projects climatic stress levels vegetative communities would experience within the species' range boundaries (Ibid.). Unsurprisingly, higher emissions scenarios resulted in a greater proportion of habitat undergoing climatic stress (Figure 28). Perhaps counterintuitively, the warm and wet scenario resulted in a greater amount of stress than the hot and dry scenario. When high emissions and warm and wet changes are combined, a much greater proportion of the vegetation communities will experience "non-analog" conditions, those outside of the range of conditions currently known in California (Ibid.).

4.14 Habitat Restoration and Species Surveys

Potential conflicts between managing riverine habitat below dams for both cold water adapted salmonids and Foothill Yellow-legged Frogs was discussed previously. In addition to problems with temperatures and pulse flows, some stream restoration projects aimed at physically creating or improving salmonid habitat can also adversely affect the frogs. For example, boulder deflectors were placed in Hurdygurdy Creek (Del Norte County) to create juvenile steelhead rearing habitat; deflectors change broad, shallow, low-velocity reaches into narrower, deeper, faster reaches preferred by the fish (Fuller and Lind 1992). Foothill Yellow-legged Frogs were documented using the restoration reach as breeding habitat annually prior to placement of the boulders, but no breeding was detected in the following three years, suggesting this project eliminated the conditions the frogs require (Ibid.). At

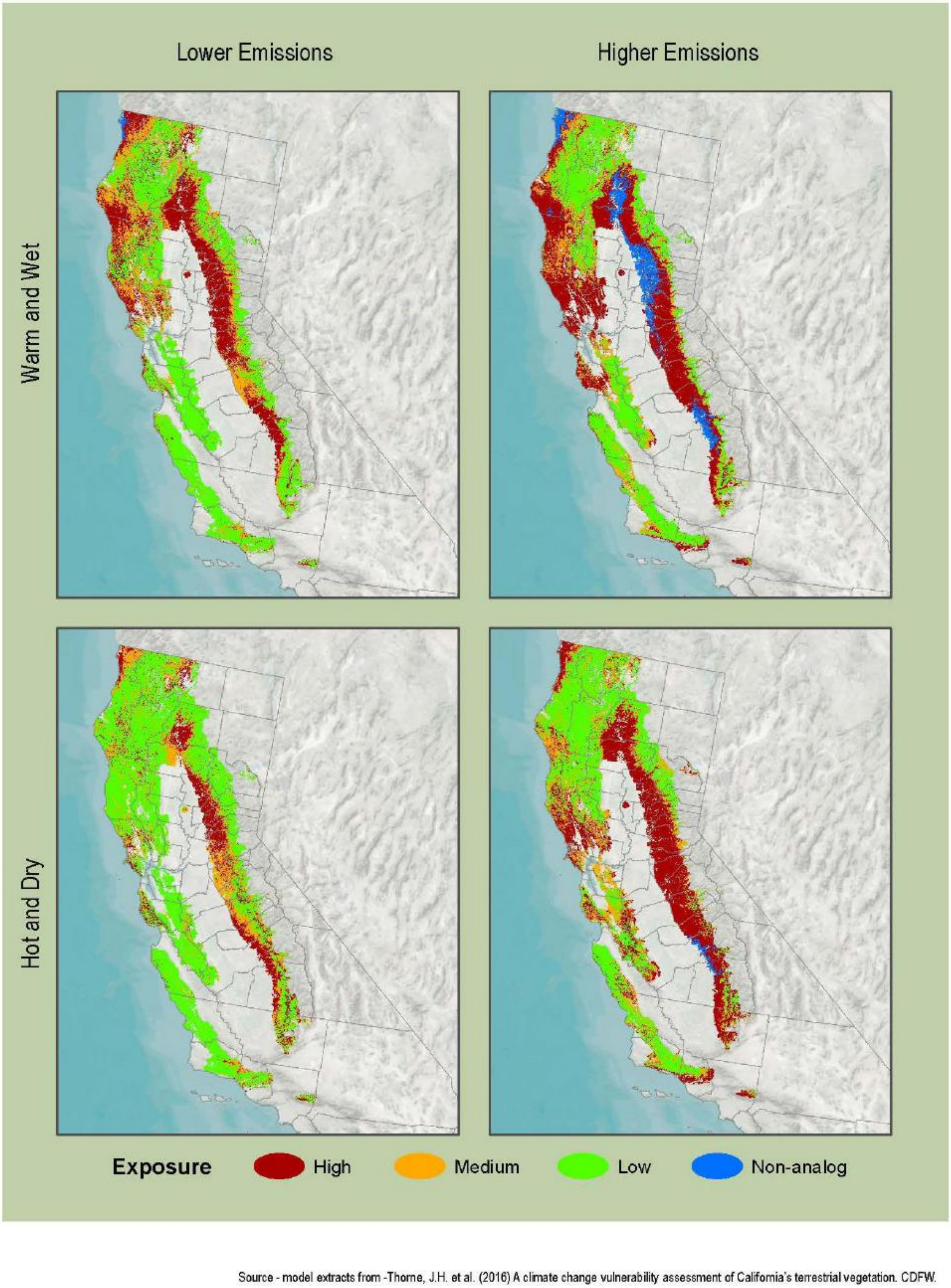

Figure 28. Vegetative community exposure to climate change in 2099 based on Thorne et al. (2016)

another location, a fish passage structure to facilitate salmonid migration above the Alameda Creek Diversion Dam was recently constructed on a Foothill Yellow-legged Frog lek site (M. Grefsrud pers. comm. 2019). The structure blocks a migratory pathway between overwintering habitat in hillside springs and seeps and the creek and creates a potential trap for frogs that fall into the structure (S. Kupferberg pers. comm. 2019). Use of rotenone to eradicate non-native fish as part of a habitat restoration project is rare, but if it is applied in streams occupied by Foothill Yellow-legged Frogs, it can kill tadpoles but is unlikely to impact post-metamorphic frogs (Fontenot et al. 1994). Metamorphosing tadpoles may be able to stay close enough to the surface to breathe air and survive but may display lethargy and experience increased susceptibility to predation (Ibid.).

Commonly when riparian vegetation is removed, regulatory agencies require a greater amount to be planted as mitigation to offset the temporal loss of habitat. This practice can have adverse impacts on habitat suitability for Foothill Yellow-legged Frogs. It is especially problematic where flood suppression by dams has resulted in encroachment into the active channel by riparian trees whose roots bind sediment and steepen the bank slopes (S. Kupferberg pers. comm. 2019). Foothill Yellow-legged Frogs have been observed moving into areas where trees were recently removed, and they are known to avoid heavily shaded areas (Lind et al. 1996, Welsh and Hodgson 2011, M. Grefsrud pers. comm. 2019).

Biologists and other stream researchers can inadvertently harm Foothill Yellow-legged Frogs. When working in Foothill Yellow-legged Frog habitat, in-stream surveyors can trample egg masses or larvae if they are not careful, and those rock-hopping on shore can unknowingly crush post-metamorphic stages that often take cover under streamside rocks (S. Kupferberg pers. comm. 2019). One method for sampling fish is electroshocking, which runs a current through the water that stuns the fish temporarily allowing them to be captured. Post-metamorphic frogs are unlikely to be killed by electroshocking; however, at high frequencies (60 Hz), they may experience some difficulty with muscle coordination for a few days (Allen and Riley 2012). This could increase their risk of predation. At 30 Hz, there were no differences between frogs that were shocked and controls (Ibid.). Tadpoles are more similar to fish in tail musculature and spinal structure and are at higher risk of injuries; however, researchers who reported observing stunned tadpoles noted they appeared to recover completely within several seconds (Ibid.). Adverse effects to Foothill Yellow-legged Frogs from electrofishing may only happen at frequencies higher than those typically used for fish sampling (Ibid.).

4.15 Small Population Sizes

Small populations are at greater risk of extirpation, primarily because the effects of demographic, environmental, and genetic stochasticity are disproportionately greater than they are on large populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). Consequently, any of the threats previously discussed will likely have an even greater adverse impact on small populations of Foothill Yellow-legged Frogs. This risk of extinction from genetic stochasticity is amplified when connectivity between the small populations, and thus gene flow, is impeded (Fahrig and Merriam 1985, Taylor et al. 1993, Lande and Shannon 1996, Palstra and Ruzzante 2008). Genetic diversity provides capacity to evolve in response to environmental changes, and the “rescue effect” of gene flow is important in minimizing probability of local extinction (Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). However, the rescue effect is diminished in conditions of high local environmental stochasticity of recruitment or survival (Eriksson et al. 2014). In addition, populations living near their physiological limits and lacking adaptive capacity may not be able to evolve in response to rapid changes (Hoffmann and Sgrò 2011). Furthermore, while pathogens or parasites rarely result in host extinction, they can increase that likelihood in small populations by driving the host populations below a critically low threshold, beneath which demographic stochasticity can lead to extinction, even if they possess the requisite genetic diversity to adapt to a changed environment (Gomulkiewicz and Holt 1995, Adams et al. 2017b).

A Foothill Yellow-legged Frog PVA revealed that, even with no dam effects considered (e.g., slower growth and increased egg and tadpole mortality), populations occurring along a hypothetical 6.2 mi reach were four times more likely to go extinct within 30 years when using the starting average density of adult females in regulated rivers (2.9/mi) compared to the starting average density of adult females from unregulated rivers (20/mi) (Kupferberg et al. 2009c). When the density of females in sparse populations was used (1.3/mi), the 30-year risk of extinction increased 13-fold (Ibid.). With dam effects, a number of the risk factors above contribute to the additional probability of local extinction such as living near their lower thermal tolerance and reduced recruitment and survival from scouring and stranding flows, poor food quality, and increased predation and competition (Kupferberg 1997a; Hoffmann and Sgrò 2011; Kupferberg et al. 2011a,b; Kupferberg et al. 2012; Eriksson et al. 2014). These factors act synergistically, contributing in part to the small size, high divergence, and low genetic diversity exhibited by many Foothill Yellow-legged Frog populations located in highly regulated watersheds (Kupferberg et al. 2012, Peek 2018).

5.0 EXISTING MANAGEMENT

5.1 Land Ownership within the California Range

Using the Department's Foothill Yellow-legged Frog presumed historical range boundary (Figure 1) and the California Protected Areas Database (CPAD), a GIS dataset of lands that are owned in fee title and protected for open space purposes by over 1,000 public agencies or non-profit organizations, the total area of the species' range in California comprises 33,656,857 ac (CPAD 2019, CWHR 2019). Approximately 37% is owned by federal agencies, 80% of which (10,060,100 ac) is managed by the Forest Service (Figure 29). Department of Fish and Wildlife-managed lands, State Parks, and other State agency-managed lands constitute around 2.6% of the range. The remainder of the range includes <1% Tribal lands, 2.3% other conserved lands (e.g., local and regional parks), and 57% private and government-managed lands that are not protected for open space purposes. It is important to note that even if included in the CPAD, a property's management does not necessarily benefit Foothill Yellow-legged Frogs. For example, the primary focus of many parks is to provide various types of recreation, which as previously described can have significantly adverse impacts on the species, and most BLM and Forest Service land is managed for multiple uses (e.g., timber harvest, mining, grazing, recreation).

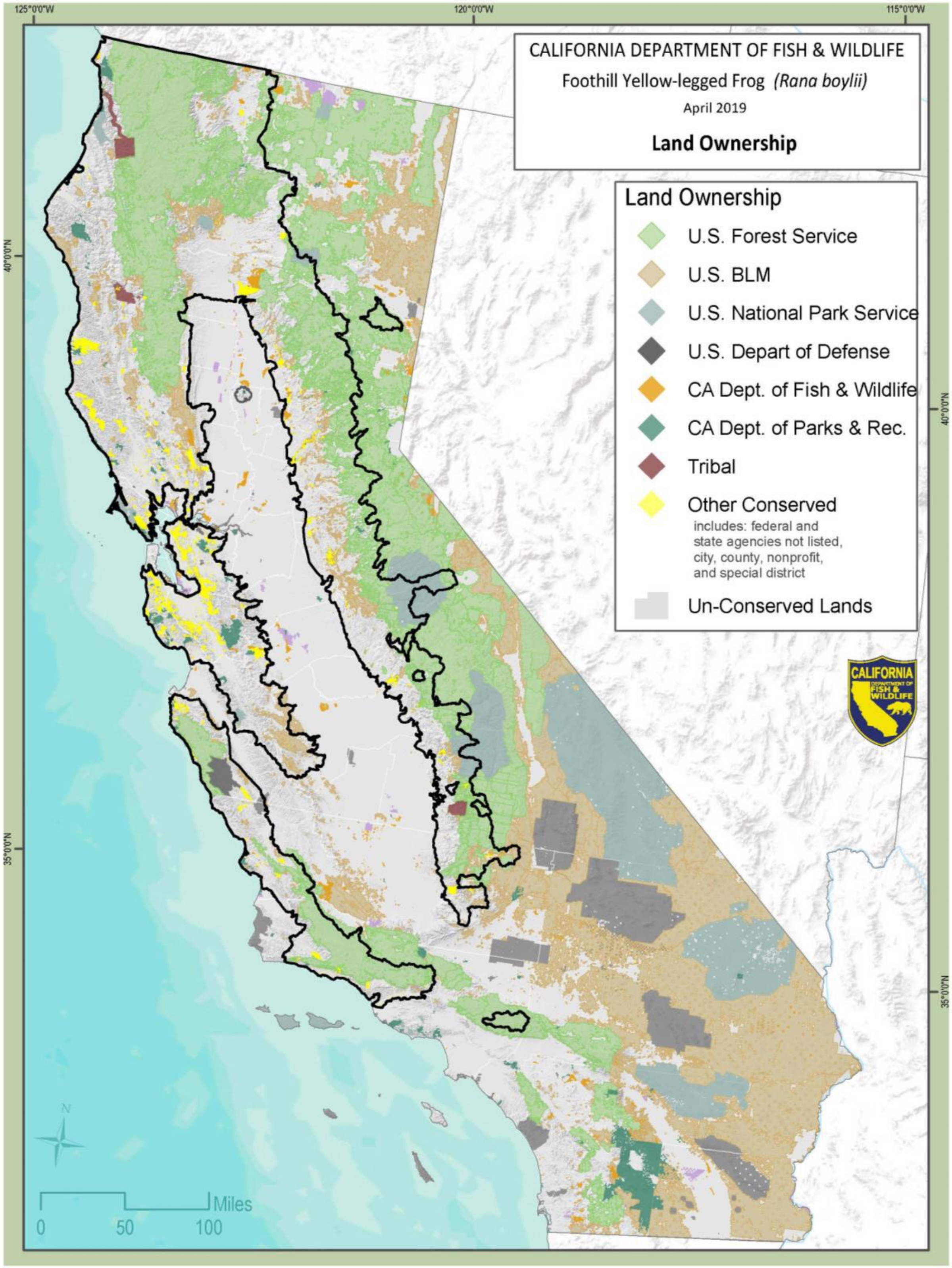

Figure 29. Conserved, Tribal, and other lands within the estimated historical range of Foothill Yellow-legged Frogs in California (BLM, CMD, CPAD, CWHR, DOD)

However, in some cases, changes in management to conserve the species may be easier to undertake on publicly-managed conserved lands than on private lands or public lands not classified as conserved.

5.2 Statewide Laws

The laws and regulations governing land use within the Foothill Yellow-legged Frog's range vary by ownership. Several state and federal environmental laws apply to activities undertaken in California that may provide some level of protection for Foothill Yellow-legged Frogs and their habitat. The following is not an exhaustive list.

5.2.1 National Environmental Policy Act and California Environmental Quality Act

Most federal land management actions must undergo National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. § 4321, et seq.) analysis. NEPA requires federal agencies to document, consider alternatives, and disclose to the public the impacts of major federal actions and decisions that may significantly impact the environment. As a BLM and Forest Service Sensitive Species, impacts to Foothill Yellow-legged Frogs are considered during NEPA analysis; however, the law has no requirement to minimize or mitigate adverse effects.

The California Environmental Quality Act (CEQA) is similar to NEPA; it requires state and local agencies to identify, analyze, and consider alternatives, and to publicly disclose environmental impacts from projects over which they have discretionary authority (Pub. Resources Code § 21000 et seq.). CEQA differs substantially from NEPA in requiring mitigation for significant adverse effects to a less than significant level unless overriding considerations are documented. CEQA requires an agency find that projects may have a significant effect on the environment if they have the potential to substantially reduce the habitat, decrease the number, or restrict the range of any rare, threatened, or endangered species (Cal. Code Regs., tit. 14, §§ 15065(a)(1), 15380.). CEQA establishes a duty for public agencies to

avoid or minimize such significant effects where feasible (Cal. Code regs., tit. 14, § 15021). Impacts to Foothill Yellow-legged Frogs, as an SSC, should be identified, evaluated, disclosed, and mitigated or justified under the Biological Resources section of an environmental document prepared pursuant to CEQA. However, a lead agency is not required to make a mandatory finding of significance conclusion for a project unless it determines on a project-specific basis that the species meets the CEQA criteria for rare, threatened, or endangered.

5.2.2 Clean Water Act and Porter-Cologne Water Quality Control Act

The Clean Water Act originated in 1948 as the Federal Water Pollution Control Act of 1948. It was heavily amended in 1972 and became known as the Clean Water Act (CWA). The purpose of the CWA was to establish regulations for the discharge of pollutants into waters of the United States and establish quality standards for surface waters. Section 404 of the CWA forbids the discharge of dredged or fill material into waters and wetlands without a permit from the ACOE. The CWA also requires an alternatives analysis, and the ACOE is directed to issue their permit for the least environmentally damaging practicable alternative. The definition of waters of the United States has changed substantially over time based on Supreme Court decisions and agency rule changes.

The Porter-Cologne Water Quality Act was established by the State in 1969 and is similar to the CWA in that it establishes water quality standards and regulates discharge of pollutants into state waters, but it also administers water rights, which regulate water diversions and extractions. The SWRCB and nine Regional Water Boards share responsibility for implementation and enforcement of Porter-Cologne as well as the CWA's National Pollutant Discharge Elimination System permitting.

5.2.3 Federal and California Wild and Scenic Rivers Acts

In 1968, the U.S. Congress passed the federal Wild and Scenic Rivers Act (WSRA) (16 U.S.C. § 1271, et seq.) which created the National Wild and Scenic River System. The WSRA requires the federal government to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The WSRA prohibits the federal government from building, licensing, funding or otherwise aiding in the building of dams or other project works on rivers or segments of designated rivers. The WSRA does not give the federal government control of private property including development along protected rivers.

California's Wild and Scenic Rivers Act was enacted in 1972 so rivers that "possess extraordinary scenic, recreational, fishery, or wildlife values shall be preserved in their free-flowing state, together with their immediate environments, for the benefit and enjoyment of the people of the state." (Pub. Res. Code, § 5093.50). Designated waterways are codified in Public Resources Code sections 5093.50-5093.70. In 1981, most of California's designated Wild and Scenic Rivers were adopted into the federal system. Currently in California, 2,000 mi of 23 rivers are protected by the WSRA, most of which are located in the northwest. Foothill Yellow-legged Frogs have been observed in 11 of the 17 designated rivers within their range (CNDDB 2019).

5.2.4 Lake and Streambed Alteration Agreements

Fish and Game Code Section 1602 requires entities to notify the Department of activities that "divert or obstruct the natural flow of, or substantially change or use any material from the bed, channel, or bank of any river, stream, or lake, or deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake." If the activity may substantially adversely affect an existing fish and wildlife resource, the Department may enter into a lake or streambed alteration agreement with the entity that includes reasonable measures necessary to protect the fish or wildlife resource (Fish & G. Code, §1602, subd. (a)(4)(B)). A lake or stream alteration agreement does not authorize take of species listed as candidates, threatened, or endangered under CESA (see Protection Afforded by Listing for CESA compliance requirements).

5.2.5 Medicinal and Adult-Use Cannabis Regulation and Safety Act

The commercial cannabis cultivation industry is unique in that any entity applying for an annual cannabis cultivation license from California Department of Food and Agriculture (CDFA) must include "a copy of any final lake or streambed alteration agreement…or written verification from the California Department of Fish and Wildlife that a lake or streambed alteration agreement is not required" with their license application (Cal. Code Regs., tit. 3, § 8102, subd. (v)). The SWRCB also enforces the laws related to waste discharge and water diversions associated with cannabis cultivation (Cal. Code Regs., tit. 3, § 8102, subd. (p)).

5.2.6 Forest Practice Act

The Forest Practice Act was originally enacted in 1973 to ensure that logging in California is undertaken in a manner that will also preserve and protect the State's fish, wildlife, forests, and streams. This law and the regulations adopted by the California Board of Forestry and Fire Protection pursuant to it are collectively referred to as the Forest Practice Rules. The Forest Practice Rules implement the provisions of the Forest Practice Act in a manner consistent with other laws, including CEQA, Porter-Cologne, CESA, and the Timberland Productivity Act of 1982. The California Department of Forestry and Fire Protection enforces these laws and regulations governing logging on private land.

5.2.7 Federal Power Act

The Federal Power Act and its major amendments are implemented and enforced by FERC and require licenses for dams operated to generate hydropower. One of the major amendments of the Federal Power Act required that these licenses "shall include conditions for the protection, mitigation and enhancement of fish and wildlife including related spawning grounds and habitat" (ECPA 1986). Hydropower licenses granted by FERC are usually valid for 30-50 years. If a licensee wants to renew their license, it must file a Notice of Intent and a pre-application document five years before the license expires to provide time for public scoping, any potentially new studies necessary to analyze project impacts and alternatives, and preparation of environmental documents. The applicant must officially apply for the new license at least two years before the current license expires.

As a federal agency, FERC must comply with federal environmental laws prior to issuing a new license or relicensing an existing hydropower project, which includes NEPA and ESA. As a result of environmental compliance or settlement agreements formed during the relicensing process, some operations have been modified and habitat restored to protect fish and wildlife. For example, the Lewiston Dam relicensing resulted in establishment of the Trinity River Restoration Program, which takes an ecosystem-approach to studying dam effects and protecting and restoring fish and wildlife populations downstream of the dam (Snover and Adams 2016). Similarly, relicensing of the Rock Creek-Cresta Project on the North Fork Feather River resulted in establishment of a multi-stakeholder Ecological Resources Committee (ERC). As a result of the ERC's studies and recommendations, pulse flows for whitewater boating were suspended for several years following declines of Foothill Yellow-legged Frogs, and the ERC is currently working toward augmenting the population in an attempt to increase abundance to a viable level.

5.3 Administrative and Regional Plans

5.3.1 Forest Plans

NORTHWEST FOREST PLAN

In 1994, BLM and the Forest Service adopted the Northwest Forest Plan to guide the management of over 37,500 mi^2 of federal lands in portions of northwestern California, Oregon, and Washington. The Northwest Forest Plan created an extensive network of forest reserves including Riparian Reserves. Riparian Reserves apply to all land designations to protect riparian dependent resources. With the exception of silvicultural activities consistent with Aquatic Conservation Strategy objectives, timber harvest is not permitted within Riparian Reserves, which can vary in width from 100 to 300 ft on either side of streams, depending on the classification of the stream or waterbody (USDA FS and BLM 1994). Fuel treatment and fire suppression strategies and practices implemented within these areas are designed to minimize disturbance.

SIERRA NEVADA FOREST PLAN

Land and Resource Management Plans for forests in the Sierra Nevada were changed in 2001 by the Sierra Nevada Forest Plan Amendment and subsequently adjusted through a supplemental Environmental Impact Statement and Record of Decision in 2004, referred to as the Sierra Nevada Framework (USDA FS 2004). This established an Aquatic Management Strategy with goals including maintenance and restoration of habitat to support viable populations of riparian-dependent species; spatial and temporal connectivity for aquatic and riparian species within and between watersheds to provide physically, chemically, and biologically unobstructed movement for their survival, migration, and reproduction; instream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats; the physical structure and condition of streambanks and shorelines to minimize erosion and sustain desired habitat diversity; and prevention of new introductions of invasive species and reduction of invasive species impacts that adversely affect the viability of native species. The Sierra Nevada Framework also includes Riparian Conservation Objectives and associated standards and guidelines specific to aquatic-dependent species, including the Foothill Yellow-legged Frog.

5.3.2 Resource Management Plans

Sequoia, Kings Canyon, and Yosemite National Parks fall within the historical range of the Foothill Yellow-legged Frog, but the species has been extirpated from these areas. The guiding principles for managing biological resources on National Park Service lands include maintenance of animal populations native to park ecosystems (Hayes et al. 2016). They also commit the agency to work with other land managers on regional scientific and planning efforts and maintenance or reintroduction of native species to the parks including conserving Foothill Yellow-legged Frogs in the Sierra Nevada (USDI NPS 1999 as cited in Hayes et al. 2016). A Sequoia and Kings Canyon National Parks Resource Management Plan does not include specific management goals for Foothill Yellow-legged Frogs, but it does include a discussion of the factors leading to the species' decline and measures to restore the integrity of aquatic ecosystems (Ibid.). The Yosemite National Park Resource Management Plan includes a goal of restoring

Foothill Yellow-legged Frogs to the Upper Tuolumne River below Hetch Hetchy Reservoir (USDI NPS 2003 as cited in Hayes et al. 2016).

5.3.3 FERC Licenses

Dozens of hydropower dams have been relicensed in California since 1999, and several are in the process of relicensing (FERC 2019). In addition to following the Federal Power Act and other applicable federal laws, Porter-Cologne Water Quality Act requires non-federal dam operators to obtain a Water Quality Certification (WQC) from the SWRCB. Before it can issue the WQC, the SWRCB must consult with the Department regarding the needs of fish and wildlife. Consequently, SWRCB includes conditions in the WQC that seek to minimize adverse effects to native species, and Foothill Yellow-legged Frogs have received some special considerations due to their sensitivity to dam operations during these licensing processes. As discussed above, the typical outcome is formation of an ERC-type group to implement the environmental compliance requirements and recommend changes to flow management to reduce impacts. The degree to which these considerations and modifications to dam operations results in its desired effect to protect healthy Foothill Yellow-legged Frog populations varies by site, but the myriad impacts from dams are difficult to overcome, and genetic evidence suggests populations in these highly regulated watersheds are fragmented and losing diversity (Peek 2018, S. Kupferberg pers. comm. 2019).

Foothill Yellow-legged Frog-specific requirements in license agreements fall into three general categories: data collection, modified flow regimes, and standard best management practices. Brief examples of each are described.

Data Collection

When little is known about the impacts of different flows and temperatures on Foothill Yellow-legged Frog occupancy and breeding success, data are collected and analyzed to inform recommendations for future modifications to operations such as temperature trigger thresholds. These surveys include locating egg masses and tadpoles, monitoring temperatures and flows, and recording their fate (e.g., successful development and metamorphosis, displacement, desiccation) during different flow operations and different water years. Examples of licenses with these conditions include the Lassen Lodge Project (FERC 2018), Rock Creek-Cresta Project (FERC 2009a), and El Dorado Project (EID 2007).

Modified Flow Regimes

When enough data exist to understand the effect of different operations on Foothill Yellow-legged Frog occupancy and success, license conditions may include required minimum seasonal instream flows, specific thermal regimes, gradual ramping rates to reduce the likelihood of early life stage scour or stranding, freshet releases (winter/spring flooding simulation) to maintain riparian processes, and cancellation or prohibition of recreational pulse flows during the breeding season. Examples of licenses with these conditions include the Poe Hydroelectric Project (SWRCB 2017), Upper American Project (FERC 2014), and Pit 3, 4, 5 Project (FERC 2007b).

BEST MANAGEMENT PRACTICES

Efforts to reduce the impacts from maintenance activities and indirect operations include selective herbicide and pesticide application, aquatic invasive species monitoring and control, erosion control, and riparian buffers. Examples of licenses with these conditions include the South Feather Project (SWRCB 2018), Spring Gap-Stanislaus Project (FERC 2009b), and the Chili Bar Hydroelectric Project on the South Fork American River (FERC 2007a).

5.3.4 Habitat Conservation Plans and Natural Community Conservation Plans

Non-federal entities can obtain authorization for take of federally threatened and endangered species incidental to otherwise lawful activities through development and implementation of a Habitat Conservation Plan (HCP) pursuant to Section 10 of the ESA. The take authorization can extend to species not currently listed under the ESA but which may become listed as threatened or endangered over the term of the HCP, which is often 25-75 years. California's companion law, the Natural Community Conservation Planning Act of 1991, takes a broader approach than either CESA or ESA. A Natural Community Conservation Plan (NCCP) identifies and provides for the protection of plants, animals, and their habitats, while allowing compatible and appropriate economic activity. There are currently four HCPs that include Foothill Yellow-legged Frogs as a covered species, two of which are also NCCPs.

HUMBOLDT REDWOOD (FORMERLY PACIFIC LUMBER) COMPANY

The Humboldt Redwood Company (HRC) HCP covers 211,700 ac of private Coast Redwood and Douglas-fir forest in Humboldt County (HRC 2015). It is a 50-year HCP/incidental take permit (ITP) that was executed in 1999, revised in 2015 as part of its adaptive management strategy, and expires on March 1, 2049. The HCP includes an Amphibian and Reptile Conservation Plan and an Aquatics Conservation Plan with measures designed to sustain viable populations of Foothill Yellow-legged Frogs and other covered aquatic herpetofauna. These conservation measures include prohibiting or limiting tree harvest within Riparian Management Zones (RMZ), controlling sediment by maintaining roads and hillsides, restricting controlled burns to spring and fall in areas outside of the RMZ, conducting effectiveness monitoring throughout the life of the HCP, and use the data collected to adapt monitoring and management plans accordingly.

Watershed assessment surveys include observations of Foothill Yellow-legged Frogs and have documented their widespread distribution on HRC lands with a pattern of fewer near the coast in the fog belt and more inland (S. Chinnici pers. comm. 2017). The watersheds within the property are largely unaffected by dam-altered flow regimes or non-native species, so aside from the operations described under Timber Harvest above that are minimized to the extent feasible, the focus on suitable temperatures and denser canopy cover for salmonids may reduce habitat suitability for Foothill Yellow-legged Frogs over time (Ibid.).

San Joaquin County Multi-Species Habitat Conservation and Open Space Plan

The San Joaquin County Multi-Species Habitat Conservation and Open Space Plan (SJMSCP) is a 50-year HCP/ITP that was signed by the USFWS on November 14, 2000 (San Joaquin County 2000). The SJMSCP covers almost all of San Joaquin County except federal lands, a few select projects, and some properties with certain land uses, roughly 900,000 ac. At the time of execution, approximately 172 ac of habitat within the SJMSCP area in the southwest portion of the county were considered occupied by Foothill Yellow-legged Frogs with another 4,484 ac classified as potential habitat, but it appears the species had been considered extirpated before then (Jennings and Hayes 1994, San Joaquin County 2000, Lind 2005). The HCP estimates around 8% of the combined modeled habitat would be converted to other uses over the permit term, but the establishment of riparian preserves with buffers around Corral Hollow Creek, where the species occurred historically, was expected to offset those impacts (San Joaquin County 2000, SJCOG 2018). However, the HCP did not require surveys to determine if Foothill Yellow-legged Frogs are benefiting from its conservation measures (M. Grefsrud pers. comm. 2019).

East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan

The East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan (ECCC HCP/NCCP) is a multi-jurisdictional 30-year plan adopted in 2007 that covers over 174,018 ac in eastern Contra Costa County (Jones & Stokes 2006). The Foothill Yellow-legged Frog appears to be extirpated from the ECCC HCP/NCCP area (CNDDB 2019). Nevertheless, suitable habitat was mapped, and impacts were estimated at well under 1% of both breeding and migratory habitat (Jones & Stokes 2006). One of the HCP/NCCP's objectives is acquiring high-quality Foothill Yellow-legged Frog habitat that has been identified along Marsh Creek (Ibid.). In 2017, the Viera North Peak 160 ac property was acquired that possesses suitable habitat for Foothill Yellow-legged Frogs (ECCCHC 2018).

Santa Clara Valley Habitat Plan

The Santa Clara Valley Habitat Plan (SCVHP) is a 50-year HCP/NCCP covering over 519,506 ac in Santa Clara County (ICF 2012). As previously mentioned, Foothill Yellow-legged Frogs appear to have been extirpated from lower elevation sites, particularly below reservoirs in this area. Approximately 17% of modeled Foothill Yellow-legged Frog habitat, measured linearly along streams, was already permanently preserved, and the SCVHP seeks to increase that to 32%. The maximum allowable habitat loss is 7 mi permanent loss and 2 mi temporary loss, while 104 mi of modeled habitat is slated for protection. By mid-2018, 8% of impact area had been accrued and 3% of habitat protected (SCVHA 2019).

Green Diamond Aquatic Habitat Conservation Plan

Green Diamond Resources Company has an Aquatic Habitat Conservation Plan (AHCP) covering 400,000 ac of their land that is focused on cold water adapted species, but many of the conservation measures are expected to benefit Foothill Yellow-legged Frogs as well (K. Hamm pers. comm. 2017). Examples include slope stability and road management measures to reduce stream sedimentation from erosion and landslides, and limiting water drafting during low flow periods with screens over the pumps to avoid entraining animals (Ibid.). Although creating more open canopy areas and warmer water temperatures is not the goal of the AHCP, the areas that are suitable for Foothill Yellow-legged Frog breeding are likely to remain that way because they are wide channels that receive sufficient sunlight (Ibid.).

6.0 SUMMARY OF LISTING FACTORS

CESA's implementing regulations identify key factors relevant to the Department's analyses and the Fish and Game Commission's decision on whether to list a species as threatened or endangered. A species will be listed as endangered or threatened if the Commission determines that the species' continued existence is in serious danger or is threatened by any one or any combination of the following factors: (1) present or threatened modification or destruction of its habitat; (2) overexploitation; (3) predation; (4) competition; (5) disease; or (6) other natural occurrences or human-related activities (Cal. Code Regs., tit. 14, § 670.1, subd. (i).

This section provides summaries of information from the foregoing sections of this status review, arranged under each of the factors to be considered by the Commission in determining whether listing is warranted.

6.1 Present or Threatened Modification or Destruction of Habitat

Most of the factors affecting the Foothill Yellow-legged Frog's ability to survive and reproduce discussed above involve habitat destruction or degradation. The most widespread, and potentially most significant, threats are associated with dams and their flow regimes, particularly in areas where they are concentrated and occur in a series along a river. Dams and the way they are operated can have up- and downstream impacts to Foothill Yellow-legged Frogs. They can result in aseasonal or asynchronous breeding cues, scouring and stranding of egg masses and tadpoles, reduction in quality and quantity of breeding and rearing habitat, slower tadpole growth rate, barriers to gene flow among populations, and establishment and spread of non-native species (Hayes et al. 2016). These impacts appear to be most severe when the dam is operated for the generation of hydropower that use hydropeaking and pulse flows (Kupferberg et al. 2009c, Peek 2018). Foothill Yellow-legged Frog abundance below dams is an average of five times lower than in unregulated rivers (Kupferberg et al. 2012). The number, height, and distance upstream of dams in a watershed influenced whether Foothill Yellow-legged Frogs still occurred at sites that were occupied in 1975 (Ibid.). Water diversions for agricultural, industrial, and municipal uses also reduce the availability and quality of Foothill Yellow-legged Frog habitat. Dams are concentrated in the Bay Area, Sierra Nevada, and southern California (Figure 19), while hydropower plants are densest in the northern and central Sierra Nevada (Figure 21).

With predicted increases in the human population, ambitious renewable energy targets, higher temperatures, and more extreme and variable precipitation falling increasingly as rain rather than snow, the need for more and taller dams and water diversions for hydropower generation, flood control, and water storage and delivery is not expected to abate in the future. California voters approved Proposition 1, the Water Quality, Supply and Infrastructure Improvement Act of 2014, which dedicated \$2.7 billion to water storage projects (PPIC 2018). In 2018, the California Water Commission approved funding for four new dams in California: expansion of Pacheco Reservoir (Santa Clara County), expansion of Los

Vaqueros Reservoir (Contra Costa County), Temperance Flat Dam (new construction) on the San Joaquin River (Fresno County), and the off-stream Sites Reservoir (new construction) diverting the Sacramento River (Colusa County) (CWC 2019). No historical records of Foothill Yellow-legged Frogs from the Los Vaqueros or Sites Reservoir areas exist in the CNDDB, and one historical (1950) collection is documented from the Pacheco Reservoir area (CNDDB 2019). However, the proposed Temperance Flat Dam site is downstream of one of the only known extant populations of Foothill Yellow-legged Frogs in the East/Southern Sierra clade (Ibid.).

The other widespread threat to Foothill Yellow-legged Frog habitat is climate change. While drought, wildland fires, floods, and landslides are natural, and ostensibly necessary, disturbance events for preservation of native biodiversity, climate change is expected to result in increased frequency and severity of these events in ways that may exceed species' abilities to adapt (Williams et al. 2008, Hoffmann and Sgrò 2011, Keely and Syphard 2016). These disturbance events, which can lead to local extirpations, will occur across a landscape of mostly fragmented and small populations, so the likelihood of natural recolonization will be highly impaired (S. Kupferberg pers. comm. 2019). Climatic changes in flow regime can lead to increased competition, predation, and disease transmission as species become concentrated in areas that remain wet into the late summer (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Loss of riparian vegetation from wildland fires can result in increased stream temperatures or concentrations of nutrients and trace heavy metals that inhibit growth and survival (Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Stream sedimentation from landslides following fire or excessive precipitation can destroy or degrade breeding and rearing habitat (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). At least some models predict unprecedented dryness in the latter half of the century (Cook et al. 2015). The effects of climate change will be realized across the Foothill Yellow-legged Frog's range, and the severity of these effects will likely differ in ways that are difficult to predict. However, the impacts from extended droughts will likely be greatest in the areas that are naturally more arid, the lower elevations and latitudes of southern California and the foothills surrounding the Central Valley (Figure 25), although some models suggest the stress to vegetation communities may be relatively high in the North Coast (Figure 28).

While most future urbanization is predicted to occur in areas outside of the Foothill Yellow-legged Frog's range, it has already contributed to the loss and fragmentation of Foothill Yellow-legged Frog habitat in California. In addition, the increased predation, wildland fires, introduced species, road mortality, disease transmission, air and water pollution, and disturbance from recreation that can accompany urbanization expand its impact far beyond its physical footprint (Davidson et al. 2002, Syphard et al. 2007, Cook et al. 2012, Bar-Massada et al. 2014). Within the Foothill Yellow-legged Frog's historical range, these effects appear most significant and extensive in terms of population extirpations in southern California and the San Francisco Bay Area.

Several other activities have the potential to destroy or degrade Foothill Yellow-legged Frog habitat, but they are less common across the range. They also tend to have relatively small areas of impact, although they can be significant in those areas, particularly if populations are already small and declining. These include impacts from mining, cannabis cultivation, vineyard expansion, overgrazing, timber harvest, recreation, and some stream habitat restoration projects (Harvey and Lisle 1998, Belsky et al. 1999, Merelender 2000, Pilliod et al. 2003, Bauer et al. 2015, Kupferberg and Furey 2015).

6.2 Overexploitation

Foothill Yellow-legged Frogs are not threatened by overexploitation. There is no known pet trade for Foothill Yellow-legged Frogs (Lind 2005). During the massive frog harvest that accompanied the Gold Rush, some Foothill Yellow-legged Frogs were collected, but because they are relatively small and have irritating skin secretions, there was much less of a market for them (Jennings and Hayes 1985). Within these secretions is a peptide with antimicrobial activity that is particularly potent against *Candida albicans*, a human pathogen that has been developing resistance to traditional antifungal agents (Conlon et al. 2003). However, the peptide's therapeutic potential is limited by its strong hemolytic activity (destroys red blood cells), so further studies will focus on synthesizing analogs that can be used as antifungals, and collection of significant numbers of Foothill Yellow-legged Frogs for lab cultures is not expected (Ibid.).

Like all native California amphibians, collection of Foothill Yellow-legged Frogs is unlawful without a permit from the Department. They may only be collected for scientific, educational, or propagation reasons through a Scientific Collecting Permit (Fish & G. Code § 1002 et seq.). The Department has the discretion to limit or condition the number of individuals collected or handled to ensure no significant adverse effects. Incidental harm from authorized activities on other aquatic species can be avoided or minimized by the inclusion of special terms and conditions in permits.

6.3 Predation

Predation is a likely contributor to Foothill Yellow-legged Frog population declines where the habitat is degraded by one or many other risk factors (Hayes and Jennings 1986). Predation by native gartersnakes can be locally substantial; however, it may only have an appreciable population-level impact if the availability of escape refugia is diminished. For example, when streams dry and only pools remain, Foothill Yellow-legged Frogs are more vulnerable to predation by native and non-native species because they are concentrated in a small area, often with little aquatic cover.

Several studies have demonstrated the synergistic impacts of predators and other stressors. Foothill Yellow-legged Frogs, primarily as demonstrated through studies on tadpoles, are more susceptible to predation when exposed to some agrochemicals, cold water, high velocities, excess sedimentation, and even the presence of other species of predators (Harvey and Lisle 1998, Adams et al. 2003, Olson and Davis 2009, Kupferberg et al. 2011b, Kerby and Sih 2015, Catenazzi and Kupferberg 2018). Foothill Yellow-legged Frog tadpoles appear to be naïve to chemical cues from some non-native predators; they have not evolved those species-specific predator avoidance behaviors (Paoletti et al. 2011). Furthermore, early life stages are often more sensitive to environmental stressors, making them more vulnerable to predation, and Foothill Yellow-legged Frog population dynamics are highly sensitive to egg and tadpole mortality (Kats and Ferrer 2003, Kupferberg et al. 2009c). Predation pressure is likely positively associated with proximity to anthropogenic changes in the environment, so in more remote or pristine places, it probably does not have a serious population-level impact.

6.4 Competition

Intra- and interspecific competition in Foothill Yellow-legged Frogs has been documented. Intraspecific male-to-male competition for females has been reported (Rombough and Hayes 2007, Wilcox and Alvarez 2019). Observations include physical aggression and a non-random mating pattern in which larger males were more often engaged in breeding (Rombough and Hayes 2007, Wheeler and Welsh 2008). A behavior resembling clutch-piracy, where a satellite male attempts to fertilize already laid eggs, has also been documented (Rombough and Hayes 2007). These acts of competition play a role in population genetics, but they likely do not result in serious physical injury or mortality. Intraspecific competition among Foothill Yellow-legged Frog tadpoles was negligible (Kupferberg 1997a).

Interspecific competition appears to have a greater possibility of resulting in adverse impacts. Kupferberg (1997a) did not observe a significant change in tadpole mortality for Foothill Yellow-legged Frogs raised with Pacific Treefrogs compared to single-species controls. However, when reared together, Foothill Yellow-legged Frog tadpoles lost mass, while Pacific Treefrog tadpoles increased mass (Kerby and Sih 2015). As described previously under Introduced Species, Foothill Yellow-legged Frog tadpoles experienced significantly higher mortality and smaller size at metamorphosis when raised with bullfrog tadpoles (Kupferberg 1997a). The mechanism of these declines appeared to be exploitative competition (as opposed to interference) through the reduction of available algal resources from bullfrog tadpole grazing in the shared enclosures (Ibid.).

The degree to which competition threatens Foothill Yellow-legged Frogs likely depends on the number and density of non-native species in the area rather than intraspecific competition, and co-occurrence of Foothill Yellow-legged Frog and bullfrog tadpoles may be somewhat rare since the latter tends to breed in lentic (still water) environments (M. van Hattem pers. comm. 2019). Interspecific competition with other native species may have some minor adverse consequences on fitness.

6.5 Disease

Currently, the only disease known to pose a serious risk to Foothill Yellow-legged Frogs is Bd. Until 2017, the only published studies on the impact of Bd on Foothill Yellow-legged Frogs suggested it could reduce growth and body condition but was not lethal (Davidson et al. 2007, Lowe 2009, Adams et al. 2017b). However, two recent mass mortality events caused by chytridiomycosis proved they are susceptible to lethal effects, at least under certain conditions like drought-related concentration and presence of bullfrogs (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Some evidence indicates disease may have played a principal role in the disappearance of the species from southern California (Adams et al. 2017b). Bd is likely present in the environment throughout the Foothill Yellow-legged Frog's range, and with bullfrogs and treefrogs acting as carriers, it will remain a threat to the species; however, given the dynamics of the two recent die-offs in the San Francisco Bay area, the probability of future outbreaks may be greater in areas where the species is under additional stressors like drought and introduced species (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Therefore, as with predation, Foothill Yellow-legged Frogs are less likely to experience the adverse impacts of diseases in more remote areas with fewer anthropogenic changes to the environment.

6.6 Other Natural Events or Human-Related Activities

Agrochemicals, particularly organophosphates that act as endocrine disruptors, can travel substantial distances from the area of application through atmospheric drift and have been implicated in the disappearance and declines of many species of amphibians in California including Foothill Yellow-legged Frogs (LeNoir et al. 1999, Davidson 2004, Lind 2005, Olson and Davis 2009). Foothill Yellow-legged Frogs appear to be significantly more sensitive to the adverse impacts of some pesticides than other native species (Sparling and Fellers 2009, Kerby and Sih 2015). These include smaller body size, slower development rate, increased time to metamorphosis, diminished immune response, and greater vulnerability to predation and malformations (Kiesecker 2002, Hayes et al. 2006, Sparling and Fellers 2009, Kerby and Sih 2015). Some of the most dramatic declines experienced by ranids in California occurred in the Sierra Nevada east of the San Joaquin Valley, where over half of the state's total pesticide usage occurs (Sparling et al. 2001).

Many Foothill Yellow-legged Frog populations are small, isolated from other populations, and possess low genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). Genetic diversity is important in providing a population the capacity to evolve in response to environmental changes, and connectivity among populations is important for gene exchange and in minimizing probability of local extinction (Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). Small populations are at much greater risk of extirpation primarily through the disproportionate impact of demographic, environmental, and genetic stochasticity than robust populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). Based on a Foothill Yellow-legged Frog PVA, populations in regulated rivers face a 4- to 13-fold greater extinction risk in 30 years than populations in unregulated rivers due to smaller population sizes (Kupferberg et al. 2009c). The threat posed by small population sizes is significant and the general pattern shows increases in severity from north to south; however, many sites, primarily in the northern Sierra Nevada, in watersheds with large hydropower projects are also at high risk.

7.0 PROTECTION AFFORDED BY LISTING

It is the policy of the State to conserve, protect, restore and enhance any endangered or threatened species and its habitat (Fish & G. Code, § 2052). The conservation, protection, and enhancement of listed species and their habitat is of statewide concern (Fish & G. Code, § 2051(c)). "Take" is defined for CESA purposes as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill (Fish & G. Code, § 86). The Fish and Game Code provides the Department with related authority to authorize "take" of species listed as threatened or endangered under certain circumstances (see, e.g., Fish & G. Code, §§ 2081, 2081.1, 2086, & 2835).

If the Foothill Yellow-legged Frog is listed under CESA, impacts of take caused by activities authorized through ITPs must be minimized and fully mitigated according to state standards (Fish & G. Code, § 2081, subd. (b)). These standards typically include protection of land in perpetuity with an easement, development and implementation of a species-specific adaptive management plan, and funding through an endowment to pay for long-term monitoring and maintenance to ensure the mitigation land meets performance criteria. Obtaining an ITP is voluntary. The Department cannot force compliance; however, any person violating the take prohibition may be criminally and civilly liable under state law.

Additional protection of Foothill Yellow-legged Frogs following listing would be expected to occur through state and local agency environmental review under CEQA. CEQA requires affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on rare, threatened, and endangered species. In common practice, potential impacts to listed species are examined more closely in CEQA documents than potential impacts to unlisted species. Where significant impacts are identified under CEQA, the Department expects project-specific avoidance, minimization, and mitigation measures to benefit the species. State listing, in this respect, and consultation with the Department during state and local agency environmental review under CEQA would be expected to benefit the Foothill Yellow-legged Frog in terms of reducing impacts from individual projects, which might otherwise occur absent listing.

For some species, CESA listing may prompt increased interagency coordination, particularly between the National Marine Fisheries Service and the Department, and the likelihood that state and federal land and resource management agencies will allocate funds toward protection and recovery actions. In the case of the Foothill Yellow-legged Frog, some multi-agency efforts exist, often associated with FERC license requirements, to improve habitat conditions and augment declining populations. The USFWS is leading an effort to develop range-wide and regional Foothill Yellow-legged Frog conservation strategies, and CESA listing may result in increased priority for limited conservation funds such as State Wildlife Grants and funding opportunities connected to level of imperilment on the International Union for Conservation of Nature's Red List.

8.0 LISTING RECOMMENDATION

CESA directs the Department to prepare this report regarding the status of the Foothill Yellow-legged Frog in California based upon the best scientific information available (Fish & G. Code, § 2074.6). CESA also directs the Department based on its analysis to indicate in the status report whether the petitioned action (i.e., listing as threatened) is warranted (Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

Under CESA, an endangered species is defined as "a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease" (Fish & G. Code, § 2062). A threatened species is defined as "a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA]" (Fish and G. Code, § 2067).

The Legislature left to the Department and the Commission, which are responsible for providing the best scientific information and for making listing decisions, respectively, the interpretation of what constitutes a "species or subspecies" under CESA. (*Cal. Forestry Assn. v. Cal. Fish and G. Com.* (2007) 156

Cal.App.4th 1535, 1548-49). Courts should give a "great deal of deference" to Commission listing determinations supported by Department scientific expertise (*Central Coast Forest Assn. v. Fish & G. Com.* (2018) 18 Cal. App. 5th 1191, 1198-99). The Commission's authority to list necessarily includes discretion to determine what constitutes a species or subspecies (*Id*. at p. 1237). The Commission's determination of which populations to list under CESA goes beyond genetics to questions of policy (*Ibid*.).

As described above, genetic divergence among populations and genetic diversity within those populations are critical to species protection. Genetic divergence indicates the amount of time that population lineages have been separated. Effective conservation strategies often identify the most divergent clades in a group of lineages as key management units. While it can be difficult to determine when populations within species have sufficiently differentiated to be considered separate species or subspecies, the population-genetics approach using the fixation index F_{ST} is the most widely used summary measure of population divergence. The high divergence values calculated for F_{ST} for Foothill Yellow-legged Frog suggest a long history of reproductive isolation for the six clades described. Further, genetic diversity provides information on population health and indicates the extent to which populations have the capacity to adapt to changing condition. Amphibians may be particularly vulnerable to the effects of low genetic diversity. The levels of genetic diversity within the six Foothill Yellow-legged Frog clades differed significantly, largely following a north-to-south pattern, and the significant reductions in connectivity and genetic diversity over short evolutionary periods raises concerns with respect to population viability and persistence.

A population of organisms considered distinct for conservation purposes based on scientific analysis of the reproductive isolation and genetic differences between population groups is eligible for listing under CESA (see *Cal. Forestry Assn. v. Cal. Fish and G.*, supra, 156 Cal.App.4th 1535 [upholding the Commission's listing of two evolutionarily significant units of Coho Salmon]. The Department has recognized that similar populations of a species can be grouped for efficient protection of bio- and genetic diversity (*Id*. at p. 1546-47). Further, genetic structure and biodiversity in California populations are important because they foster enhanced long-term stability (*Id*. at p. 1547). Diversity spreads risk and supports redundancy in the case of catastrophes, provides a range of raw materials that allow adaptation and persistence in the face of long-term environmental change, and leads to greater abundance (*Ibid*.). In consideration of the scientific information contained herein, the Department has determined that each of the six Foothill Yellow-legged Frog genetic clades described in this status report— Northwest/North Coast, Feather River, Northeast/Northern Sierra, East/Southern Sierra, West/Central Coast, and Southwest/South Coast—qualify as a "species or subspecies" under CESA and listing the Foothill Yellow-legged Frog by genetic clade is the prudent approach due to the disparate degrees of imperilment among them. The Department, based on the best science, included areas where the historical range is uncertain, but populations may be discovered within the defined clade boundaries (Figure 6). The Department includes and makes the following recommendation in this status report as submitted to the Commission in an advisory capacity based on the best available science.

NORTHWEST/NORTH COAST: Not warranted at this time.

Clade-level Summary: This is the largest clade with the most robust populations (highest densities) and the greatest genetic diversity. This area is the least densely populated by humans; contains relatively few hydropower dams, particularly further north; and has the highest precipitation in the species' California range. The species is still known to occur in most, if not all, historically occupied watersheds; presumed extirpations are mainly concentrated in the southern portion of the clade around the heavily urbanized San Francisco Bay area. The proliferation of cannabis cultivation, particularly illicit grows in and around the Emerald Triangle, the apparent increase in severe wildland fires in the area, and potential climate change effects are cause for concern, so the species should remain a Priority 1 SSC here with continued monitoring for any change in its status.

FEATHER RIVER: Threatened.

Clade-level Summary: This is the smallest clade and has a high density of hydropower dams. It also recently experienced one of the largest, most catastrophic wildfires in California history. Despite these threats, Foothill Yellow-legged Frogs appear to continue to be relatively broadly distributed within the clade, although with all the dams in the area, most populations are likely disconnected. The area is more mesic and experienced less of a change in precipitation in the most recent drought than the clades south of it. The clade is remarkable genetically and morphologically as it is the only area where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs overlap and can hybridize. The genetic variation within the clade is greater than the other clades except for the Northwest/North Coast. Most of the area within the clade's boundaries is Forest Service-managed, and little urbanization pressure or known extirpations exist in this area. Recent FERC licenses in this area require Foothill Yellow-legged Frog specific conservation, which to date has included cancelling pulse flows, removing encroaching vegetation, and translocating egg masses and in situ head-starting to augment a population that had recently declined.

NORTHEAST/NORTHERN SIERRA: Threatened.

Clade-level Summary: The Northeast/Northern Sierra clade shares many of the same threats as the Feather River clade (e.g., relatively small area with many hydropower dams). The area is also more mesic and experienced less of a change in precipitation during the recent drought than more southern clades. However, this pattern may not continue as some models suggest loss of snowmelt will be greater in the northern Sierra Nevada, and one of the climate change exposure models suggests that a comparatively large proportion of the lower elevations will experience climatic conditions not currently known from the area (i.e., non-analog) by the end of the century. Recent surveys suggest the area continues to support several populations of the species, some of which seem to remain robust, with a fairly widespread distribution. However, genetic analyses from several watersheds suggest many of these populations are isolated and diverging, particularly in regulated reaches with hydropeaking flows.

EAST/SOUTHERN SIERRA: Endangered.

Clade-level Summary: Like the Southwest/South Coast clade, widespread extirpations in this area were observed as early as the 1970s. Dams and introduced species were credited as causal factors in these declines in distribution and abundance, and mining and disease may also have contributed. This area is relatively arid, and drought effects appear greater here than in northern areas that exhibit both more precipitation and a smaller difference between drought years and the historical average. There is a relatively high number of hydropower generating dams in series along the major rivers in this clade and at least one new proposed dam near one of the remaining populations. This area is also the most heavily impacted by agrochemicals from the San Joaquin Valley.

WEST/CENTRAL COAST: Endangered.

Clade-level Summary: Foothill Yellow-legged Frogs appear to be extirpated from a relatively large proportion of historically occupied sites within this clade, particularly in the heavily urbanized northern portion around the San Francisco Bay. In the northern portion of the clade, nearly all the remaining populations (which may be fewer than a dozen) are located above dams, which line the mountains surrounding the Bay Area, and two are known to have undergone recent disease-associated die-offs. These higher elevation sites are more often intermittent or ephemeral streams than the lower in the watersheds. As a result, the more frequent and extreme droughts that have dried up large areas may have contributed to recent declines. Illegal cannabis cultivation, historical mining effects, overgrazing, and recreation likely contributed to declines and may continue to threaten remaining populations.

SOUTHWEST/SOUTH COAST: Endangered.

Clade-level Summary: The most extensive extirpations have occurred in this clade, and only two known extant populations remain. Both are small with apparently low genetic diversity, making them especially vulnerable to extirpation. This is also an area with a large human population, many dams, and naturally arid, fire-prone environments, particularly in the southern portion of the clade. Introduced species are widespread, and cannabis cultivation is rivaling the Emerald Triangle in some areas (e.g., Santa Barbara County). Introduced species, expanded recreation, disease, and flooding appear to have contributed to the widespread extirpations in southern California over 40 years ago.

9.0 MANAGEMENT RECOMMENDATIONS

The Department has evaluated existing management recommendations and available literature applicable to the management and conservation of the Foothill Yellow-legged Frog to arrive at the following recommendations. These recommendations, which represent the best available scientific information, are largely derived from the Foothill Yellow-legged Frog Conservation Assessment, the California Energy Commission's Public Interest Energy Research Reports, the Recovery Plans of West Coast Salmon and Steelhead, and the California Amphibian and Reptile Species of Special Concern (Kupferberg et al. 2009b,c, 2011a; NMFS 2012, 2013, 2014, 2016; Hayes et al. 2016; Thomson et al. 2016).

9.1 Conservation Strategies

Maintain current distribution and genetic diversity by protecting existing Foothill Yellow-legged Frog populations and their habitats and providing opportunities for increased connectivity and gene flow. Increase abundance to viable levels in populations at risk of extirpation due to small sizes, when appropriate, through in situ or ex situ captive propagation and translocations. Use habitat suitability and hydrodynamic habitat models to identify historically occupied sites that may currently support Foothill Yellow-legged Frogs or could with minor habitat improvements or modified management. Investigate the utility of using other amphibians as indicators of whether a site may be able to support Foothill Yellow-legged Frogs like the presence of Pacific Treefrogs or newts (*Taricha* spp.). Re-establish extirpated populations in suitable habitat through captive propagation and translocations. Prioritize areas in the southern portions of the species' range where extirpations and loss of diversity have been the most severe.

If establishing reserves, prioritize areas containing high genetic variation in Foothill Yellow-legged Frogs (and among various native species) and climatic gradients where selection varies over a small geographical area. Environmental heterogeneity can provide a means of maintaining phenotypic variability which increases the adaptive capacity of populations as conditions change. These reserves should provide connectivity to other occupied areas to facilitate gene flow and allow for ongoing selection to fire, drought, thermal stresses, and changing species interactions.

9.2 Research and Monitoring

Attempt to rediscover potentially remnant populations in areas where they are considered extirpated, prioritizing the southern portions of the species' range. Collect environmental DNA in addition to conducting visual encounter surveys to improve detectability. Concurrently assess presence of threats and habitat suitability to determine if future reintroductions may be possible. Collect genetic samples from any Foothill Yellow-legged Frogs captured for use in landscape genomics analyses and possible future captive propagation and translocation efforts. Attempt to better clarify clade boundaries where there is uncertainty. Study whether small populations are at risk of inbreeding depression, whether genetic rescue should be attempted, and if so, whether that results in hybrid vigor or outbreeding depression.

Continue to evaluate how water operations affect Foothill Yellow-legged Frog population demographics. Support and coordinate existing monitoring efforts and establish more long-term monitoring programs in regulated and unregulated (reference) rivers across the species' range, but particularly in areas like the Sierra Nevada where most large hydropower dams in the species' range are concentrated. Assess whether the timing of pulse flows influences population dynamics, particularly whether early releases have a disproportionately large adverse effect by eliminating the reproductive success of the largest, most fecund females, who appear to breed earlier in the season. Investigate survival rates in poorly understood life stages, such as tadpoles, young of the year, and juveniles. Determine the extent to which pulse flows contribute to displacement and mortality of post-metamorphic life stages.

Collect habitat variables that correlate with healthy populations to develop more site-specific habitat suitability and hydrodynamic models. Investigate the upstream and downstream extent of populations to document the conditions along the peripheries where marginal habitat becomes completely unsuitable. Study the potential synergistic effect of increased flow velocity and decreased temperature on tadpole fitness. Examine the relationship between changes in flow, breeding and rearing habitat connectivity, and scouring and stranding to develop site-specific, benign ramping rates. Incorporate these data and demographic data into future PVAs for use in establishing frog-friendly flow regimes in future FERC relicensing or license amendment efforts and habitat restoration projects. Ensure long-term funding for post-license restoration monitoring to evaluate attainment of expected results and for use in adapting management strategies accordingly.

Evaluate the distribution of other threats such as cannabis cultivation, vineyard expansion, livestock grazing, mining, timber harvest, and urbanization and roads in the Foothill Yellow-legged Frog's range. Study the short- and long-term effects of wildland fires and fire management strategies. Assess the extent to which these potential threats pose a risk to Foothill Yellow-legged Frog persistence in both regulated and unregulated systems.

Investigate how reach-level or short-distance habitat suitability and hydrodynamic models can be extrapolated to a watershed level. Study habitat connectivity needs such as the proximity of breeding sites and other suitable habitats along a waterway necessary to maintain gene flow and functioning meta-population dynamics.

9.3 Habitat Restoration and Watershed Management

Remove or modify physical barriers like dams and poorly constructed culverts and bridges to improve connectivity and natural stream processes. Remove anthropogenic features that support introduced predators and competitors such as abandoned mine tailing ponds that support bullfrog breeding. Where feasible, conduct active control and management efforts to decrease the abundance of bullfrogs, non-native fish, and crayfish (where they are non-native). In managed rivers, manipulate stream flows to negatively affect non-native species that are not adapted to a winter flood/summer drought flow regime. Where appropriate, construct natural barriers (e.g., boulders, waterfalls) to prevent upstream migration of crayfish and non-native fish.

Adopt a multi-species approach to channel restoration projects and managed flow regimes (thermal, velocity, timing) and mimic the natural hydrograph to the greatest extent possible. When this is impractical or infeasible, focus on minimizing adverse impacts by gradually ramping discharge up and down, creating and maintaining gently sloping and sun-lit gravel bars and warm calm edgewater habitats for tadpole rearing, and mixing hypolimnetic water (from the lower colder stratum in a reservoir) with warmer surface water before release if necessary to ensure appropriate thermal conditions for successful metamorphosis. Promote restoration and maintenance of habitat heterogeneity (different depths, velocities, substrates, etc.) and connectivity to support all life stages and gene flow. Avoid damaging Foothill Yellow-legged Frog breeding habitat when restoring habitat for other focal species like listed anadromous salmonids.

9.4 Regulatory Considerations and Best Management Practices

Develop range-wide minimum summer base flow requirements that protect Foothill Yellow-legged Frogs and their habitat with appropriate provisions to address regional differences using new more ecologically meaningful approaches such as percent-of-flow (or modified percent-of-flow) strategies for watersheds (e.g., Yarnell et al. 2013, Mierau et al. 2018). Limit water diversions during the dry season and construction of new in-stream dams by focusing on off-stream water storage strategies that are managed to prevent establishment of non-native predators and competitors.

Ensure and improve protection of riparian systems. Require maintenance of appropriate riparian buffers and canopy coverage (i.e., partly shaded) around occupied habitat or habitat that has been identified for potential future reintroductions. Restrict instream work to dry periods where possible. Prohibit fording in and around breeding habitat. Avoid working near streams after the first major rains in the fall when Foothill Yellow-legged Frogs may be moving upslope toward tributaries and overwintering sites. Use a 0.125 inch mesh screen on water diversion pumps and limit the rate and amount of water diverted such that depth and flow remain sufficient to support Foothill Yellow-legged Frogs of all life stages occupying the immediate area and downstream. Install exclusion fencing, where appropriate, being mindful that predators such as river otters may take advantage of the fencing to catch frogs (S. Kupferberg pers. comm. 2019). If Foothill Yellow-legged Frog relocation is required, conduct this activity early in the season because moving egg masses is easier than moving tadpoles.

Reduce habitat degradation from sedimentation, pesticides, herbicides, and other non-point source waste discharges from adjacent land uses, including along tributaries of rivers and streams. Limit mining to parts of rivers not used for oviposition, such as deeper pools or reaches with few tributaries, and at times of year when frogs are more common in tributaries (i.e., fall and winter). Manage recreational activities in or adjacent to Foothill Yellow-legged Frog habitat (e.g., OHV and hiking trails, camp sites, boating ingress/egress, flows, and speeds) in a way that minimizes adverse impacts. Siting cannabis grows in areas with better access to roads, gentler slopes, and ample water resources could significantly reduce threats to the environment. Determine which, when, and where agrochemicals should be restricted to reduce harm to Foothill Yellow-legged Frogs and other species. Ensure all new road crossings and modifications to existing crossings (bridges, culverts, fills, and other crossings) accommodate at least 100-year flood flows and associated bedload and debris.

9.5 Partnerships and Coordination

Establish collaborative partnerships with agencies, universities, and non-governmental organizations working on salmon and steelhead recovery and stream restoration. Anadromous salmonids share many of the same threats as Foothill Yellow-legged Frogs, and recovery actions such as barrier removal, restoration of natural sediment transport processes, reduction in pollution, and eradication of non-native predators should be planned and executed in a manner that benefits the frogs as well. Ensure Integrated Regional Water Management Plans and fisheries restoration programs take Foothill Yellow-legged Frog conservation into consideration during design, implementation, and maintenance.

Encourage local governments to place conditions on new developments to minimize negative impacts on riparian systems. Promote and implement initiatives and programs that improve water conservation use efficiency, reduce greenhouse gas emissions, promote sustainable agriculture and smart urban growth, and protect and restore riparian ecosystems. Shift reliance from on-stream storage to off-stream storage, resolve frost protection issues (water withdrawals), and ensure necessary flows for all life stages in all water years.

Establish a Department-coordinated staff and citizen scientist program to systematically monitor occupied stream reaches across the species' range.

9.6 Education and Enforcement

Support programs to provide educational outreach and local involvement in restoration and watershed stewardship, such as Project Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land and water use on Foothill Yellow-legged Frog survival.

Provide additional funding for increased law enforcement to reduce ecologically harmful stream alterations and water pollution and to ensure adequate protection for Foothill Yellow-legged Frogs at pumps and diversions. Identify and address illegal water diverters and out-of-compliance diverters, seasons of diversion, off-stream reservoirs, well pumping, and bypass flows to protect Foothill Yellow-legged Frogs. Prosecute violators accordingly. Provide additional environmental and enforcement staff for oversight of permit and environmental document compliance (i.e., fulfilling commitments in NEPA and CEQA documents to undertake activities to avoid, minimize, and mitigate adverse impacts; carrying out mitigation requirements in HCPs, NCCPs, FERC licenses; etc.).

10.0 ECONOMIC CONSIDERATIONS

The Department is charged in an advisory capacity in the present context to provide a written report and a related recommendation to the Commission based on the best scientific information available regarding the status of Foothill Yellow-legged Frog in California. The Department is not required to prepare an analysis of economic impacts (See Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

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APPENDIX A

Acronyms and Abbreviations

Acronym/ Abbreviation	*Definition*
ac	acre
ACOE	United States Army Corps of Engineers
AHCP	Aquatic Habitat Conservation Plan
Bd	*Batrachochytrium dendrobatidis*
BLM	United States Bureau of Land Management
CDFA	California Department of Food and Agriculture
CE	Common Era
CEQA	California Environmental Quality Act
CNDDB	California Natural Diversity Database
CPAD	California Protected Areas Database
CSVRA	Carnegie State Vehicular Recreation Area
CWA	Clean Water Act
DNA	deoxyribonucleic acid
DWR	California Department of Water Resources
ECCC	East Contra Costa County
ERC	Ecological Resources Committee
ESA	Endangered Species Act
F	Fahrenheit
FERC	Federal Energy Regulatory Commission
ft	foot
GIS	Geographic Information System
HCP	Habitat Conservation Plan
hr	hour
HRC	Humboldt Redwood Company
Hz	Hertz
ITP	Incidental Take Permit
lb	pound
LC	lethal concentration
mi	mile
MRC	Mendocino Redwood Company

NCCP	Natural Communities Conservation Plan
NEPA	National Environmental Policy Act
OHV	Off-Highway Vehicle
PLSS	Public Land Survey System
ppm	parts per million
PVA	Population Viability Analysis
RADSeq	Restriction-site Associated DNA Sequencing
RMZ	Riparian Management Zone
s	second
SCVHP	Santa Clara Valley Habitat Plan
SJMSCP	San Joaquin County Multi-Species Habitat Conservation and Open Space Plan
SSC	Species of Special Concern
SUL	snout-to-urostyle length
SWRCB	State Water Resources Control Board
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
WQC	Water Quality Certification
WUI	wildland-urban interface
WSRA	Wild and Scenic Rivers Act
yr	year

APPENDIX B

Metric Unit Conversions

Standard Unit	*Conversion to Metric Units*
acre	1 acre = 0.4047 hectare
acre-foot	1 acre-foot = 1,233.48 cubic meters
Fahrenheit	(°F – 32) x 5/9 = °Celsius
foot	1 foot = 0.3048 meter
inch	1 inch = 2.54 centimeters; 1 in = 25.4 millimeters
pound/acre	1 pound/acre = 1.12 kilograms/hectare
mile	1 mile = 1.6093 kilometers
parts per million	1 part per million = 1 microgram/gram

APPENDIX C

Solicitations for Information

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Wildlife Branch
1812 9th Street
Sacramento, CA 95811
www.wildlife.ca.gov

EDMUND G. BROWN, Jr., Governor
CHARLTON H. BONHAM, Director

July 24, 2017

SUBJECT: NOTIFICATION OF STATUS REVIEW FOR FOOTHILL YELLOW-LEGGED FROG

To whom it may concern:

The California Department of Fish and Wildlife (Department) has initiated a status review of the Foothill Yellow-legged Frog (*Rana boylii*) pursuant to Fish and Game Code section 2074.6 and is providing this notice pursuant to Fish and Game Code section 2074.4 to solicit data and comments on the petitioned action from interested and affected parties.

The Department has initiated this status review following the Fish and Game Commission's (Commission) decision to accept for consideration the petition to list the species under the California Endangered Species Act (CESA) at its June 21, 2017 meeting. Having provided public notice (Cal. Reg. Notice Reg. 2017, No. 27-Z, pp. 986-987; Fish & G. Code, § 2074.2), the Foothill Yellow-legged Frog is now a candidate species under CESA. As a candidate species, the Foothill Yellow-legged Frog receives the same legal protection afforded to an endangered or threatened species (Fish & G. Code, § 2085).

The Department has 12 months to review the petition, evaluate the available information, and report back to the Commission whether or not the petitioned action is warranted. (Fish & G. Code, § 2074.6.) The Department's recommendation must be based on the best scientific information available to the Department. (Fish & G. Code, § 2074.6.)

Anyone with data or comments on the Foothill Yellow-legged Frog's ecology, genetics, life history, distribution, abundance, habitat, the degree and immediacy of threats to reproduction or survival, adequacy of existing management, and recommendations for management of the species, is hereby requested to provide such data or comments to:

California Department of Fish and Wildlife
Attn: Laura Patterson
1812 9th Street
Sacramento, California 95811
wildlifemgt@wildlife.ca.gov

Please submit two hard copies if submitting by surface mail. If submitting by email, please include "Foothill Yellow-legged Frog" in the subject heading.

Responses and information received by **August 31, 2017,** will be evaluated for incorporation in the Department's final report to the Commission. The Department's written report will indicate, based on the best scientific information available, whether the Department concludes that the petitioned action is warranted or not warranted. Receipt of the report will be placed on the agenda for the next available meeting of the Commission after delivery. The report will be made available to the public at that time. Following receipt of the Department's report, the Commission will allow a 30-day public comment period prior to taking any action on the Department's recommendation.

As a candidate species, the Foothill Yellow-legged Frog receives the same legal protection afforded to an endangered or threatened species under the California Endangered Species Act (Fish & G. Code, § 2085). Research on Foothill Yellow-legged Frog requires appropriate permits issued pursuant to Fish and Game Code Section 2081(a). Detection information on Foothill Yellow-legged Frogs should be sent to the California Natural Diversity Data Base at https://www.wildlife.ca.gov/Data/CNDDB/Submitting-Data.

Interested researchers or anyone with questions may contact Laura Patterson at 916-341-6981 or at the email or address above

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Wildlife Branch
1812 9th Street
Sacramento, CA 95811
www.wildlife.ca.gov

EDMUND G. BROWN, Jr., Governor
CHARLTON H. BONHAM, Director

July 24, 2017

Honorable [Name]
[Title]
[Tribe name]
[Address]

SUBJECT: NOTIFICATION OF STATUS REVIEW FOR FOOTHILL YELLOW-LEGGED FROG

Dear Honorable Tribal Representative:

The California Department of Fish and Wildlife (Department) has initiated a status review of the Foothill Yellow-legged Frog (*Rana boylii*) pursuant to Fish and Game Code section 2074.6 and is providing this notice pursuant to Fish and Game Code section 2074.4 to solicit data and comments on the petitioned action from interested and affected Tribes. The Department has initiated this status review following the Fish and Game Commission's (Commission) decision to accept for consideration the petition to list the species under the California Endangered Species Act (CESA) at its June 21, 2017 meeting. Having provided public notice (Cal. Reg. Notice Reg. 2017, No. 27-Z, pp. 986-987; Fish & G. Code, § 2074.2), the Foothill Yellow-legged Frog is now a candidate species under CESA. As a candidate species, the Foothill Yellow-legged Frog receives the same legal protection afforded to an endangered or threatened species (Fish & G. Code, § 2085).

The Department has 12 months to review the petition, evaluate the available information, and report back to the Commission whether or not the petitioned action is warranted (Fish & G. Code, § 2074.6). The Department's recommendation must be based on the best scientific information available. The Department would welcome your Tribe to provide any data or comments on the species' ecology, genetics, life history, distribution, abundance, habitat, the degree and immediacy of threats to its reproduction or survival, the adequacy of existing management, and recommendations for management of the species.

Please provide such data or comments to "Attn: Laura Patterson" at the address in the letterhead. Please provide two hard copies if submitting by surface mail. Comments may also be sent via email to: wildlifemgt@wildlife.ca.gov. If submitting by email, please include "Foothill Yellow-legged Frog" in the subject heading. Please submit Foothill Yellow-legged Frog detection information to the California Natural Diversity Database at: https://www.wildlife.ca.gov/Data/CNDDB/Submitting-Data.

The Department respectfully requests your Tribe provide any responses and information before **August 31, 2017** to allow sufficient time to evaluate the information for possible incorporation in the Department's final status review report to the Commission. The written report will indicate, based on the best scientific information available, whether the Department concludes that the petitioned action is warranted or not warranted. Receipt of the status review report will be placed on the agenda for the next available Commission meeting after delivery. The report will be made available to the public at that time. Following receipt of the Department's report, the Commission will allow a 30-day public comment period prior to taking any action on the Department's recommendation.

The Department welcomes direct communication and consultation to discuss the status review of Foothill Yellow-legged Frog and to identify any impacts to Tribal interests or cultural resources. The Department is committed to open communication with your Tribe under its Tribal Communication and Consultation Policy, which is available through the Department's Tribal Affairs webpage at https://www.wildlife.ca.gov/General-Counsel/Tribal-Affairs.

If you would like more information on the Foothill Yellow-legged Frog status review, please contact Laura Patterson at 916-341-6981 or the Department via email at wildlifemgt@wildlife.ca.gov or at the address above. To request formal government-to-government consultation pursuant to the Department's Tribal Communication and Consultation Policy, please respond in writing to Tribal Liaison Nathan Voegeli by email tribal.liaison@wildlife.ca.gov or by mail to Department of Fish and Wildlife, 1416 9th Street, Suite 1341, Sacramento, CA 95814. Please designate and provide contact information for the appropriate Tribal lead person.

We look forward to your response and input on the Foothill Yellow-legged Frog status review.

Sincerely,

Kari D. Lewis

Kari Lewis, Acting Chief
Wildlife Branch

ec: California Department of Fish and Wildlife

Stafford Lehr, stafford.lehr@wildlife.ca.gov
Deputy Director, Wildlife and Fisheries Division

Nathan Voegeli, tribal.liaison@wildlife.ca.gov
Tribal Liaison, Office of the General Counsel

Scott Gardner, scott.gardner@wildlife.ca.gov
Acting Nongame Wildlife Program Manager, Wildlife Branch

Laura Patterson, laura.patterson@wildlife.ca.gov
Senior Environmental Scientist (Specialist), Wildlife Branch

California Endangered Species Act, Endangered Species, Public Participation

CDFW Seeks Information Related to Foothill Yellow-legged Frog

July 21, 2017

The California Department of Fish and Wildlife (CDFW) is seeking information relevant to a proposal to list the Foothill Yellow-legged Frog as a threatened species.

The Foothill Yellow-legged Frog (*Rana boylii*) inhabits lower elevation creeks, streams and rivers throughout the Klamath, Coast, Sierra Nevada and formerly the Transverse ranges of California. They can be found in a variety of habitat types such as chaparral, oak woodland, mixed coniferous forest, riparian sycamore and cottonwood forest, as well as wet meadows.

In December 2016, the Center for Biological Diversity submitted a petition to the California Fish and Game Commission to formally list the Foothill Yellow-legged Frog as threatened under the California Endangered Species Act. The listing petition described a variety of threats to the survival of Foothill Yellow-legged Frogs in California. These include direct and indirect impacts associated with dams, water diversions and development, invasive species, disease, climate change and other activities such as marijuana cultivation, timber harvest, mining, recreation, road building and urbanization. The Commission followed CDFW's recommendation and voted to advance the species to candidacy on June 21, 2017. The Commission published findings of this decision on July 7, 2017, triggering a 12-month period during which CDFW will conduct a status review to inform the Commission's decision on whether to list the species.

As part of the status review process, CDFW is soliciting information from the public regarding the Foothill Yellow-legged Frog's ecology, genetics, life history, distribution, abundance, habitat, the degree and immediacy of threats to reproduction or survival, adequacy of existing management and recommendations for management of the species. Comments, data and other information can be submitted in writing to:

California Department of Fish and Wildlife
Attn: Laura Patterson
1812 Ninth St.
Sacramento, CA 95811

Comments may also be submitted by email to wildlifemgt@wildlife.ca.gov. If submitting comments by email, please include "Foothill Yellow-legged Frog" in the subject heading.

All comments received by **Aug. 31, 2017** will be evaluated prior to submission of the CDFW report to the Commission. Receipt of the report will be placed on the agenda for the next available meeting of the Commission after delivery and the report will be made available to the public at that time. Following the receipt of the CDFW report, the Commission will allow a 30-day public comment period prior to taking any action on CDFW's recommendation.

The Center for Biological Diversity's listing petition and CDFW's petition evaluation for the Foothill Yellow-legged Frog are available at www.fgc.ca.gov/CESA/index.aspx#fylf.

# # #

Media Contacts:
Laura Patterson, CDFW Wildlife Branch, (916) 341-6981
Kyle Orr, CDFW Communications, (916) 322-8958

APPENDIX D

Public and Tribal Comments

Note: The attached comments were received during the public solicitation for information period plus one week. The reports and papers provided are not included due to their excessive size, and copyrights in some cases, but are available upon request.

Patterson, Laura@Wildlife

From: Trent Saxton
Sent: Friday, July 21, 2017 7:24 PM
To: Wildlife Management
Subject: Your Yellow Frog search is a joke and you know it...here is the real reason

LIVE, WORK OR RECREATE IN THE RED ZONE—START PACKING THE FROG IS MOVING IN!

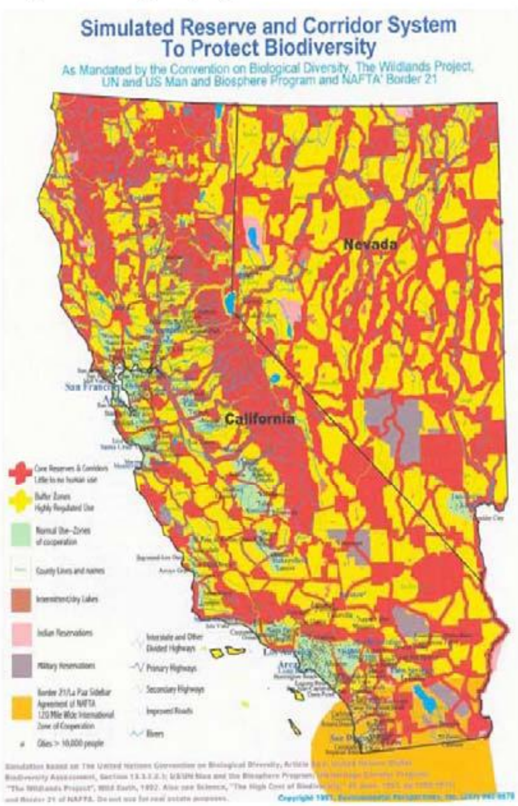
PROOF FISH AND WILDLIFE ENDANGERED FROG IS A FRAUD!

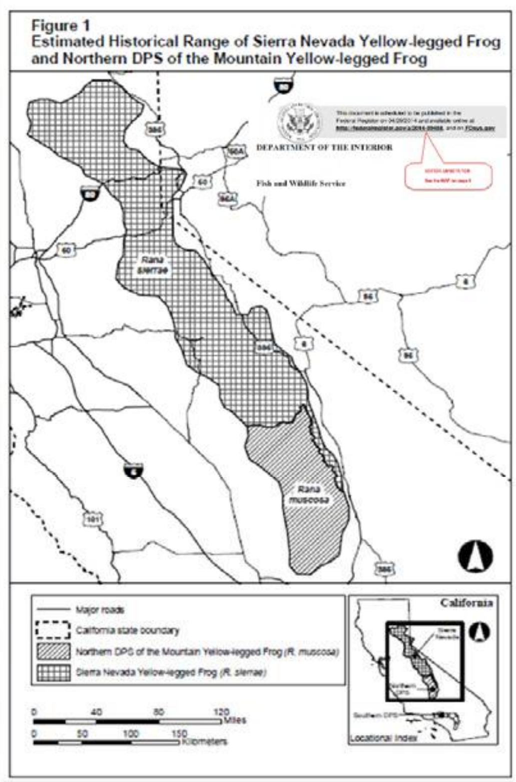
COMPARE WILDLANDS PROJECT MAP, WITH LEGEND FOR RED—LITTLE TO NO HUMAN USE, And THE "ESTIMATED HISTORICAL RANGE OF Sierra Nevada Yellow Legged Frog provided in the

Source of Map below:
http://discerningtoday.org/

1.1. Background—On January 27, 2010, the Fish and Game Commission (Commission) received a petition from the Center for Biological Diversity (Center) to list all populations of Mountain Yellow Legged Frog (MYLF) as "Endangered" under California Endangered Species Act (CESA). (A Status Review of the Mountain Yellow-Legged Frog, pg. 1)

Source of Map below:
http://federalregister.gov/a/2014-09488 at pg. 8





PROOF OF A HIDDEN AGENDA BEHIND, THE CALIFORNIA FISH & WILDLIFE ENGANGERED FROG HOAX.

These two maps were created approximately twenty years apart, by entirely different entities, yet the area identified for the "endangered frog is almost an exact overlay of the large area in Red designated for "Little to No Human Use" in the UN NAFTA Wildlands Project!

Patterson, Laura@Wildlife

From: Sinnen, Wade@Wildlife
Sent: Friday, July 21, 2017 10:14 AM
To: Patterson, Laura@Wildlife
Subject: RE: CDFW Seeks Information Related to Foothill Yellow-legged Frog

Hi Laura,

I'm not sure who may compiling information for this petition but wanted to point out there are several reports on the species that can be obtained from the following Trinity River restoration Program web portal:

http://odp.trrp.net/Search/Search.aspx

Regards,

Wade

Wade Sinnen
Senior Environmental Scientist (supervisor)
CA Department of Fish and Wildlife
5341 Ericson Way
Arcata, CA 95521

From: Wildlife CDFWNews
Sent: Friday, July 21, 2017 9:38 AM
To: Wildlife CDFW_ALL <CDFW_All@wildlife.ca.gov>
Subject: CDFW Seeks Information Related to Foothill Yellow-legged Frog

This draft news release is being sent to all CDFW employees. It is not yet public. Please do not distribute. If you have any concerns, please contact the individual(s) listed at the top of the release (do not reply to this email). When it is made public, it will be posted at www.wildlife.ca.gov/news.

California Department of Fish and Wildlife News Release

July 21, 2017

Media Contacts:
Laura Patterson, CDFW Wildlife Branch, (916) 341-6981
Kyle Orr, CDFW Communications, (916) 322-8958

CDFW Seeks Information Related to Foothill Yellow-legged Frog

The California Department of Fish and Wildlife (CDFW) is seeking information relevant to a proposal to list the Foothill Yellow-legged Frog as a threatened species.

The Foothill Yellow-legged Frog (*Rana boylii*) inhabits lower elevation creeks, streams and rivers throughout the Klamath, Coast, Sierra Nevada and formerly the Transverse ranges of California. They can be found in a variety of habitat types such as chaparral, oak woodland, mixed coniferous forest, riparian sycamore and cottonwood forest, as well as wet meadows.

In December 2016, the Center for Biological Diversity submitted a petition to the California Fish and Game Commission to formally list the Foothill Yellow-legged Frog as threatened under the California Endangered Species Act. The listing petition described a variety of threats to the survival of Foothill Yellow-legged Frogs in California. These include direct and indirect impacts associated with dams, water diversions and development, invasive species, disease, climate change and other activities such as marijuana cultivation, timber harvest, mining, recreation, road building and urbanization. The Commission followed CDFW's recommendation and voted to advance the species to candidacy on June 21, 2017. The Commission published findings of this decision on July 7, 2017, triggering a 12-month period during which CDFW will conduct a status review to inform the Commission's decision on whether to list the species.

As part of the status review process, CDFW is soliciting information from the public regarding the Foothill Yellow-legged Frog's ecology, genetics, life history, distribution, abundance, habitat, the degree and immediacy of threats to reproduction or survival, adequacy of existing management and recommendations for management of the species. Comments, data and other information can be submitted in writing to:

California Department of Fish and Wildlife
Attn: Laura Patterson
1812 Ninth St.
Sacramento, CA 95811

Comments may also be submitted by email to wildlifemgt@wildlife.ca.gov. If submitting comments by email, please include "Foothill Yellow-legged Frog" in the subject heading.

All comments received by **Aug. 31, 2017** will be evaluated prior to submission of the CDFW report to the Commission. Receipt of the report will be placed on the agenda for the next available meeting of the Commission after delivery and the report will be made available to the public at that time. Following the receipt of the CDFW report, the Commission will allow a 30-day public comment period prior to taking any action on CDFW's recommendation.

The Center for Biological Diversity's listing petition and CDFW's petition evaluation for the Foothill Yellow-legged Frog are available at www.fgc.ca.gov/CESA/index.aspx#fylf.

Patterson, Laura@Wildlife

From: Eric Olson
Sent: Friday, July 21, 2017 2:52 PM
To: Patterson, Laura@Wildlife
Subject: Foothill Yellow-legged Frog

Laura,
I saw the TWS post on facebook about the call for information on Foothill Yellow-legged Frog. I'm not sure that I have much to add, but when I did my master's work in the Sutter Buttes I searched the creeks within the State Park for the species but never found them. I also confirmed the ID of the one specimen that is at Chico State from the Buttes.

My personal opinion is that if a FYLF population was present at the Sutter Buttes, the feral pigs have probably wiped them all out. All of the creeks I encountered during the summer were reduced to small pools,and those pools almost always were turned into pig wallows. That, along with other researchers not being recording the species other than the one specimen leads me to believe that they have been extirpated from the Buttes.

Anyway, that's probably all old news for you, but just in case it was useful I thought I would let you know.

Thanks and good luck!
Eric

--
Eric Olson
Northern California Preserve Manager
Center for Natural Lands Management

Patterson, Laura@Wildlife

From: Rosalind Helfand
Sent: Saturday, July 22, 2017 1:17 PM
To: Wildlife Management
Subject: Foothill Yellow-legged Frog - Attn Laura Patterson

Dear Ms. Patterson,

Hello. I'm submitting observations on Foothill Yellow-legged Frog habitat.

On October 7, 2016 at around 4pm, my husband and I observed and photographed three Foothill Yellow-legged Frogs in a shallow stream with clear water moving moderately fast feeding into the Smith River. This was not far from Stout Grove in Jedediah Smith Redwoods State Park.

The environment was very cool (although it was a very warm day in the sun) with dense trees and foliage and fully shaded at the time. The frogs both sat on rocks in the stream and hid in the water under tree debris (mostly bits of redwood tree) lining the sides of the stream.

The stream ran under a pedestrian bridge for a fairly heavily used trail and the frogs were found close to the bridge location -- both down and upstream.

It's clear that the habitat is fragile. If the stream were to dry up or be blocked or polluted, or if people were to walk in and around it regularly, it appears it would be a threat to the frogs.

We're happy to submit our photographs if desired.

Thank you!

Rosalind Helfand and Steven Calcote

--
Rosalind Helfand
Advisor/Director/Programming Developer, Nonprofits & Government

Patterson, Laura@Wildlife

From: Alan Peterson
Sent: Saturday, July 22, 2017 2:17 PM
To: Wildlife Management
Subject: Foothill Yellow-legged Frog
Attachments: Foothill-Yellow-Legged-Frog.jpg

Sorry, the attachment didn't make it onto the last email. Here it is again:

In response to the request for information about the foothill yellow-legged frog, they can be found around the tributaries to the Mad River near Blue Lake, California. I photographed this one next to Boundary Creek during April of this year.

Patterson, Laura@Wildlife

From: jimkatta
Sent: Sunday, July 23, 2017 9:14 AM
To: Wildlife Management
Subject: Foothill Yellow Frog

I have been a California Fisherman for 45yrs. I have bought California Fishing licenses for 39yrs. I remember the good old days of fishing the San Gabriel River, Piru Creek, Cucamonga Creek and the Arroyo Seco Creek. So Cal trout fishing was good back in those days. That stupid frog ruined it, more people trout fish than watch that frog. That was a typical California maneuver wrecking something that was good for a bunch of the citizens to make a few people happy. I say lift the ban and start stocking the creeks again!

Sent from Mail for Windows 10

Patterson, Laura@Wildlife

From: Holly Dalton
Sent: Monday, July 24, 2017 12:33 AM
To: Wildlife Management

I , amfrom Northern California. I read the article on the frogs, I have also noticed most anfibian species are disappearing... (banana slugs, snails, a lot of turtles and snakes..) as well as most incects..and ..fish....where are surf fish..?

Patterson, Laura@Wildlife

From: larry kellerhals
Sent: Monday, July 24, 2017 2:26 PM
To: Wildlife Management
Subject: Foothill yellow legged frog

Man does not effect 1% of the total forest acreage. Locking man out will not change a thing as far as endangered species are concerned.
Larry Kellerhals

Sent from my Verizon 4G LTE Droid

Patterson, Laura@Wildlife

From: David Ingraham
Sent: Tuesday, July 25, 2017 12:24 AM
To: Wildlife Management
Subject: The possible listing of the Yellow legged frog as recommended by certain environmental groups

I must object to this listing of the yellow legged frog as endangered. Poor management of the perpetuation of the species is the problem and should be the recourse to improve numbers of the species. It has all ways been the California fish and game duty to help species survive, by devoting high intensity farming of the species at either hatcheries, or game farms. Then reintroducing the species back into the wild. I recommend using some of the game reserves to set up small eco-habitat, such as an open fenced terrarium of the perfect environment to provide advantages for the species to survive. The environmentalist are trying to destroy the right of the people to harvest the natural resources of public land to advance their communist agenda of government control over our lands. That The Fish and Wild life would be in collusion to their agenda of enemies of the rights of the people and traitors to the United States of America.
Proper management of out public lands require harvesting and fire breaks This designation would stop good land management of public lands. Creating an endangered species is the way environmentalists have created conditions of bad forest management , by creating a much more dangerous environment for all.

David J. Ingraham

Patterson, Laura@Wildlife

From: Ray & Diane
Sent: Wednesday, July 26, 2017 8:59 AM
To: Wildlife Management
Subject: Foothill Yellow Legged Frog

I presume this is a different frog than used as justification to remove fish from several of the lakes I have fished for over 65 years in the Desolation Valley Wilderness. Another lake (Island) is on the hit list for this year even tho fish are not the problem as scientifically proven. Please replant all these lakes and vacate this failed science.

Ray Melson
Sent from my iPad

Patterson, Laura@Wildlife

From: Clayton Strahan
Sent: Wednesday, July 26, 2017 9:57 AM
To: Wildlife Management
Subject: Yellow legged Frog

Dear Mrs. Patterson
I'd like to take a moment express my sincere concerns associated with the potential listing of the yellow legged frog. I have been employed as a peak ranger for more than a decade and deal daily with the many challenges associated with the rapidly increasing environmental regulations resulting from ESA listings such as the arroyo toad, the least turns vario and the SoCal steelhead. Additionally as and avid outdoorsmen, hunter and conservationists I have watched as rampant environmental regulations have reduced, limited and or all together taken away opportunity and access from the public. With that said I also recognize that ESA protections are important and am supportive of reasonable and practical regulations aimed at protecting endangered or threatened species.

However, in this case I am very concerned that this listing is nothing more than a veiled attack by the center for biological diversity to further limit recreational opportunities and to forward the environmental agenda of a small but powerful group of the states population. I challenge the commission to finally take a long hard look at the number of lawsuits filed by the center for biological diversity and to consider the fact that this organization along with 2 others has crippled the state and its residents with bogus environmental requests and lawsuits in an effort to advance their agenda. At what point will the commission take an actual hard look and start considering the balance of humans versus environmental regulation. As noted, I am supportive of reasonable regulation, but at this point in time I cannot support the listing of another species that i believe will only further limit my access to public lands because of the threats of organizations like center for biological diversity. I chsllenge the commission and other regulatory organizations to have a backbone. The ESA was intended to protect endangered species and to provide balance between and angered species and humans, and instead the pendulum has swung out of control because of the fear of litigation. I assure you the majority of tax layers would gladly spend money fight fight such aggeegious threats and claims and would rather do so then to have unreasonableand costly regulations placed on them.

I ask the commission that if they do take steps to list this species, that they do so with sound science and with a backbone. I hope that the commission takes the opportunity to make it clear to organizations like the center for biological diversity that they will not be influenced or controlled by the threat of litigation and that if listed regulations imposed will be based on balance between man and wildlife and that they will end this wildlife first attitude they have had in the past.

Sincerely
Clayton Strahan
Resident of Tehachapi, Ca

Patterson, Laura@Wildlife

From: gregbosworth
Sent: Wednesday, July 26, 2017 12:21 PM
To: Wildlife Management
Subject: foothill yellow legged frog

This frog, and the enviro Nazi's of this state are ruining rural mountain economies!!! No fish planting in the rivers and streams means no tourists, no tourists mean no money for local business. What are WE supposed to do??? Are mountain economies to go extinct themselves, over this reptile??? NO MORE ENVIRO FACISM!!!!! PEOPLE NOT FROGS!!!! Theres nothing hard about it!

Patterson, Laura@Wildlife

From: Terry Peterson
Sent: Thursday, July 27, 2017 1:26 AM
To: Wildlife Management
Subject: Foothill Yellow-legged Frog

This is by far the dumbest thing in years. The impact economically and to the general health of people that rely on those streams and waterways far outweighs the damn frog. This is stupid.

Terry Peterson

Patterson, Laura@Wildlife

From: Phillip Reyes
Sent: Thursday, July 27, 2017 5:40 AM
To: Wildlife Management
Subject: Foothill yellow legged frog

Since the ban on dredging I have only seen a decline in fish and wildlife populations AND a decrease in prosperity and population in these northern California communities. If we're really worried about the environment, how about not tunneling water to so. cal. for a start? How about leaving alone the folks who have lived off of and have taken good care of the lands up here in no. Cal? Why are "we" pretending to care about the environment and simultaneously publicly funding environmentally and economically destructive policies, programs and projects??? It's Naziism and it's affecting PEOPLE who are much more important to me than a yellow legged frog that has not been impacted at all by people carying on their business as they always have up here. Leave us alone and stop further restricting access to and use of OUR land.

Patterson, Laura@Wildlife

From: Steve Regis
Sent: Tuesday, August 1, 2017 6:59 PM
To: Wildlife Management
Subject: Yellow Legged Foothill Frog

This frog is classified near-threatened. If DFW lists it, all inland fishing in California will be destroyed. DFW barely analyzed the wild and misleading claims of the Center for Biodiversity since they were pre-disposed in favor of anything to block fishing and hunting and public use of lands.

Patterson, Laura@Wildlife

From: Welsh, Hartwell - FS
Sent: Wednesday, August 9, 2017 4:21 PM
To: Patterson, Laura@Wildlife
Subject: Rana boylii information request
Attachments: RABO initiation ms 071217akc.doc; Figures 28Mar17.pptx

Hi Laura:
Attached is a manuscript that is currently in review with the Journal of Herpetology. Please treat this information as unpublished research (until we have it accepted for publication). I hope it proves useful during your review process.
Best,
Hart

Hartwell H. Welsh, Ph.D.
Research Wildlife Biologist - Emeritus
Conservation of Biodiversity
Forest Service
Pacific Southwest Research Station

Caring for the land and serving people

Patterson, Laura@Wildlife

From:	Voegeli, Nathan@Wildlife
Sent:	Thursday, August 10, 2017 8:13 AM
To:	Patterson, Laura@Wildlife
Subject:	FW: Foothill Yellow-Legged Frog

fyi

--

Nathan Voegeli
Attorney, Office of the General Counsel
California Department of Fish and Wildlife
916-651-7653

From: THPO@gratonrancheria.com [
Sent: Wednesday, August 09, 2017 4:52 PM
To: Voegeli, Nathan@Wildlife <Nathan.Voegeli@wildlife.ca.gov>
Subject: Foothill Yellow-Legged Frog

Dear Nathan Voegeli,

The Tribe has received the project notification letter dated July 24, 2017, requesting interest and input regarding the Foothill Yellow-Legged Frog. We appreciate your effort to contact the Tribe. The Tribal Heritage Preservation Office staff has reviewed the project information. Based on the project details, the Tribe does not have any comments to provide at this time. Should the project be modified the Tribe respectfully requests project notification and the opportunity to review the project. Thank you for contacting the Tribe with this notice and the opportunity to provide comment.

Sincerely,

Buffy McQuillen
Tribal Heritage Preservation Officer (THPO)
Native American Graves Protection and Repatriation Act (NAGPRA)

Antonette Tomic
THPO Administrative Assistant
Federated Indians of Graton Rancheria

Patterson, Laura@Wildlife

From: Cedric Twight
Sent: Thursday, August 10, 2017 12:34 PM
To: Patterson, Laura@Wildlife
Subject: NOAA CA Central Valley Salmon Recovery Coordinator
Attachments: Brian Ellrott.vcf

Hello Laura,

The person that is coordinating the placement of listed salmon above dams in the Central Valley is Brian Elliott. It is my understanding that NOAA has had studies completed on several rivers above dams where they think reintroductions may be successful. Those studies may have relatively current FYLF information in them. Brian may be able to expedite you receiving that information. Good Luck.

Cedric Twight
Manager of California Regulatory Affairs
Sierra Pacific Industries

SIERRA PACIFIC INDUSTRIES

Patterson, Laura@Wildlife

From: Friends of Tesla Park
Sent: Friday, August 11, 2017 1:30 PM
To: Wildlife Management
Cc: Grefsrud, Marcia@Wildlife
Subject: Comments submitted on proposal to list Foothill Yellow-legged Frog (Rana boylii) as Threatened under CESA
Attachments: FYLF boylii letter to CDFW Aug 11 2017.pdf

Dear Ms. Patterson:

Attached are comments submitted for the status review being conducted by the California Department of Fish and Wildlife with regard to the proposal to list Foothill Yellow-legged Frog (*Rana boylii)* as Threatened under California Endangered Species Act. The signers of this letter, which include Save the Frogs, Sierra Club, Ohlone Audubon Society, Save Mount Diablo, Citizens Committee to Complete the Refuge, SPRAWLDEF, and Friends of Tesla Park support listing the Foothill Yellow-legged Frog as Threatened under CESA and designation of the Corral Hollow Creek Watershed as critical habitat.

Thank you.

Nancy Rodrigue

Friends of Tesla Park
www.TeslaPark.org

Friends of Tesla Park is an alliance dedicated to establishing Tesla Park as a non-motorized low impact historical and natural resource park and preserve.

Ohlone Audubon Society

August 11, 2017

SENT VIA US MAIL AND E-MAIL

California Department of Fish and Wildlife
Attn: Laura Patterson
1812 Ninth St.
Sacramento, CA 95811
wildlifemgt@wildlife.ca.gov.

Re: Proposal to list Foothill Yellow-legged Frog (*Rana boylii)* as Threatened under California Endangered Species Act

To Whom It May Concern:

We write in support of the California Fish and Game Commission proposal to list *Rana boylii*, the Foothill yellow-legged frog (FYLF) as a threatened species under the California Endangered Species Act (CESA). The signers of this letter are part of the Friends of Tesla Park alliance, a group of individuals and organizations working to preserve public wildlands in southeastern Alameda County, in an area commonly referred to as the Tesla park land and Corral Hollow Creek watershed.

Public and open space lands are often-times assumed to provide sanctuary for species in decline. This letter demonstrates, using the biologically rich Corral Hollow Creek watershed (Fig. 1) as a case study, that unregulated, or under-regulated, activities on publicly owned lands can have significant, adverse impacts to FYLF, and thus they require protection under CESA. These frogs have long been known to occur in Corral Hollow Creek. Museum records of abundant FYLF populations date back to 1911 and continue through time until the last few decades[1]. The persistence of FYLF has become tenuous because of the destruction and modification of their fluvial habitat due to Off Highway Vehicle (OHV) use at the Carnegie State Vehicular Recreation Area (CSVRA). Proposed expansion of CSVRA into Tesla threatens future

[1] University of California, Berkeley Museum of Vertebrate Zoology. Available url [http://arctos.database.museum/SpecimenSearch.cfm] accessed 8/5/2015.

destruction of habitat that is currently intact. In this letter, we highlight the inadequacy of existing regulatory mechanisms within the California State Parks Off-Highway Motor Vehicle Recreation (OHMVR) Division to protect FYLF. We also highlight the vulnerability of small isolated populations to stochastic events that can lead to extirpation and the implications of climate change for FYLF.

Although we focus on the Corral Hollow Creek watershed, the threat posed by OHV use to this species on publicly owned land is not limited to this one location. Similar OHV related threats occur elsewhere in the range of FYLF including Frank Raines OHV Park (Stanislaus Co. along Del Puerto Creek), Hollister Hills State Vehicular Recreation Area, and the Clear Creek area managed by the Bureau of Land Management (San Benito Co.). There are other publicly owned lands that are not specifically designated for OHV use, but where OHV use is allowed in the watersheds either currently, or historically, occupied by FYLF. Included in this category are the various US National Forests[2] (e.g. in the foothills of the Sierra Nevada). Improved regulatory mechanisms are needed to halt the decline of this species and aid its recovery in the streams and rivers flowing through public lands.

[2] See list of US National Forests with OHV use at http://ohv.parks.ca.gov/?page_id=23140

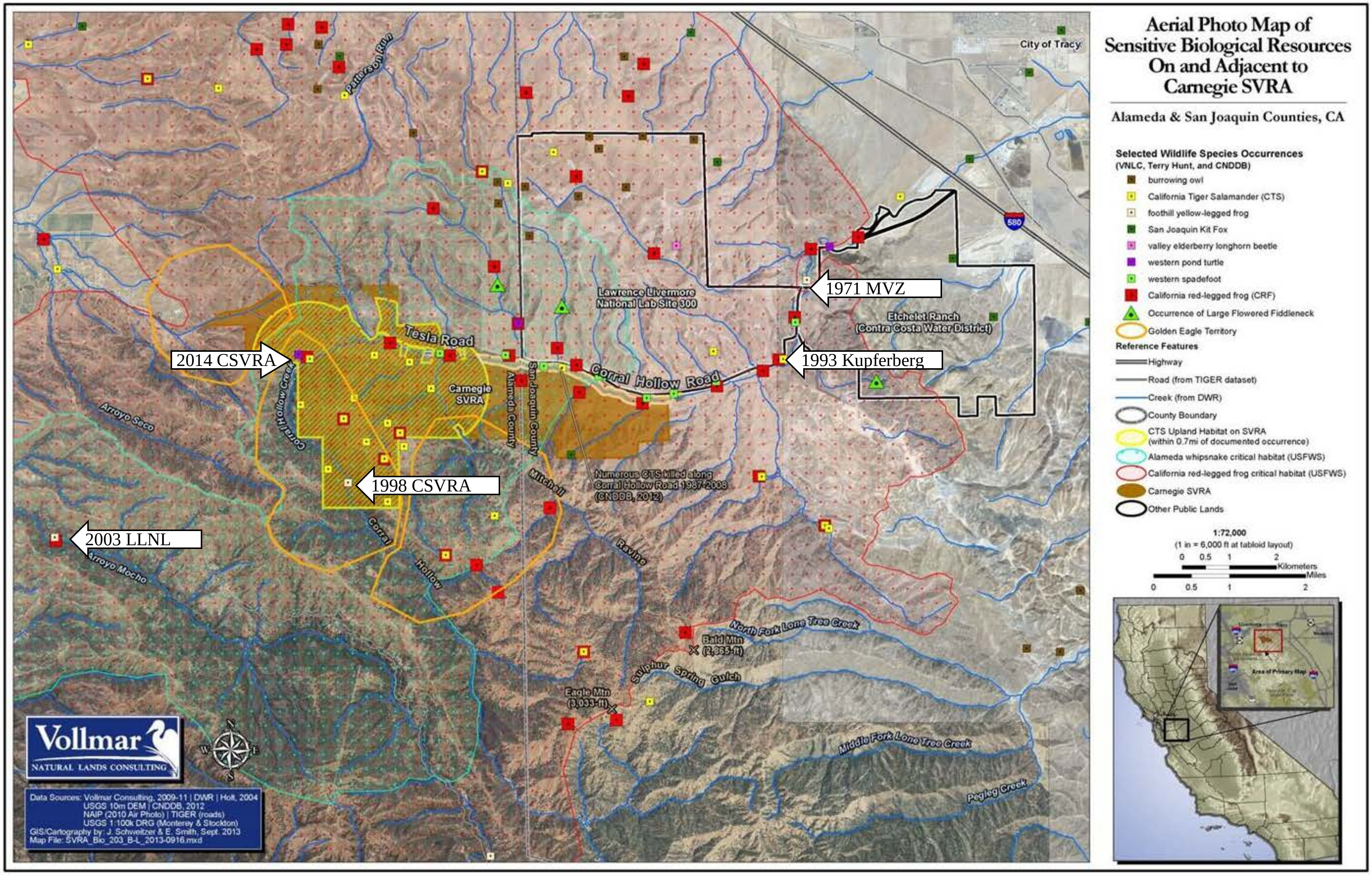


Figure 1 Locations (bold white arrows with years and observers) of Foothill yellow legged frogs observed in the Corral Hollow watershed and vicinity. Observer codes: CSVRA = Carnegie State Vehicular Recreation Area; LLNL = Lawrence Livermore National Laboratory; MVZ = Museum of Vertebrate Zoology at UC Berkeley; Kupferberg = Sarah Kupferberg personal observation/unpublished data.

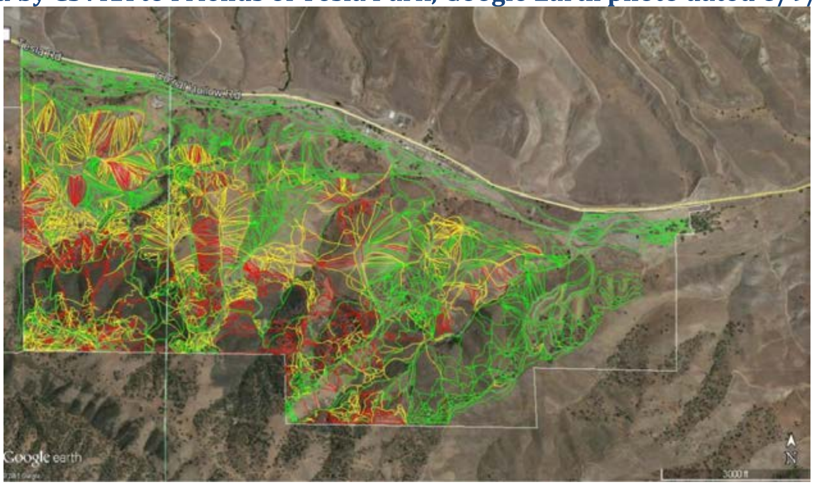
THREATS TO FOOTHILL YELLOW-LEGGED FROGS IN CORRAL HOLLOW

Multiple anthropogenic stressors are contributing to range wide declines of FYLF. Water diversion, extraction, and flow regulation pose major threats, with extirpation having occurred most frequently downstream of large dams[3], but declines have happened in free-flowing streams as well. Heavy erosion and transport of sediment to streams deteriorate conditions, can cause local extirpations[4], and subsequently isolate remaining populations.

1 SEDIMENTATION OF FLUVIAL HABITAT DUE TO OHV INDUCED EROSION

FYLF are now absent from historically occupied reaches of Corral Hollow Creek where OHV use occurs and downstream of the heavily sedimented reach. The stream reach where FYLF still occur is at risk of the same fate if OHV use expands. Twenty years ago, California State Parks purchased land upstream of the existing 1,575-acre CSVRA and is planning a 3,100-acre expansion. The present SVRA hosts at least 0.14 miles of trails per acre (Fig. 2).

Figure 2. Map view of CSVRA OHV trails and erosion status (lines shown as green, yellow, or red). GIS shapefile provided by CSVRA to Friends of Tesla Park; Google Earth photo dated 6/9/2014.



Extrapolation from this estimate of density yields a prediction of at least 447 miles of new OHV trails in the expansion area (*i.e.* 0.14 miles/acre *x* 3100 acres). This linear tally and extrapolation greatly under-represents the amount of de-vegetated area prone to erosion around all trails, not only those designated yellow and red by CSVRA, where severe soil loss occurs (Fig. 3). We believe that CESA protection of a species in the streams receiving the sediment will improve regulation of this detrimental activity.

[3] Kupferberg, S. J., W. J. Palen, A. J. Lind, S. Bobzien, A. Catenazzi, J. Drennan, and M. E. Power. 2012. Effects of flow regimes altered by dams on survival, population declines, and range-wide losses of California river-breeding frogs. Conservation Biology 26:513–524

[4] Sweet, S. S. 1983. Mechanics of a natural extinction event: *Rana boylii* in southern California." Program of the 26th Annual Meeting of the Society for the Study of Amphibians and Reptiles and 31st Annual Meeting of the Herpetologists League at the University of Utah [August 7-12]. Vol. 93

Figure 3. Map view (left) comparing CSVRA-designated trails (lines) and ratings (red, yellow, green color coding) to area of barren surfaces visible in a background aerial image (6/9/2014 Google Earth); associated hillside-gully erosion (right, location of photograph shown by arrow, 4/1/2015).

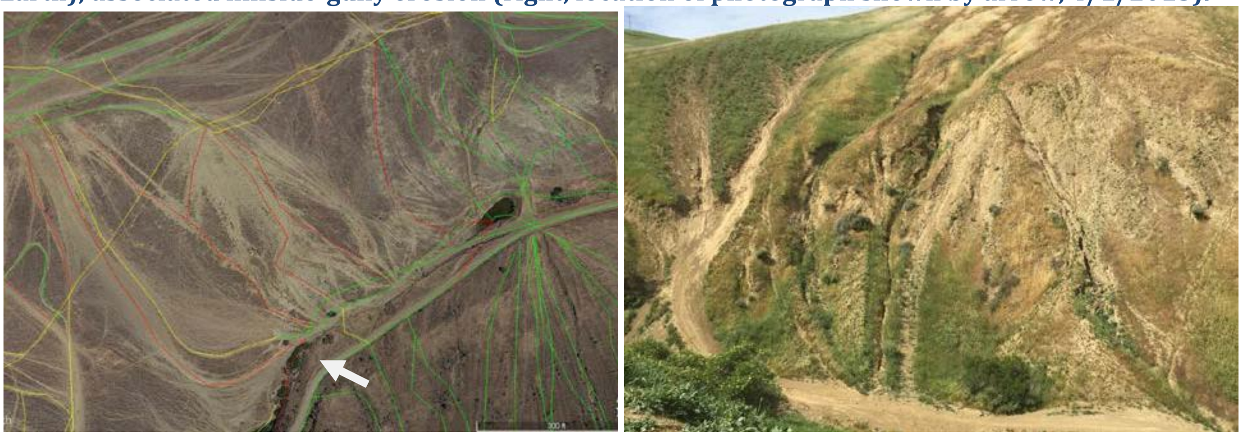


Figure 4. Pervasive hillside runoff concentrated in OHV trails where barren soils become over-saturated and erode in Carnegie SVRA (12/11/2014).

During storms, runoff bearing the fine sediment from the hillsides enters the creeks (Figs. 4, 5). The sediment buries the former stream channel, alters the channel's cross-sectional shape, and decreases the availability of suitable depth, velocity, and substrate habitats preferred by FYLF. These physical habitat features are central requirements for FYLF[5],[6]. As was noted in the Recovery Plan for California red-legged frogs regarding habitat quality in Corral Hollow Creek, "off-road vehicle activities upstream … are decreasing the suitability of the ecological reserve due to high rates of sedimentation during peak stream flows"[7].

Climate change will likely exacerbate the erosion problems. Rainfall patterns are changing from a continuous rainy season that recharges ground water and sustains baseflows to droughts punctuated by intense storms generating maximum runoff and peak streamflows. 'Atmospheric river' storms, such as the one that occurred in December 2014 (Fig. 5), now

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[5] Kupferberg, S. J. 1996. Hydrologic and geomorphic factors affecting conservation of the foothill yellow legged frog (*Rana boylii*). Ecological Applications 6:1332–1344.

[6] Yarnell, S. M., A. J. Lind, and J. F. Mount. 2010. Dynamic flow modeling of riverine amphibian habitat with application to regulated flow management. River Research and Applications 28: 177–191.

[7] US Fish and Wildlife Service. 2002. Recovery plan for the California red-legged frog (*Rana aurora draytonii*). *US Fish and Wildlife Service, Portland, OR*.

contribute 80% of Bay Area annual rainfall, compared to 30-50% in the past[8]. Atmospheric rivers are bands of moisture laden air that extend across the Pacific Ocean from the tropics. Some global climate change experts, such as USGS hydrologist Mike Dettinger, predict that "under current climate scenarios, atmospheric rivers will hit Northern California twice as often by 2100 as they do now."[8]

Figure 5. Fine sediment discharge from OHV area to Corral Hollow Creek. (12/11/2014).

2 SMALL POPULATION SIZE AND ISOLATION

FYLF have been sporadically encountered in Corral Hollow Creek in Carnegie SVRA (2014[9], 1998[10], Fig. 1). Both observations were in the proposed CSVRA expansion area, upstream of the current riding area and reaches presently receiving excessively large loads of sediment. The recent sighting was of a single juvenile, which by virtue of its size had metamorphosed the previous summer/fall. This indicates that there is likely a breeding site in the vicinity, yet no appropriately timed and geographically extensive surveys have been conducted to determine the location of the breeding site. Without such information, SVRA expansion plans cannot be modified appropriately. Indeed, specific protection of FYLF was not addressed in the 2016 final EIR approved by CSVRA[11]. As an example of inadequate surveys, TRA Environmental Consultants conducted a survey on Oct. 17, 2013, when the reach was dry. Not surprisingly, no FYLF were detected.

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[8] Rowntree, L. 2015. When it rains, it pours: historic drought and atmospheric rivers. BayNature available url [https://baynature.org/articles/when-it-rains-it-pours/] accessed 8/5/2015.

[9] DeSilva, T. and A. Meisel. 2015. 2011-2014 Habitat Monitoring Systems Report CSVRA.

[10] California Department of Parks and Recreation. 2000. Carnegie State Vehicle Recreation Area General Plan Amendment Environmental Impact Report. Livermore, CA. Prepared by Jones & Stokes. San Jose, CA.

[11] Carnegie State Vehicular Recreation Area. 2016. General Plan Revision, Environmental Impact Report, State Clearinghouse Number 2012052027. Available url accessed 8/10/2017 http://www.carnegiegeneralplan.com/document-library]

FYLF were not historically sparse in Corral Hollow Creek, but their distribution appears to have become fragmented. The 2004 CSVRA Draft Habitat Conservation Plan (p. 6-13)[12], UC Berkeley Museum of Vertebrate Zoology specimens from 1971 (MVZ:Herp:98194), and a survey conducted in 1993 by Dr. Sarah Kupferberg (unpublished data via personal communication) report large numbers of tadpoles downstream of what is now CSVRA. The present rarity of FYLF in Corral Hollow Creek places them at risk of extirpation. A population projection model developed for this species[13] indicates extirpation is extremely sensitive to population size. The likelihood of recolonization after extirpation in Corral Hollow Creek is low because dispersal usually follows watercourses[14] and there are barriers both upstream and downstream of the extant FYLF. Upstream, there is a ridge separating the presently occupied site from the nearest extant population 4 miles away in Arroyo Mocho[15] (Fig. 1). Carnegie SVRA represents the downstream barrier.

3 NEED FOR CESA PROTECTION & IMPLEMENTATION OF CONSERVATION GUIDELINES

California ESA protection of FYLF would improve the implementation of conservation guidelines. The Draft Habitat Conservation Plan from 2004 was never adopted. Presently, the Natural Resource Management Guidelines in CSVRA's General Plan and FEIR approved and certified in October 2016 are insufficient to avoid or minimize impacts on FYLF because the buffer zone along Corral Hollow Creek is too narrow. Furthermore, tributaries are not protected from OHV use and crossings are allowed. Connectivity to seeps and off-channel water bodies is not accounted for. The General Plan and EIR assertion that a 'Limited Recreation Area' (≤ 150 feet on one or the other side of Corral Hollow Creek) would protect FYLF ignores the scientific literature about movement and dispersal in this species. CSVRA also does not consistently establish the 150-foot buffer and limited recreation does not exclude OHV use entirely. It has long been known that juveniles disperse away from natal streams and have been caught up to 600 feet away from a stream channel[16]. FYLF use small tributaries and seeps[17] and move from hundreds to thousands of meters in dendritic stream networks[18]. Development of a recovery plan for FYLF would ground guidelines in science. Further CSVRA is not generally meeting the 150-foot buffer standard within the existing SVRA.

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[12] CSVRA 2004. General Plan Amendment, Draft multiple species Habitat Conservation Plan. prepared by HDR Aug. 2004. Received via Public Records Act Request by Friends of Tesla Park.

[13] Kupferberg, S. J., A. J. Lind, and W. J, Palen. 2009. Pulsed flow effects on the Foothill yellow-legged frog (*Rana boylii*): Population modeling. Final Report. California Energy Commission, PIER. Publication number 500-09-02a. 80 pp. Available url accessed 6/27/2015 [http://www.fs.fed.us/psw/publications/lind/lind(KupferbergCEC-500-2009-xxx).pdf]

[14] Bourque, R. M. 2008. Spatial ecology of an inland population of the Foothill yellow-legged frog (*Rana boylii*) in Tehama County, California. MS Thesis, California State University, Humboldt. 93 pp.

[15] California Natural Diversity Database

[16] Twitty, V., D. Grant, and O. Anderson. 1967. Amphibian orientation: An unexpected observation. Science 155: 352–353.

[17] Gonsolin T. E. 2010. Ecology of foothill yellow-legged frogs in upper Coyote Creek, Santa Clara County, CA. State University of California, San Jose. MS Thesis. 110 pp; Rombough, C. J. 2006. Wintering habitat use by juvenile foothill yellow-legged frogs (*Rana boylii*): the importance of seeps. Northwestern Naturalist 87: 159.

[18] Bourque, R. M. 2008. Spatial ecology of an inland population of the Foothill yellow-legged frog (*Rana boylii*) in Tehama County, California. MS Thesis, California State University, Humboldt.

4 CRITICAL HABITAT AND DISTINCT POPULATION SEGMENT

We believe that Corral Hollow Creek should be designated as critical habitat for FYLF given the location of the watershed within the species' geographic range and the potential for recovery in the publicly owned land if the expansion area can be designated as a preserve with no OHV use. At the latitude of the watershed, 37.6°, Lind[19] estimated that the frogs were missing from more than two thirds of historically occupied sites (Fig. 6). Analysis of mitochondrial DNA data strongly suggests that populations of FYLF at this latitude and further south in the Central California Coast Range constitute a distinct genetic lineage[20]. Samples from the nearby population in Arroyo Mocho were part of Lind et al.'s "Clade D", and we assume Corral Hollow frogs would fall in this lineage.

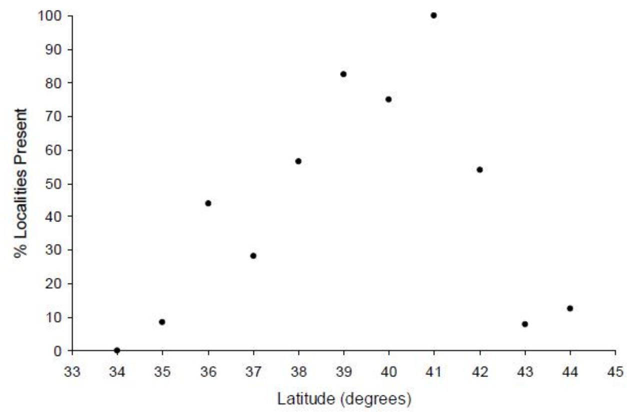

Figure 6. Percent of historic localities with FYLF present in relation to latitude (from Lind 2005).

We urge the California Fish and Game Commission to facilitate research efforts using contemporary nuclear DNA analysis techniques to verify that the Corral Hollow Creek population of FYLF is part of a Distinct Population Segment. Ryan Peek, Ph.D. candidate at UC Davis, is currently working on a project to extend the work of Lind et al.[16] using the same samples which have been maintained in a frozen archive. The most difficult aspect of the project is the logistics of collecting new tissue samples from additional populations of FYLF to fill in geographic sampling gaps. FYLF are often in remote and difficult to access locations. The listing process, status review, and assembly of a working group of scientists and public land managers could provide a unique opportunity to expedite the collection and delivery of tissue samples to Mr. Peek. An accurate assessment of Distinct Population Segments could be produced relatively quickly given a coordinated effort.

An additional geographic reason for designating the Tesla area as Critical Habitat is its location in both an east-west corridor connecting the xeric San Joaquin Desert biome and the mesic biome of the East Bay Hills and a north-south corridor in the Diablo Range (Fig. 7). If the Corral Hollow population of FYLF recovers under CESA protection, it could serve

[19] Lind, A. J. 2005. Reintroduction of a declining amphibian: determining an ecologically feasible approach for the foothill yellow-legged frog (*Rana boylii*) through analysis of decline factors, genetic structure, and habitat associations. Doctoral dissertation, University of California, Davis.

[20] Lind, A. J., P. Q. Spinks, G. M. Fellers, and H. B. Shaffer. 2011. Rangewide phylogeograpy and landscape genetics of the Western U. S. endemic frog *Rana boylii* (Ranidae): implications for the conservation of frogs and rivers. Conservation Genetics 12:269-284.

as a genetically appropriate source population for reintroduction efforts to historic localities in Contra Costa county in watersheds in the Mount Diablo area[21,22].

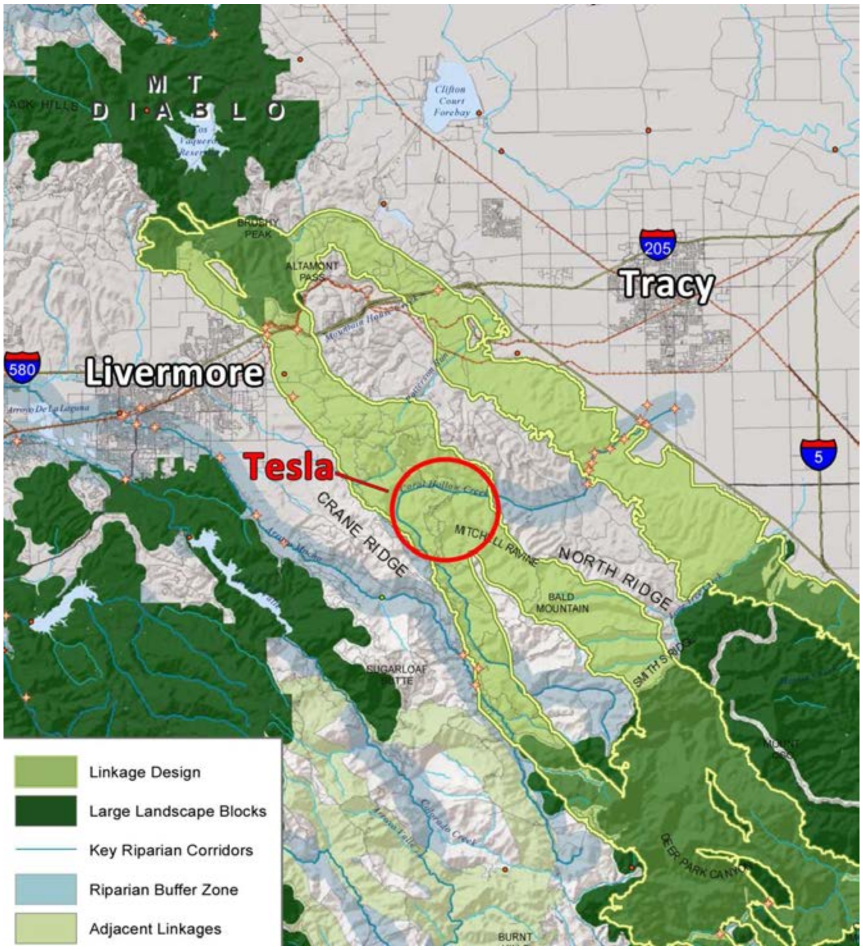

Figure 7. The red circle shows the location of the Tesla Park area (CSVRA expansion area) in a designated critical wildlife linkage corridor[23] between watersheds in Contra Costa Co. and on Mt. Diablo where FYLF are presumed extirpated to the Arroyo Mocho and Corral Hollow watersheds where the frogs are extant. Image reproduced and modified from Penrod et al. 2013.

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[21] University of California, Berkeley, Museum of Vertebrate Zoology. Specimen #60187 availabel url [http://arctos.database.museum/guid/MVZ:Herp:60187] accessed 8/11/2015.

[22] Jennings, M.R. and M.P. Hayes. 1994. Amphibian and Reptile Species of Special Concern in California. Final Report submitted to the California Department of Fish and Game, Inland Fisheries Division. Contract No. 8023. 255 pp.

[23] Penrod, K., P.E. Garding, C. Paulman, P. Beier, S. Weiss, N. Schaefer, R. Branciforte and K. Gaffney. 2013. Critical Linkages: Bay Area & Beyond. Produced by Science & Collaboration for Connected Wildlands, Fair Oaks, CA

5 CONCLUSION

Thank you for the opportunity to share our observations of a significant threat to FYLF that exists on publicly owned lands and should be taken into consideration when developing conservation strategies and making a listing determination under the California Endangered Species Act. The examples provided from CSVRA illustrate the significant threats to FYLF posed by OHV use. Because the management practices we have highlighted are OHMVR Division state-wide policies, it must be assumed that similar risks exist throughout the species range in California where OHV use occurs. If FYLF were protected by the California Endangered Species Act, management of OHV use and expansion of OHV use into sensitive areas could be more effectively regulated.

Given this case study and other information about the species, we urge California Fish and Game Commission to provide full protection to Foothill yellow-legged frog under the California Endangered Species Act including: (1) conducting a full status review of FYLF; (2) listing FYLF as threatened; and (3) designating the Corral Hollow Creek watershed as part of the Critical Habitat needed to maintain what will likely prove to be a Distinct Population Segment. The protection of FYLF habitat on the public land known as Tesla is particularly urgent given the degradation of habitat occurring downstream within the existing CSVRA.

Please contact us at Friends of Tesla Park, PO Box 2502, Livermore, CA 94551, Friendsofteslapark@gmail.com, for questions or information regarding this letter.

Sincerely yours,

Nancy Rodrigue
Friends of Tesla Park
friendsofteslapark@gmail.com
www.teslapark.org

Kerry Kriger, Ph.D.
Executive Director, SAVE THE FROGS!
kerry@savethefrogs.com
www.savethefrogs.com

Carin High
Citizens Committee to Complete the Refuge
cccrrefuge@gmail.com
www.bayrefuge.org/

Janis Turner
Sierra Club Bay Chapter, Tri-Valley Group
www.sierraclub.org/san-francisco-bay

Bill Hoppes
Ohlone Audubon Society
hoppes1@sbcglobal.net
www.ohloneaudubon.org

Jeff Miller
Executive Director, Alameda Creek Alliance
alamedacreek@hotmail.com
www.alamedacreek.org

Meredith Hendricks
Land Programs Director, Save Mount Diablo
mhendricks@savemountdiablo.org
www.savemountdiablo.org

Norman La Force
SPRAWLDEF
n.laforce@comcast.net

Patterson, Laura@Wildlife

From: Holly Dalton
Sent: Monday, August 21, 2017 9:14 PM
To: Wildlife Management
Subject: Frog status..

The bull frogs and little yellow frogs have been gone in mendocino country for years, we have no surf fish left on the Fort Bragg coastal ranges the deer populationis almost non exesstant.. it is really sad.

Patterson, Laura@Wildlife

From: Sarah Kupferberg
Sent: Tuesday, August 22, 2017 12:30 PM
To: Patterson, Laura@Wildlife
Subject: copies of reports, previous letters to USFWS, re Rana boylii and a query about electro-fishing
Attachments: Kupferberg etal 2013 final report 3.24.13.pdf; peek kupferberg catenazzi.pdf; USFWS boylii letter from Angelo Reserve.pdf; Kupferberg Lind and Palen Population Model final report.pdf

Hello Laura,
I response to the call for information regarding Rana boylii I wanted to provide you with copies of reports and letters I have written in the past that are not as easily accessed as journal articles. It has recently come to my attention that links to the various CEC reports that were previously on a UC Davis website are no longer active and that the reports are also missing from the CEC's website. I am attaching files to this e-mail, but also wanted to generally offer my services in helping you track down material if you need it. For example I have hard copies of some Master's theses on boylii (Tom Van Wagner, Earl Gonsolin) that I could loan.

On another front entirely, I wanted to pass along a question from some salmonid fish researchers working at the Angelo Reserve where I do much of my work In the course of their electrofishing to catch pit-tagged steelhead, they routinely shock Rana boylii. They wanted to know if CDFW had guidance or recommendations. Should they go through sites and try to catch and remove frogs prior to shocking for fish to avoid 'by-catch' of frogs. I did not personally witness how the frogs reacted to elector-fishing, but they said that it looked pretty dramatic, the frogs go completely rigid, but as soon as the current is turned off they very rapidly swim away and disappear. They also wanted to know if the candidacy status would affect their reporting requirements on their scientific collecting permits. I understand that you are not the one granting SCP's for fisheries, but am wondering if the team of people who cover salmonid SCP's are in the loop, so to speak.

Please don't hesitate to ask if there are any ways that I can help in the information gathering process.

-sk

Patterson, Laura@Wildlife

From: House, Matt
Sent: Wednesday, August 23, 2017 2:48 PM
To: Wildlife Management
Subject: Foothill Yellow-legged Frog
Attachments: FYLF_GDRCo_CommentLetter_8-21-2017_final.pdf

Attached please find a comment letter from Green Diamond Resource Company regarding your request for information relevant to a proposal to list the foothill yellow-legged frog.

-Matt

GREEN DIAMOND
RESOURCE COMPANY

California Timberlands Division
P.O. Box 1089
Arcata, California
95518-1089

T (707) 668-4400
F (707) 668-4402
www.greendiamond.com

August 21, 2017

California Department of Fish and Wildlife
Attn: Laura Patterson
1812 Ninth St.
Sacramento, CA 95811

RE: Information relevant to a proposal to list the Foothill Yellow-legged Frog as threatened under the California Endangered Species Act.

Dear California Department of Fish and Wildlife:

Green Diamond Resource Company, California Timberlands Division (Green Diamond) is submitting information in response to your solicitation for material relevant to a proposal to list the foothill yellow-legged frog as threatened under the California Endangered Species Act.

Historical and current range and population levels: Foothill yellow-legged frogs (FYLF) have been documented since 1993 on Green Diamond California timberlands when aquatic surveys began in earnest and have a distribution that includes lotic habitats from relatively large rivers to zero-order (Strahler 1957) streams. Efforts to document the distribution of this species have included various types of biological assessment and monitoring surveys that have been conducted along watercourses throughout Green Diamond's California ownership (currently ~ 365,000 acres). Based on the information compiled to date, relatively large rivers and streams throughout Green Diamond's ownership (e.g., Van Duzen River, Eel River, Mad River, Redwood Creek, Klamath River, and Smith River) as well as lower portions of adjoining smaller tributaries (e.g., Cañon Creek, North Fork Mad River, Roach Creek, Tectah Creek, and Terwer Creek) provide suitable breeding habitats for FYLF. We have also documented that many adjoining tributaries to these breeding habitats are often occupied by adult and juvenile frogs and we believe these habitats provide suitable resources for juvenile rearing, summer foraging, and overwintering. During all but one of these survey types, observations of FYLF were supplemental to the survey objectives. One survey effort has been conducted by Green Diamond since 2008 to monitor trends in a subpopulation of FYLF in the Mad River watershed within timberlands owned by Green Diamond. Green Diamond biologists have been conducting the FYLF egg mass surveys annually and surveys are planned to continue.

This study has consisted of annual surveys along an approximate 2.2 km reach in the lower portion of the Mad River near Blue Lake, CA (Figure 1). Preliminary results from this study are presented below (Figure 2). Since initiation, 5,556 egg masses have been documented. The annual average density of egg masses over 10 years of surveys is 258 egg masses per km. These density estimates of egg masses equate to a minimum estimate of female FYLF that deposited the eggs (Wheeler and Welsh 2008).

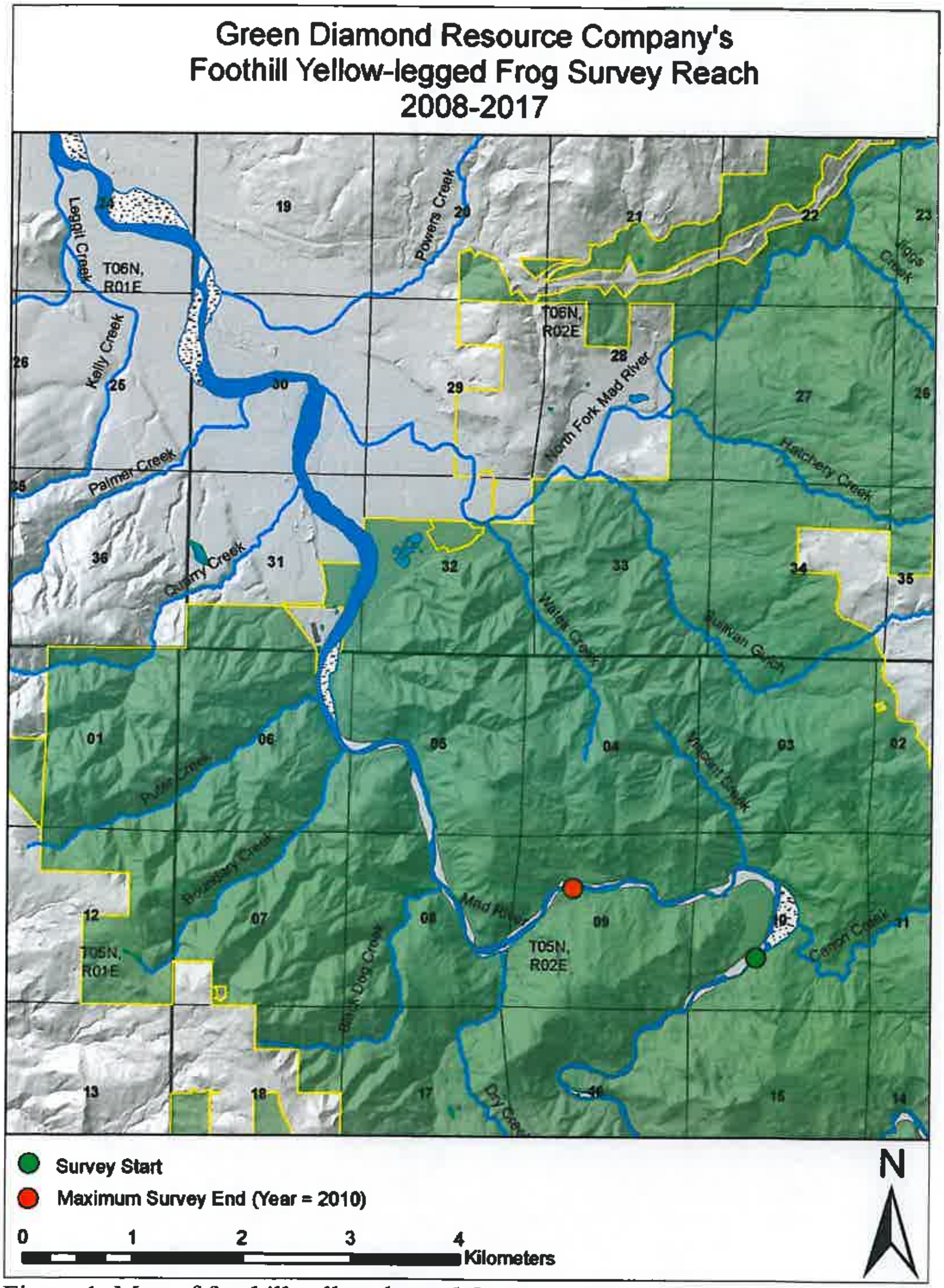


Figure 1. Map of foothill yellow-legged frog egg mass survey reach along the Mad River on Green Diamond California timberlands near Blue Lake, CA.

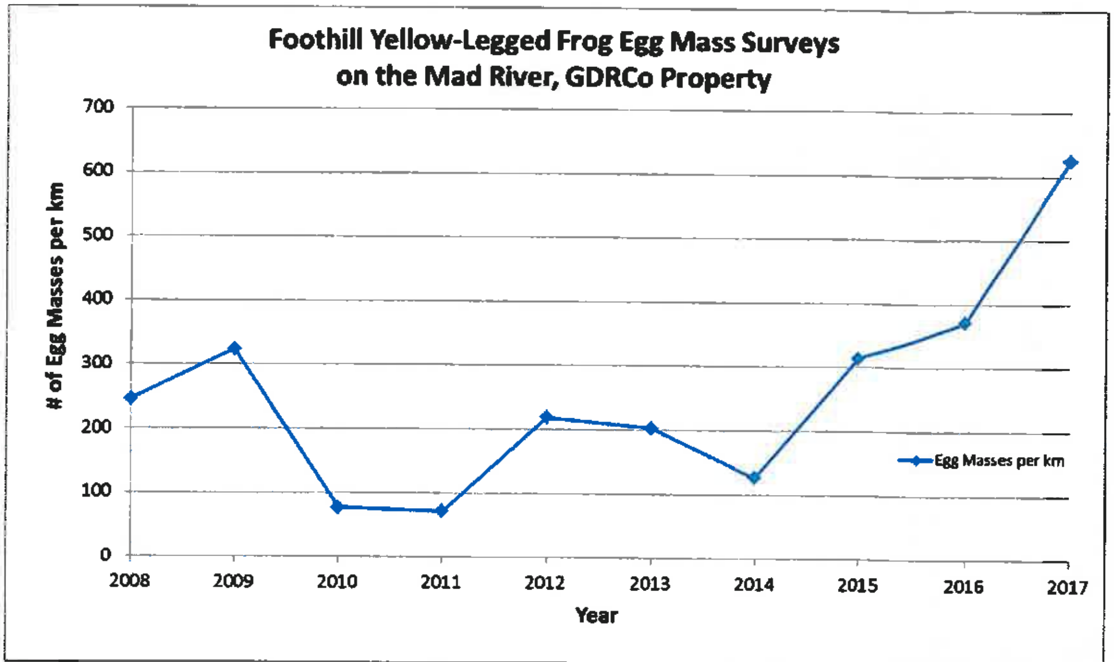


Figure 2. Foothill yellow-legged frog egg mass densities observed along the Mad River during annual survey efforts on Green Diamond California timberlands near Blue Lake, CA from 2008 to 2017.

In 2009, an egg mass density of 323.6 per km was the highest number documented for this monitoring project, which is also the highest density documented for the species (Bourque and Bettaso 2011). The 2017 survey exceeded that documented in 2009 with 625 egg masses per km. Based on the results of this annual survey, this population within the Mad River watershed appears to be very robust and has been increasing in numbers in recent years.

Past and ongoing conservation measures for species and its habitats:

In 2007, National Marine Fisheries Service and the U.S. Fish and Wildlife Service approved an Aquatic Habitat Conservation Plan and Candidate Conservation Agreement with Assurances (AHCP) for implementation on over 400,000 acres of Green Diamond's timberlands in northern California. Despite the FYLF not being among the six covered species in the AHCP, the conservation measures and riparian management measures of the plan also provide protections for FYLF habitat. Green Diamond's AHCP includes conservation measures for riparian management, slope stability, road management, and harvest-related ground disturbance that provide protections for FYLFs. The benefits of the riparian management measures are to maintain and enhance key riparian functions such as providing temperature control, nutrient inputs, channel stability, sediment control and large woody debris recruitment potential for streams. The slope stability measures are designed to minimize management-related landslides and sediment delivery to streams. The road management measures are designed to reduce sediment delivery into watercourses from road sources, including surface erosion from roads, road-related landslides and watercourse crossing failures. Additionally the road measures include water drafting provisions that limit drafting during low flows and provide screen specifications to avoid impinging animals. The harvest-related ground disturbance measures are designed to reduce sediment delivery to watercourses from harvest activities by minimizing soil disturbance, soil compaction, and with time-of-year operating restrictions. Collectively the measures were designed to avoid or address specific impacts and provide habitat improvements for the covered species but many of these measures should also serve to ensure the conservation of FYLF habitats.

While Green Diamond's AHCP is focused on cold-water adapted species and is not designed to create more open canopy situations with increased solar input and warmer water temperature conditions favorable to FYLF, the current conservation measures provide protection for FYLF habitats. The conditions along the larger watercourses that are breeding habitats are likely to remain suitable to FYLF due to the width of the watercourses and ample sunlight on these systems.

The benefits of Green Diamond's AHCP should be considered with any assessment of potential impacts of current forest practices on FYLF populations in north coastal California. In addition, the California Forest Practice Rules provide specific protection for watercourses and lakes during timber harvest activities that receive mandatory permits after a review by the lead agency, California Department of Forestry and Fire Protection. Green Diamond assesses potential FYLF habitat during the preparation and review of each timber harvest plan.

After considering the potential impacts of Green Diamond's current forest management practices on FYLF, we believe our existing management is effective at minimizing potential impacts to FYLF and their habitat. Additionally the FYLF population assessment that GDRCo conducts on a segment of stream along the Mad River suggests that this species has a large number of breeding females annually per km with pronounced increasing numbers in recent years.

Green Diamond appreciates the opportunity to provide comments and information to the California Department of Fish and Wildlife on FYLF distribution, abundance and adequacy of existing management strategies in managed timberlands of north coastal California for consideration during the status review for this species.

Sincerely,

Keith A. Hamm

Keith A. Hamm
Conservation Planning Manager
Green Diamond Resource Company

References:

Bourque, R. M. and J. B. Bettaso (2011). "Rana Boylii (Foothill Yellow-legged Frog), REPRODUCTION." Herpetological Review 42(4): 589.

Strahler, A. N. (1957). "Quantitative Analysis of Watershed Geomophology." Transactions of the American Geophysical Union 38(6): 913-920.

Wheeler, C.A. and H.H. Welsh (2008). "Mating strategy and breeding patterns of the Foothill Yellow-legged Frog (*Rana boylii*)." Herpetological Conservation and Biology 3(2): 128-142.

Patterson, Laura@Wildlife

From: Kristen Hein Strohm
Sent: Thursday, August 24, 2017 8:07 PM
To: Wildlife Management
Subject: Foothill Yellow-legged Frog

Dear Ms. Patterson,

Sierra Streams Institute has collected data on foothill yellow-legged frog (*Rana boylii*) populations, habitat conditions, and anthropogenic impacts at several sites in the Bear and Yuba watersheds in the northern Sierra Nevada during the past two breeding seasons. We have also tested frogs for chytrid fungus at several sites in both watersheds, and have collaborated with Ryan Peek of UC Davis. We respectfully request that the results of these scientific studies be considered along with the other available statewide data in CDFW's 12-month status review for this species. We also request that Tom Van Wagner's data from studies in Clear Creek and Shady Creek be considered; it is our understanding that he will be submitting those data separately.

I have attached a preliminary report of Sierra Streams Institute's Bear River Watershed visual encounter surveys performed in 2016. Our 2017 data is currently being entered, QCed, and analyzed. I will submit the 2017 report by the end of October 2017. That report will contain substantial information about habitat conditions and impacts within the Bear River Watershed. It will also delineate the locations of foothill yellow-legged frogs observed within the footprint of the proposed Centennial Reservoir on the Bear River.

Sierra Streams Institute's 2017 report will also contain more information on our chytrid test methodology, coordinates of the sites where we collected skin swabs, and more. In the mean time, here is a brief summary of the chytrid results. All skin swab samples were tested for chytrid at the Amphibian Disease Lab at the San Diego Zoo.

Chytrid results for foothill yellow-legged frogs swabbed in spring/summer 2016 under the direct supervision of Ryan Peek and performed under his permit:

- Steephollow Creek upstream of its confluence with the Bear River and downstream of Lowell Hill Rd: 8/10 positive
- Bear River near the Chicago Park Powerhouse: 3/5 positive
- Greenhorn Creek near Hwy 174: 1/3 positive (the positive one was a California toad found dead at the water's edge; all other swabs this year were from foothill yellow-legged frogs)
- Clear Creek: 0/4 positive

Chytrid results for American bullfrogs swabbed in spring/summer 2015 under Sierra Streams Institute's scientific collecting permit:

- 3/3 tested positive at the confluence of Deer & Squirrel Creeks
- 1/1 tested positive on Squirrel Creek upstream of the Deer Creek confluence
- 3/5 tested positive on Deer Creek above Lake Wildwood
- 0/4 tested positive in Lower Scotts Flat Lake

With gratitude and best wishes,

Kristen Hein Strohm
Wildlife Biologist
Sierra Streams Institute

Patterson, Laura@Wildlife

From: Kim McHenry
Sent: Friday, August 25, 2017 9:23 PM
To: Wildlife Management
Subject: Foothill yellow legged frog

Im 73 years old and raised nearly 1 million dollars for CWA over 17 yrs (colusa crab cioppino dinners) i have barged 1 million salmon smolts to the golden gate .
I have a 65 ft comm. fishing vessel which i fished for 57 years.
I also farm 600 acres of rice in maxwell ca.
I have seen the egret and blue heron population multiply hundreds of times in the last 60 yrs. If you will go to youre frog pond at early and late hrs. You will see unbelievable tadpole and frog predation from these beautiful birds, i have watched the same animals reduce the bulfrog population to nearly zero in all waterways in sac valley.
Having always being extremely observant i know see these birds n huge flocks in coastal red legged frog habitate.
If you will spend a couple of hrs w field glases observing you eill see where all the frogs have gone. Sometimes by protecting one species you have inadvertantly upset natures way. Dont blame every one and everything, the answer is right in front of you!
Michael d mchenry

Sent from my iPhone

Patterson, Laura@Wildlife

From: Michael Westphal
Sent: Monday, August 28, 2017 6:13 PM
To: Patterson, Laura@Wildlife
Subject: Rana boylii request for information

Hi Laura,

Can you please accept this as my response to your request for information regarding the foothill yellow-legged frog, Rana boylii.

Rana boylii is considered to be a "Sensitive Species" and thus a focus of management planning by BLM.

Rana boylii is present on lands managed by Bureau of Land Management within the jurisdiction of the Central Coast Field Office.

We know them to be present in numerous creeks converging on San Benito Mountain within the Clear Creek Management Area in San Benito and western Fresno Counties.

I have also observed them frequently in Laguna Creek where it is forded by Coalinga Road in San Benito County. In the past two years I have not seen them there.

I have observed them in Cantua Creek on private and public lands in west Fresno County, most recently in 2013.

This summer I observed a small population in Jacalitos Creek, west Fresno County, in the Devil's Gate gorge.

I know them to be present in Del Puerto Creek, in Sulphur Creek (a tributary of Smith Creek on Mt. Hamilton) and in Soquel Creek in the Santa Cruz Mountains.

I have also observed them breeding in Cazadero Creek in Sonoma County.

A major concern of mine is that, should Clear Creek Management Area be re-opened to off-road vehicular use, as has been proposed in the US Congress, siltation and other effects of OHV will negatively impact the species. At present CCMA is closed to OHV use.

I would be happy to supply more precise locality data, and to elaborate on potential threats to any of the above-named populations, should you so desire.

Thank you for allowing me to contribute to this matter,

Mike Westphal
Ecologist
US Bureau of Land Management

Sent from my iPad

Patterson, Laura@Wildlife

From: Anderson, David
Sent: Thursday, August 31, 2017 8:53 AM
To: Wildlife Management
Subject: Foothill Yellow-legged Frog
Attachments: Yellowlegged frog survey RedwCr 8-28-2017.pdf; 2016 REDW CR SSHD REPORT.pdf; Deformed Frog Survey Report fy 2001.pdf; Deformed Frog Survey Report fy 2002.pdf; Deformed Frog Survey Report fy 2003.pdf; Deformed Frog Survey Report fy 2004.pdf; Deformed Frog Survey Report fy 2005.pdf

Laura Patterson,

Attached are a number of reports from Redwood National Park of Yellow-legged frog monitoring or notes on Redwood Creek, Humboldt County, within the park.

The early reports (2001-2005) are deformed frog surveys on mainstem Redwood Creek between Forty-four Creek and Bond Creek confluences.

The 2016 summer steelhead report has information in the wildlife observed table that shows their occurrence when noted in the 24 mile survey Redwood Creek reach as well as numbers counted in a short reach from Lacks to Panther Creeks.

In a survey done this week (8/28/2017) of Redwood Creek from Forty-four Creek to Bond Creek, numbers of adults and young frogs are reported.

If you have any questions, please contact me at the phone number or email listed below.

David Anderson

--
David G. Anderson
Fishery Biologist
Redwood National and State Parks
121200 Highway 101 P.O. Box 7
Orick, California 95555
707 465-7771 ph

Patterson, Laura@Wildlife

From: Don Ashton
Sent: Thursday, August 31, 2017 11:01 PM
To: Wildlife Management
Subject: Foothill Yellow-legged Frog
Attachments: FYLF_AshtonComments.pdf

Laura,
I have been quite busy in the field summer (with limited internet access), but would like to add my comments for your consideration in the FYLF listing decision. I will be more available (i.e., in the office) through the fall and winter if additional information is needed.

Thank you for your careful consideration during this review process.
--
Don Ashton

California Department of Fish and Wildlife
Attn: Laura Patterson *(916) 341-6981*
1812 Ninth St.
Sacramento, CA 95811

31 August 2017

Email: wildlifemgt@wildlife.ca.gov.
subject: "Foothill Yellow-legged Frog"

I am writing to provide California Department of Fish and Wildlife (CDFW) with information relevant to the current proposal to list the Foothill Yellow-legged Frog (*Rana boylii*, FYLF) as a threatened species under the California Endangered Species Act.

As you may know already, I have studied FYLF in Northern California for many years, and much of my work has focused on impacts related to downstream effects of dams and ways to improve flow management to reduce those impacts. And while those efforts have led to incremental benefits to populations downstream of dams, population recovery has been slow. Added pressures of climate change and the largely unregulated marijuana industry have potential to ameliorate any gains made by improved flow management for this already imperiled species.

Reproductive success of FYLF in my study areas in the Trinity River, Trinity County was very low this year. High flows in the Spring delayed onset breeding. Subsequently, rapidly descending hydrograph led to desiccation of nearly all eggmasses observed. I can provide a detailed report of our observations this summer once the data has been fully processed and reviewed following the end of the field season.

This comment period occurs during an especially busy time for us actively working in the field, so I am limited on time to provide a through summary of currently available information, but urge you to consult recent publications and consult with those involved in ongoing research with this species during your review. I will be in the field though much of September and the first half October, but should be much more available later autumn and through the winter. Please don't hesitate to contact me for additional information during the review process.

Thank you,

Don Ashton

Patterson, Laura@Wildlife

From: Stanish, Anastasia@CALFIRE
Sent: Thursday, August 31, 2017 3:24 PM
To: Patterson, Laura@Wildlife
Subject: FW: approved, signed FYLF letter
Attachments: CAL FIRE Foothill Yellow-Legged Frog Letter Aug 31, 2017.pdf

Laura, please see the attached letter from CAL FIRE providing data from Soquel State Forest. Thanks for the opportunity to provide information. As my supervisor indicates below, a hard copy is in the mail.

Stacy Stanish, RPF No. 3000
Senior Environmental Scientist - Forest Practice Biologist

CA Department of Forestry and Fire Protection
6105 Airport Road
Redding, CA 96002
Phone: (916) 616-8643

From: Cafferata, Pete@CALFIRE
Sent: Thursday, August 31, 2017 3:12 PM
To: Stanish, Anastasia@CALFIRE
Cc: Coe, Drew@CALFIRE ; Huff, Eric@CALFIRE ; Hall, Dennis@CALFIRE ; Spencer, Michelle@CALFIRE
Subject: approved, signed FYLF letter

Stacy:
Here is approved, signed FYLF letter. I am assuming you want to submit this to DFW staff. Michelle will mail the hard copy.
Thanks.
Pete

Pete Cafferata
Watershed Protection Program Manager, Forester III
California Department of Forestry and Fire Protection
PO Box 944246
Sacramento, CA 94244
Office: (916) 653-9455

DEPARTMENT OF FORESTRY AND FIRE PROTECTION
P.O. Box 944246
SACRAMENTO, CA 94244-2460
(916) 653-7772
Website: www.fire.ca.gov

August 31, 2017

Laura Patterson
California Department of Fish and Wildlife
1812 9th Street
Sacramento, California 95811

Subject: Data and Comments on the Status Review of the Foothill Yellow-Legged Frog (*Rana boylii*)

Dear Ms. Patterson:

The California Fish and Game Commission voted to make Foothill Yellow-Legged Frog (*Rana boylii*) (FYLF) a "threatened" candidate species under the authority of the California Endangered Species Act at the June 2017 Commission meeting. As such, California Department of Fish and Wildlife (CDFW) is conducting a Status Review and accepting input for the species during its candidacy. The California Department of Forestry and Fire Protection (CAL FIRE) appreciates the opportunity to provide data and comments as you develop the Status Review for FYLF.

CAL FIRE is the lead agency that regulates timber harvesting activities on approximately seven million acres of private and state forestland in the State of California under the authority of the California Forest Practice Act and Rules. These rules are intended to preserve and protect fish, wildlife, and other natural and cultural resources. Additionally, CAL FIRE manages eight Demonstration State Forests, totaling about 71,000 acres. The forests are managed through the development of Timber Harvesting Plans (THP's) that address and mitigate potential impacts to listed and special status species. Typical THPs identify whether a proposed project is within the range of such a species, if habitat is present, and if individuals are known to be present. Mitigation and avoidance measures may then be proposed if any of those conditions exist.

According to the CDFW's Biogeographic Information and Observation System (BIOS), FYLF range layers indicate that all of the Demonstration State Forests are within the range of FYLF. For the most part, FYLF protocol or visual encounter surveys for the species have not been conducted on the Demonstration State Forests, with the exception of Soquel Demonstration State Forest (SDSF). SDSF is located in Santa Cruz County, where the East Branch of Soquel Creek and its tributaries flow through the Forest.

In the Center for Biological Diversity's "*Petition to List the Foothill Yellow-Legged Frog (Rana boylii) as Threatened Under the California Endangered Species Act*," population data ranging from 1992-2008 were reported for Soquel Creek from a California Natural Diversity Database (CNDDB) search in 2016, with the narrative qualification that populations were small to moderate. In order to provide current information and data, a local volunteer herpetology group in Santa Cruz has been conducting annual surveys for amphibians and reptiles, including FYLF, since 2011. As part of the conditions of their scientific collecting permit, results of the surveys are regularly submitted for inclusion in the CNDDB. For ease of access, an abbreviated version of the data with occurrence locations previously submitted to the CNDDB is attached as a table at the end of this letter. General information and photos of individuals, egg masses, and habitat from those surveys can also be found at the following location: naherp.com. The volunteer herpetologists plan to continue regular surveys and to provide their results to the CNDDB.

CAL FIRE looks forward to the findings of CDFW's Status Review and to providing further input. If you have any questions or comments regarding this letter, please contact CAL FIRE Forest Practice Biologist, Stacy Stanish at Anastasia.Stanish@fire.ca.gov or (916) 616-8643.

Sincerely,

HELGE ENG
Deputy Director
Resource Management

Foothill Yellow-Legged Frog survey results relative toSoquel Creek and Soquel Demonstration State Forest:

Date	Time	Locale	Latitude	Longitude	Datum	Method	Age	Qty
10/13/11	16:26	Soquel Creek SDSF	37.07768	-121.921	NAD27	Visual encounter	YoY	1
07/08/12	15:45	Soquel Creek downstream for Long Ridge	37.07647	-121.924	WGS84	Visual encounter	Larva	8
07/08/12	16:00	Soquel Creek 50' downstream for Long Ridge	37.07823	-121.921	WGS84	DOR	Larva	5
09/16/12	10:32	Soquel Creek below bridge	37.07402	-121.924	WGS84	Visual encounter	YoY	1
09/18/12	9:15	Soquel Creek below bridge	37.07293	-121.926	WGS84	Visual encounter	YoY	1
09/18/12	10:20	Soquel Creek below bridge	37.07215	-121.925	WGS84	Visual encounter	YoY	3
05/16/13	14:00	Soquel Creek SDSF	37.07883	-121.92	WGS84	Visual encounter	Juvenile	2
05/16/13	14:05	Soquel Creek SDSF	37.07883	-121.92	WGS84	Visual encounter	Larva	61
05/16/13	14:10	Soquel Creek SDSF	37.07925	-121.92	WGS84	Visual encounter	Juvenile	1
05/02/15	13:10	Sulfurs Spring on Sulfur Springs Rd	37.08514	-121.888	WGS84	Visual encounter	Juvenile	4
05/02/15	15:18	SDSF Soquel Creek below bridge	37.07311	-121.925	WGS84	Visual encounter	Eggs	1
05/02/15	15:19	SDSF Soquel Creek below bridge	37.07345	-121.924	WGS84	Visual encounter	Juvenile	1
05/02/15	15:44	SDSF Soquel Creek below lower bridge crossing	37.07314	-121.925	WGS84	Visual encounter	Sub-Adult	1
05/02/15	15:45	Soquel Creek downstream from lower bridge	37.07231	-121.925	WGS84	Visual encounter	Larva	1
05/02/15	16:20	Soquel Creek downstream from lower bridge	37.07289	-121.926	WGS84	Visual encounter	Eggs	2
05/02/15	16:20	Soquel Creek downstream from lower bridge	37.073	-121.925	WGS84	Visual encounter	Larva	3
05/02/15	16:25	Soquel Creek downstream from lower bridge	37.07289	-121.926	WGS84	Log flipping	Adult	2
05/02/15	16:40	Soquel Creek downstream from lower bridge	37.07244	-121.925	WGS84	Visual encounter	Eggs	2
09/11/15	14:30	Soquel Creek SDSF	37.09143	-121.885	WGS84	Visual encounter	Juvenile	1
09/27/15	10:42	Soquel Creek SDSF	37.09265	-121.888	WGS84	Visual encounter	Juvenile	2
09/27/15	10:50	Soquel Creek SDSF	37.09267	-121.887	WGS84	Visual encounter	Juvenile	1
09/27/15	11:45	Soquel Creek SDSF	37.09357	-121.892	WGS84	Visual encounter	Varying	4
09/27/15	14:25	Soquel Creek SDSF	37.08772	-121.902	WGS84	Visual encounter	Adult	1
09/27/15	14:30	Soquel Creek SDSF	37.08663	-121.903	WGS84	Visual encounter	Adult	1
09/27/15	14:35	Soquel Creek SDSF	37.0867	-121.903	WGS84	Visual encounter	Adult	1
09/27/15	15:00	Soquel Creek SDSF	37.0848	-121.907	WGS84	Visual encounter	Adult	1
09/27/15	15:04	Soquel Creek SDSF	37.08475	-121.908	WGS84	Rock flipping	Adult	1
09/27/15	15:20	Soquel Creek SDSF	37.08358	-121.91	WGS84	Rock flipping	Adult	1
09/27/15	15:23	Soquel Creek SDSF	37.08357	-121.91	WGS84	Visual encounter	Adult	2
09/27/15	15:35	Soquel Creek SDSF	37.0838	-121.912	WGS84	Visual encounter	Adult	2
10/11/15	11:05	Soquel Creek SDSF	37.08708	-121.865	WGS84	Visual encounter	Juvenile	2
10/11/15	11:20	Soquel Creek SDSF	37.08738	-121.866	WGS84	Visual encounter	Metamorp	3
10/11/15	11:30	Soquel Creek SDSF	37.0876	-121.866	WGS84	Visual encounter	Metamorp	4
10/11/15	11:50	Soquel Creek SDSF	37.08795	-121.867	WGS84	Visual encounter	Varying	6
10/11/15	13:30	Soquel Creek SDSF	37.09053	-121.877	WGS84	Visual encounter	Adult	1
10/11/15	13:50	Soquel Creek SDSF	37.09073	-121.88	WGS84	Rock flipping	Juvenile	1
05/22/16	0:35	Soquel Creek SDSF	37.0937	-121.891	WGS84	Visual encounter	Larva	4
05/22/16	11:20	Soquel Creek SDSF	37.09262	-121.886	WGS84	Visual encounter	Larva	4
05/22/16	11:30	Soquel Creek SDSF	37.09243	-121.887	WGS84	Visual encounter	Larva	1
05/22/16	11:45	Soquel Creek SDSF	37.0931	-121.888	WGS84	Visual encounter	Larva	3
05/22/16	13:00	Soquel Creek SDSF	37.09338	-121.892	WGS84	Visual encounter	Larva	1
05/22/16	13:50	Soquel Creek SDSF	37.09153	-121.895	WGS84	Visual encounter	Larva	2
05/22/16	14:10	Soquel Creek SDSF	37.09158	-121.896	WGS84	Visual encounter	Larva	4
05/22/16	14:28	Soquel Creek SDSF	37.08907	-121.899	WGS84	Visual encounter	Adult	1
05/22/16	14:55	Soquel Creek SDSF	37.08688	-121.901	WGS84	Visual encounter	Sub-Adult	1
05/22/16	15:04	Soquel Creek SDSF	37.08667	-121.902	WGS84	Visual encounter	Larva	2
05/22/16	15:15	Soquel Creek SDSF	37.08703	-121.904	WGS84	Visual encounter	Larva	3
05/22/16	15:30	Soquel Creek SDSF	37.08672	-121.905	WGS84	Visual encounter	Larva	6
07/30/16	10:35	Soquel Creek SDSF near Fern Gulch X Saw Pit trail	37.08392	-121.91	WGS84	Visual encounter	Adult	1
07/30/16	10:55	Soquel Creek SDSF near Fern Gulch X Saw Pit trail	37.08345	-121.911	WGS84	Visual encounter	Adult	1
07/30/16	11:07	Soquel Creek SDSF near Fern Gulch X Saw Pit trail	37.08383	-121.912	WGS84	Visual encounter	Adult	1
07/30/16	11:30	Soquel Creek SDSF below Saw Pit trail	37.08363	-121.913	WGS84	Visual encounter	Larva	1
07/30/16	13:15	Soquel Creek SDSF below Saw Pit trail	37.07552	-121.925	WGS84	Visual encounter	Larva	2
07/30/16	13:27	Soquel Creek SDSF near Long Ridge Rd.	37.0749	-121.926	WGS84	Visual encounter	Larva	1
07/30/16	13:45	Soquel Creek SDSF Below bridge.	37.07188	-121.925	WGS84	Visual encounter	Larva	1
07/30/16	14:00	Soquel Creek SDSF Below bridge.	37.07283	-121.926	WGS84	Visual encounter	Adult	1
07/30/16	14:15	Soquel Creek SDSF Below bridge.	37.07112	-121.926	WGS84	Visual encounter	Larva	1
07/30/16	14:15	Soquel Creek SDSF Below bridge.	37.0695	-121.926	WGS84	Visual encounter	Adult	1
10/08/16	10:30	Amaya Creek	37.08278	-121.929	WGS84	Visual encounter	Adult	1
10/08/16	11:19	SDSF Amaya Creek	37.0806	-121.928	WGS84	Visual encounter	Adult	1
10/08/16	11:52	SDSF Amaya Creek	37.0791	-121.928	WGS84	Visual encounter	Adult	1
10/08/16	12:41	SDSF Amaya Creek	37.07547	-121.926	WGS84	Visual encounter	Adult	1
10/08/16	12:45	SDSF Amaya Creek	37.07891	-121.928	WGS84	Visual encounter	Adult	1
10/08/16	13:15	SDSF Amaya Creek	37.0774	-121.928	WGS84	Visual encounter	Adult	1
07/21/17	11:00	SDSF Sue's Creek	37.08317	-121.9	WGS84	Visual encounter	Sub-Adult	1
07/21/17	12:15	SDSF Sue's Creek	37.08323	-121.899	WGS84	Visual encounter	Adult	3

Patterson, Laura@Wildlife

From: Cedric Twight
Sent: Thursday, August 31, 2017 5:09 PM
To: Patterson, Laura@Wildlife
Subject: Sierra Pacific Ind_FYLF_comment letter 8-31-2017
Attachments: SPI FYLF listing comment letter_p.pdf

Laura Patterson,
Attached find Sierra Pacific Industries initial comments regarding the potential listing of the FYLF.

Cedric Twight
Manager of California Regulatory Affairs
Sierra Pacific Industries
P.O. Box 496014
Redding, CA 96049-6014

SIERRA PACIFIC
INDUSTRIES

SIERRA PACIFIC INDUSTRIES

Forestry Division • P.O. Box 496014 • Redding, California 96049-6014
Phone (530) 378-8000 • FAX (530) 378-8139

August 31, 2017

California Department of Fish and Wildlife
Attn: Laura Patterson
1812 Ninth St.
Sacramento, CA 95811

Dear Laura Patterson,

This letter is in response to the California Fish and Wildlife is seeking information that relates to its decision to accept for consideration the petition submitted to list foothill yellow-legged frog (FYLF) as a threatened species under the California Endangered Species Act.

Sierra Pacific Industries (SPI) has not done extensive surveys of its forestlands for FYLF, however we have identified FYLF in several streams over the last 20 years. In some instances SPI resource managers have re-surveyed areas after timber harvesting activities were completed. See the table below for the name of the stream where FYLF surveys have occurred, the number of individual FYLF observed and surveyor comments.

CA 2.2 Watershed	Year of Survey	Stream Name Surveyed	Visual Encounter Surveyor	Frog count	Egg mass count.	Comments
McCormick Creek	2017	Long Canyon Creek	Luke Wagner	6	0	N/A
McCormick Creek	2017	Griswold	Kym Underwood	12	0	N/A
Lower Panther Creek	2017	Unnamed Class II	Luke Wagner	1	0	N/A
5517.530301	2017	Near St. Catherine's creek	Joe King	3	0	N/A
5517.410101	2016	Trib. of Oregon Creek	Dario Davidson	2	0	N/A
5517.540003	2014	Trib. of North fork of North fork American R.	Amanda Shufelberger	3	0	N/A
5514.550302	2014	Trib. of North fork American R.	Amanda Shufelberger	10	0	N/A

5517.410203	2017	Near Grouse Creek	Sarah Smayda	8	20	
5517.320304	2009	Trib. of South Yuba River	Amanda Shufelberger	1		2010-same results (1 adult)
5517.420202	2009	Indian Creek	Amanda Shufelberger	5		Frogs are there every time I've visited that creek 2010-2017
5516.340202	2015	Steephollow Creek	Carl Bystry	2	0	N/A
5516.340201	2015	Steephollow Creek	Amanda Shufelberger	9	0	N/A
5517.420203	2010	Near Moore's Flat Creek	Amanda Shufelberger	3	0	N/A
5517.320103	2010	Trib. of Trib. of Poorman Creek	Amanda Shufelberger	1	0	N/A
5517.340302	2016	Diamond Creek	Dakota Mork	3	0	N/A
5517.530301	2016	Trib. of Humbug Creek	Dakota Mork	1	0	N/A
5517.530301	2016	Trib. of Little Humbug Crk	Dakota Mork	1	0	N/A
					0	N/A
6534.500505	2001	McCormick Creek	Dan Applebee	1	0	N/A
6534.500505	2001	Long Canyon	Dan Applebee	1	0	N/A
5517.410203	2007	Squirrel Creek	Kevin N Roberts	2	0	N/A
1106.400508	2011	Coffee Creek.	Jessica O'Brien	2	0	N/A
1106.310201	1997	Lower Browns Creek	S. Self, J. Kelley, Boullion	30	0	N/A
5517.420202	2006	Kanaka Creek, near Red Ledge mine, old NDDB site.	Rick Carr (CDF), Kevin N Roberts and DFG	1	0	N/A
6534.500602	2001	Mill Creek	Dan Applebee	1	0	N/A
5514.540002	2010	Government Spring, trib to NF American River	Kevin N Roberts	5	0	N/A
6534.500602	2001	Mill Creek	Dan Applebee	1	0	N/A

5517.320201	2007	Trib to Missouri Canyon, South Yuba River	Daniel Boudreaux	4	0	N/A
6534.220105	2001	Rose Creek	Dan Applebee	1	0	N/A

Although the survey effort for FYLF is far from exhaustive the occurrences of FYLF on SPI forestland appear to be fairly wide spread. This brings into question how much of the available habitat along unregulated streams (streams not subjected to atypical flux flows from dam releases) has been surveyed. Should the Fish and Game Commission require that a more thorough sampling of FYLF habitat on unregulated streams be conducted prior to making a listing decision? A more thorough census of FYLF would provide a good basis for a listing decision and also that data could be used as baseline data for future population and adaptive management assessments.

In researching FYLF data sources to provide information for this letter, the Department's Natural Diversity Database (NDDB) has a large number of observations helpful for your analysis. But, some of the scientific studies conducted in California and cited in the Department's evaluation of the FYLF listing petition are not in the NDDB. Two examples, Bourque (2008) and Wheeler et al. (2015), contain occurrence location information which appear to be absent from NDDB. The locations of scientific studies used in the listing process should be added to the NDDB.

Internet websites, iNaturalist.org and www.naherp.com both contain recent reports of FYLF observations in California which would be relevant to the Department's analysis.

Federal Energy Regulatory Commission permit applications contain many references to FYLF for the various relicensing applications for dams in California. The Department should include information found in these documents.

The Department should consult with their fisheries staff biologists who presumably evaluate stream habitat in deciding when and where to plant fish for recreational fishing. Recent work to evaluate the effects of fish stocking on natural stream processes should include readily available information on frog presence or absence.

Kupferberg et al. (2008) state that the foothill yellow-legged frog's entire life cycle is associated with fluvial environments and adult frogs are almost always found close to water, from small creeks to large rivers, and often use cover within the stream as a primary refuge. Clutches of eggs are laid on in-channel substrates in spring or early summer, and larvae metamorphose in late summer or early fall prior to the onset of the next rainy season's floods. Bourque (2008) used radio telemetry to determine the distance male and female adult frogs moved away from the wetted channel. Bourque's results indicated that in the spring (April-June) and fall/winter (October-January) the maximum distance from water for both males and females was 10.7 m and 40 m respectively. Rombough (2006) indicates that overwintering habitat includes streams/rivers and in tributaries and at seeps along stream/river edges where frogs hide under woody debris and rocks along the stream margins.

Sierra Pacific Industries believes that the California Forest Practice rules provide appropriate protections for the FYLF in 14 CCR 916, 936, 956. In particular the protection measures from 936.4(b) state:

A combination of the rules, the plan, and mitigation measures shall provide protection for the following:

a. Water temperature control.

b. Streambed and flow modification by large woody debris.

c. Filtration of organic and inorganic material.

d. Upslope stability.

e. Bank and channel stabilization.

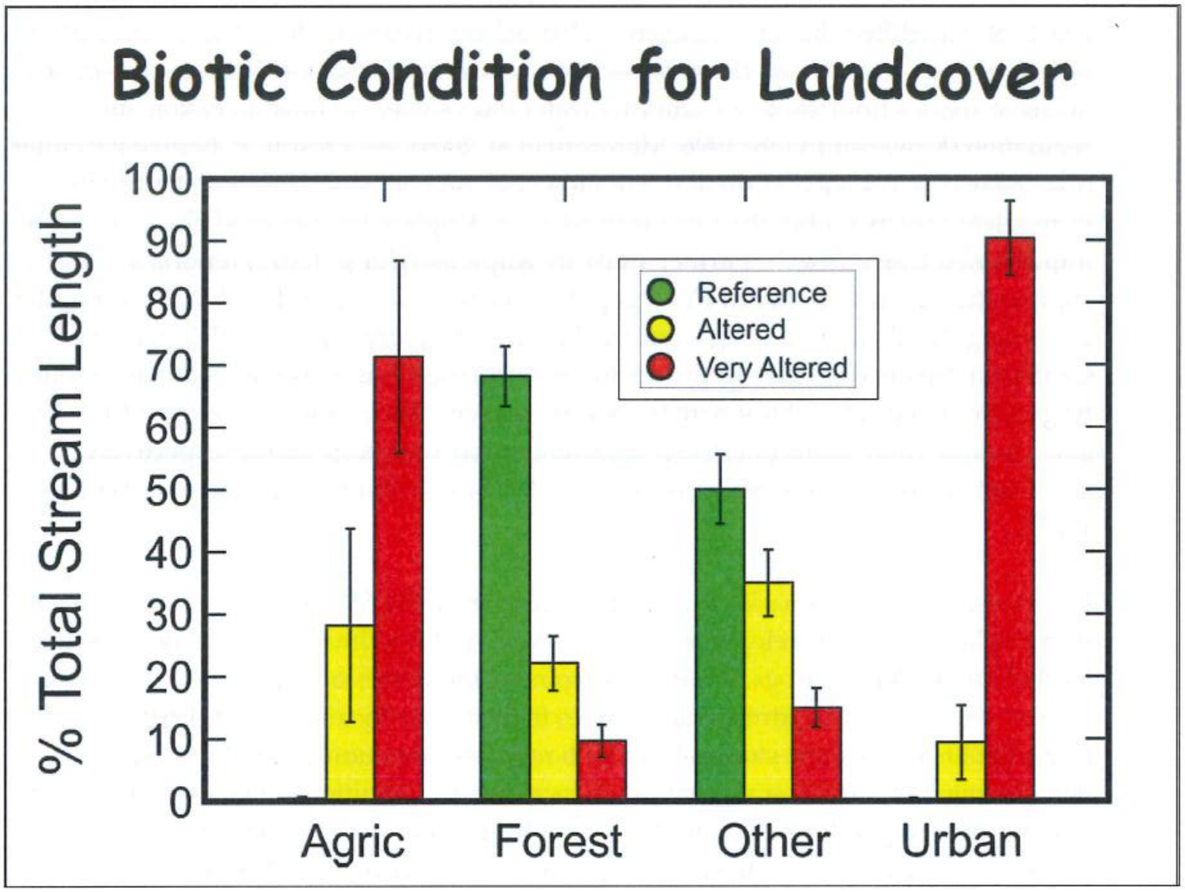
f. Spawning and rearing habitat for salmonids

g. Vegetation structure diversity for fish and wildlife habitat, possibly including but not limited to:

1. Vertical diversity
2. Migration corridor
3. Nesting, roosting, and escape
4. Food abundance
5. Microclimate modification
6. Snags
7. Surface cover"

The California Forest Practice Rules (CFPR) and their implementation through the Timber Harvest Plan (THP) process, which is a certified regulatory program under PRC 21080.5, include an interdisciplinary review team consisting of CAL FIRE (Lead Agency), Regional Water Quality Control Board, California Department of Fish and Wildlife, and California Geological Survey. The lead and responsible agencies assess each THP for its compliance with CFPR, Fish and Game codes, Porter Cologne Water Quality Control Act and CEQA. During THP implementation and following the completion of operations agencies perform regulatory compliance monitoring. In combination, the existing regulations, review, and state agency compliance monitoring means that there is a robust regulatory framework in place to protect FYLF. The Department should acknowledge the work of Registered Professional Foresters, private landowners, and departments and staff of California's Natural Resources Agency in protecting functioning watercourse habitats where FYLF occur.

Because timber harvesting is subject to a robust regulatory framework, timber harvesting should not be considered a significant threat to the ongoing survival of FYLF. The instream and near stream conditions on both industrial and non-industrial private timberlands have been assessed through the Surface Water Ambient Monitoring Program (SWAMP). The SWAMP program is implemented by CDFW scientists and the results from sampling from 2000-2007, as reported by Harrington (2012), is shown in the graphic below.



These SWAMP data provide a good indication of where the threat of habitat alteration exists. Independent of the CDFW SWAMP sampling SPI contracted with the CSU Chico Foundation to collect 35 additional benthic macroinvertebrate (BMI) samples on its timberlands between 2014 and 2016, including many areas that were salvaged logged following wildfire. These samples have all been archived in the California Environmental Data Exchange Network (CEDEN). The reason BMI samples were collected is because macroinvertebrates cannot escape pollution, macroinvertebrates have the capacity to integrate the effects of the stressors to which they are exposed, in combination and over time (US EPA website). Using the BMI samples SPI calculated the California Stream Condition Index (CSCI) scores and output using R scripts defined in Mazor et al. (2015). CSCI score categories were applied as defined in Rehn et al. (2015). Most (n = 29) of the 35 CSCI scores fell into the Likely Intact category with the remaining six samples scoring Possibly Altered. No sample fell into the Likely Altered or Very Likely Altered categories.

After review of the scientific literature on FYLF, it appears that what threatens its existence are water management activities downstream of the 1,250 dams in California under the jurisdiction of the California Department of Water Resources (CDWR 2017). Kupferberg et al. (2008) summarizes the impacts of dams succinctly. "Potential causes are many, but those related to dams and flow regulation are especially ubiquitous. Habitats have been destroyed and fragmented as river channels were converted to reservoirs. Alterations to the disturbance regime and sediment budget of dammed rivers have drastically modified the remaining river channel environment. Predation by nonnative predators such as bullfrogs (*Rana catesbeiana*), fish, and crayfish has increased as these invasive species flourished in California waterways subject to flow diversion and regulation (Moyle and Light 1996; Marchetti et al. 2004). As a result, *R. boylii* have either disappeared or declined to small population sizes relative to nearby populations in unregulated rivers within the same watershed (S. Kupferberg, personal observation, and unpublished USFS data)." Further study by Kupferberg et al. (2012) reports a comparative analysis between FYLF populations prior to 1975 and 1996-2010 on regulated and unregulated rivers in Oregon and California. Kupferberg et al. (2012) reports, "For California presence of dams in the upstream watershed was associated with an absence of frogs. Compared with sites where frogs were present, there were an average of 1.9, 1.6, and 2.1 times more dams (all sizes), large dams, and very large dams, respectively, upstream of sites where frogs were absent at the time of our study, but present before 1975."

Hayes et al. (2016) summaries the threat from dams in the following: "The most robust data implicate water development and diversions as the primary cause of declines in foothill yellow-legged frogs. Water development and diversions are a prominent risk because they result in hydrological changes that chronically affect several aspects of the frog's life history. Recent studies from both regulated and unregulated rivers have demonstrated that small-scale changes in local habitat conditions, such as water velocities, depths, and temperatures, which often result from water management activities and landscape-scale changes, can lead to (1) inconsistent environmental cues for breeding, (2) lower growth rates for tadpoles, (3) scouring or stranding of egg masses and tadpoles, (4) reductions of overall habitat suitability for breeding and rearing, (5) barriers to gene flow around reservoirs, and (6) establishment of nonnative predators in reservoirs that then spread into the rivers."

High intensity wildfire is another threat to FYLF. This is because where wildfires burn at high intensity it kills all the vegetation, removes the protective organic layer from the soil and creates a hydrophobic layer that impedes water infiltration and increases the rate of water run-off, which leads to accelerated sheet, rill and gully erosion. The soil transported downslope following an intense wildfire can cover over aquatic substrates limiting the reproductive success of FYLF (Yarnell 2015). Soil-embedded substrates reduce the amount of refugia for tadpoles to avoid high velocity water events (Hayes et al. 2016). While wildfires are unpredictable, one essential tool in limiting their intensity is to reduce vegetation density on upland slopes. The use of sustainable forestry practices to mitigate the potential impacts of high intensity wildfire on aquatic resources should be considered as a conservation measure for FYLF. It would be short-sighted to identify sustainable forestry practices as a threat under the current regulatory framework, since potential forestry related impacts are mitigated through the THP process, while at the same time these forestry activities can lead to beneficial or restorative effects for FYLF.

Bevers et al. (2004) estimated that for fuel modifications to effectively support fire suppression activities, approximately 54-88% of the landscape would need to receive fuel treatments (sustainable forestry practices). Because of the deleterious effects of high intensity fire, reducing fire severity should be a conservation goal of any listing action. With this in mind sustainable forestry practices should be viewed as a conservation action not a threat to the FYLF.

Sierra Pacific Industries believes the solution for ensuring the continued existence of FYLF in California is maintaining the hydrologic function of the streams and rivers downstream of water impoundments. We believe endangered species efforts should be focused on foothill areas generally below forested lands where marginally functioning populations of FYLF occur. We also encourage the implementation of sustainable forestry practices that reduce the risk of high intensity fires in a meaningful way.

Sincerely,

Cedric Twight

Cedric Twight
Regulatory Affairs Manager
Sierra Pacific Industries

Cc California Fish and Game Commission

References:

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Patterson, Laura@Wildlife

From: Vibeke Figueroa
Sent: Friday, September 1, 2017 9:57 AM
To: Wildlife Management
Cc: Andy Fecko; bstorey@placer.ca.gov
Subject: Letter from PCWA and Placer County Regarding the Foothill Yellow-Legged Frog
Attachments: Foothill Yellow-Legged Frog.pdf

Dear Ms. Patterson:

Please find the attached letter from PCWA and Placer County with the subject: foothill yellow-legged frog.

Thank you,

Vibeke Figueroa
Administrative Aide
Placer County Water Agency
Resource Development
TEL: (530) 823-4973

PCWA
water • energy • stewardship

Placer County
CALIFORNIA

September 1, 2017

VIA EMAIL TO: Wildlifemgt@wildlife.ca.gov

California Department of Fish and Wildlife
Attention: Laura Patterson
1812 9th Street
Sacramento, CA 95811

SUBJECT: Foothill Yellow-Legged Frog

Dear Ms. Patterson:

The Placer County Water Agency (PCWA or Agency) owns and operates the Middle Fork American River Project (MFP), a multi-purpose water supply and hydro-electric development that was constructed by the people of Placer County to secure the water rights and resources necessary to provide for economic development within the county.

The Agency, like many other hydro-electric facility owners in the Sierra, recently completed a Federal Energy Regulatory Commission process to renew our operating license for the MFP. During this eight year long process, the Agency and its business partner the County of Placer spent a considerable amount of time, money and effort to study and protect the Foothill Yellow-legged frog. While this species has seen declines across much of its endemic range, it is locally abundant in the Rubicon and Middle Fork American River watersheds.

The Agency believes that three factors weigh against the immediate listing of the Foothill Yellow-legged frog under California endangered species act protection:

1. While some local populations have been studied extensively, like those in the American River watershed, other systems have received far less attention. We believe more study is warranted in watersheds statewide before a listing is recommended.

2. Many watersheds in the state that have hydro-electric projects present are being re-managed for the benefit of frogs. Specific management measures that decrease flow fluctuations during critical breeding and tadpole development stages that will benefit

frog reproduction and survival have been ordered by state and federal agencies in FERC relicensing proceedings. Many of these measures have only recently been operationalized, and require time and monitoring to assess their effectiveness. We suggest an intensive five year monitoring period beginning in 2018 (which most FERC licensees have agreed to undertake) in order to better understand how new license conditions will benefit frog populations.

3. The recent moratorium placed on suction dredging in California's streams will likely have a positive impact on frog populations. During the intensive study and monitoring period we recommend, an assessment can be made regarding the effectiveness of these new limitations.

Overall, we believe existing and forthcoming management actions should be given time to become operational and mature before a new regulatory process is undertaken. The sum total of upcoming management actions will positively benefit the species, and may make a State listing moot.

Sincerely,

PLACER COUNTY WATER AGENCY

Einar Maisch
General Manager

PLACER COUNTY

David Boesch
County Executive Officer

Patterson, Laura@Wildlife

From: Cedric Twight
Sent: Tuesday, September 5, 2017 2:09 PM
To: Patterson, Laura@Wildlife
Subject: FW: Yellow Legged Frogs Information
Attachments: 5BCRP_Chapter_5_Cons_Stgy_FPD.pdf

Hello Laura,

I got this back from Butte County Planner Dan Breedon, I know its "late" but could be a useful trail to follow (And yes, I'm not complaining ☺). The attached document references occurrences in Butte county on pg. 5-104. The text on 5-104 also references "Appendix A" which shows the "Distribution and extent (areal or linear) of each covered species' modeled habitat located within the Plan Area (Appendix A; Table 5–4, Existing Extent Modeled Covered Species Habitat Types and Covered Plant Species Occurrences within CAZs and UPAs [see separate files])." http://www.buttehcp.com/BRCP-Documents/Formal-Public-Draft-EISEIR/index.html
The link will get you to Appendix A.

I hope this helps. Are there other Counties with HCP? Might be a treasure trove of information.
Good Luck. Cedric

From: Breedon, Dan
Sent: Tuesday, September 05, 2017 11:16 AM
To: Cedric Twight
Subject: Yellow Legged Frogs

Cedric,

Sorry I have been a bit backlogged. Got your message. I don't have any experience with this particular species. You may wish to speak with Chris Devine ad the Butte County Association of Governments. Chris is heading up the Butte Regional Conservation Plan http://www.buttehcp.com/index.html and may have some information to share.

You may want to check out the Conservation Strategy from the BRCP (attached, see page 5-104).

Dan Breedon, AICP, Principal Planner
Department of Development Services
7 County Center Drive, Oroville, CA 95965

APPENDIX E

External Peer Review Solicitation Letters

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Wildlife Branch
P.O. Box 944209
Sacramento, CA 94244-2090
www.wildlife.ca.gov

GAVIN NEWSOM, Governor
CHARLTON H. BONHAM, Director

May 21, 2019

Sarah J. Kupferberg, Ph.D.
Independent Consultant
Questa Engineering
818 Mendocino Avenue
Berkeley, CA 94707
skupferberg@gmail.com

Dear Dr. Kupferberg:

RE: FOOTHILL YELLOW-LEGGED FROG (*RANA BOYLII*)
DEPARTMENT OF FISH AND WILDLIFE, PEER REVIEW STATUS REPORT

Thank you for agreeing to serve as a scientific peer reviewer for the Department of Fish and Wildlife's (Department) Draft Status Review of the Foothill Yellow-legged Frog (*Rana boylii*). A copy of this report, dated May 21, 2019, is enclosed for your use in that review. The Department seeks your expert analysis regarding the scientific validity of the report and its assessment of the status of the Foothill Yellow-legged Frog in California. **The Department would appreciate receiving your peer review input on or before June 21, 2019**.

The Department seeks your review as part of formal proceedings pending before the California Fish and Game Commission (Commission) under the California Endangered Species Act (CESA). As you may know, the Commission, as a constitutionally established entity distinct from the Department, exercises exclusive statutory authority under CESA to add species to the state lists of endangered and threatened species (Fish & G. Code, § 2070). The Department serves in an advisory capacity during listing proceedings, charged by the Fish and Game Code to use the best scientific information available to make related recommendations to the Commission (Fish & G. Code, § 2074.6).

The Commission first received the "Petition to List the Foothill Yellow-legged Frog (*Rana boylii*) as Threatened" (Petition) on December 14, 2016 and published a formal notice of receipt on January 20, 2017 (Cal. Reg. Notice Register 2017, No. 3-Z, p. 46). On April 17, 2017, the Department provided the Commission with its "Evaluation of the Petition from the Center for Biological Diversity to List the Foothill Yellow-legged Frog (*Rana boylii*) as Threatened under the California Endangered Species Act" to assist the Commission in making a determination as to whether the petitioned action may be warranted based on the sufficiency of scientific information (Fish & G. Code, §§ 2073.5

& 2074.2; Cal. Code Regs., tit. 14, § 670.1, subds. (d) & (e).). Focusing on the information available to it relating to each of the relevant categories, the Department recommended to the Commission that the Petition be accepted.

The draft report forwarded to you today reflects the Department's effort to identify and analyze available scientific information regarding the status of Foothill Yellow-legged Frog in California. An endangered species is defined as "a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease" (Fish and G. Code, § 2062). A threatened species is defined as "a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA]" (Fish and G. Code, § 2067). At this time, the Department suggests listing the species under CESA is warranted for five of six recently described genetic clades based on the available science. The Department proposes to recommend endangered status for the South Coast, Central Coast, and Southern Sierra clades; threatened status for the Northern Sierra and Feather River clades; and "not warranted at this time" for the North Coast clade. We underscore, however, that scientific peer review plays a critical role in the Department's effort to develop and finalize its recommendations to the Commission as required by the Fish and Game Code.

Because of the importance of your effort, we ask you to focus your review on the scientific information regarding the status of Foothill Yellow-legged Frog in California. As with our own effort to date, your peer review of the science and analysis regarding each of the listing factors prescribed in CESA (Cal. Code Regs., Tit. 14, § 670.1(i)(1)(A)) (i.e., present or threatened habitat modification, overexploitation, predation, competition, disease, and other natural occurrences or human-related activities that could affect the species) are particularly important.

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Please submit your comments electronically to Laura Patterson, Senior Environmental Scientist (Specialist) with the Wildlife Branch at Laura.Patterson@wildlife.ca.gov or at the address in the letterhead above. If you have any questions, you may reach Laura Patterson by phone at (916) 341-6981.

If there is anything the Department can do to facilitate your review, please let me know. Thank you again for your contribution to the status review effort and the important input it provides during the Commission's related proceedings.

Sincerely,

Kari Lewis, Chief
Wildlife Branch
Department of Fish and Wildlife

Enclosure

ec: **Department of Fish and Wildlife**

Stafford Lehr, Deputy Director
Wildlife and Fisheries Division
Stafford.Lehr@wildlife.ca.gov

Kevin Shaffer, Chief
Fisheries Branch
Kevin.Shaffer@wildlife.ca.gov

Erin Chappell, Wildlife Branch
Nongame Program Manager
Erin.Chappell@wildlife.ca.gov

Laura Patterson, Wildlife Branch
Senior Environmental Scientist (Specialist)
Laura.Patterson@wildlife.ca.gov

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Wildlife Branch
P.O. Box 944209
Sacramento, CA 94244-2090
www.wildlife.ca.gov

GAVIN NEWSOM, Governor
CHARLTON H. BONHAM, Director

May 21, 2019

Amy J. Lind, Ph.D.
Hydroelectric Coordinator
Tahoe and Plumas National Forests
USDA Forest Service
631 Coyote St.
Nevada City, CA 95959
alind@fs.fed.us

Dear Dr. Lind:

RE: FOOTHILL YELLOW-LEGGED FROG (*RANA BOYLII*)
DEPARTMENT OF FISH AND WILDLIFE, PEER REVIEW STATUS REPORT

Thank you for agreeing to serve as a scientific peer reviewer for the Department of Fish and Wildlife's (Department) Draft Status Review of the Foothill Yellow-legged Frog (*Rana boylii*). A copy of this report, dated May 21, 2019, is enclosed for your use in that review. The Department seeks your expert analysis regarding the scientific validity of the report and its assessment of the status of the Foothill Yellow-legged Frog in California. **The Department would appreciate receiving your peer review input on or before June 21, 2019**.

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If there is anything the Department can do to facilitate your review, please let me know. Thank you again for your contribution to the status review effort and the important input it provides during the Commission's related proceedings.

Sincerely,

Kari Lewis

Kari Lewis, Chief
Wildlife Branch
Department of Fish and Wildlife

Enclosure

ec: **Department of Fish and Wildlife**

Stafford Lehr, Deputy Director
Wildlife and Fisheries Division
Stafford.Lehr@wildlife.ca.gov

Kevin Shaffer, Chief
Fisheries Branch
Kevin.Shaffer@wildlife.ca.gov

Erin Chappell, Wildlife Branch
Nongame Program Manager
Erin.Chappell@wildlife.ca.gov

Laura Patterson, Wildlife Branch
Senior Environmental Scientist (Specialist)
Laura.Patterson@wildlife.ca.gov

May 21, 2019

Jimmy A. McGuire, Ph.D.
Professor, Department of Integrative Biology
Curator of Herpetology, Museum of Vertebrate Zoology
3101 Valley Life Sciences Building
University of California
Berkeley, CA 94720
mcguirej@berkeley.edu

Dear Dr. McGuire:

RE: FOOTHILL YELLOW-LEGGED FROG (*RANA BOYLII*)
DEPARTMENT OF FISH AND WILDLIFE, PEER REVIEW STATUS REPORT

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Sincerely,

Kari Lewis

Kari Lewis, Chief
Wildlife Branch
Department of Fish and Wildlife

Enclosure

ec: **Department of Fish and Wildlife**

Stafford Lehr, Deputy Director
Wildlife and Fisheries Division
Stafford.Lehr@wildlife.ca.gov

Kevin Shaffer, Chief
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Erin Chappell, Wildlife Branch
Nongame Program Manager
Erin.Chappell@wildlife.ca.gov

Laura Patterson, Wildlife Branch
Senior Environmental Scientist (Specialist)
Laura.Patterson@wildlife.ca.gov

May 21, 2019

Ryan A. Peek, Ph.D.
Post-doctoral Researcher
Center for Watershed Sciences
One Shields Avenue
University of California
Davis, CA 95616
rapeek@ucdavis.edu

Dear Dr. Peek:

RE: FOOTHILL YELLOW-LEGGED FROG (*RANA BOYLII*)
DEPARTMENT OF FISH AND WILDLIFE, PEER REVIEW STATUS REPORT

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Sincerely,

Kari Lewis, Chief
Wildlife Branch
Department of Fish and Wildlife

Enclosure

ec: **Department of Fish and Wildlife**

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Wildlife and Fisheries Division
Stafford.Lehr@wildlife.ca.gov

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Nongame Program Manager
Erin.Chappell@wildlife.ca.gov

Laura Patterson, Wildlife Branch
Senior Environmental Scientist (Specialist)
Laura.Patterson@wildlife.ca.gov

APPENDIX F

External Peer Review Comments

Patterson, Laura@Wildlife

From: Sarah Kupferberg <skupferberg@gmail.com>
Sent: Wednesday, June 19, 2019 5:43 PM
To: Patterson, Laura@Wildlife
Subject: Re: Peer Review Request: Foothill Yellow-legged Frog Status Review
Attachments: DRAFT FYLF Status Review-2019.05.21 (kupferberg comments) (AutoRecovered).docx; review kupferberg.docx

Hello Laura,
Please find attached my comments on the Draft Status Review and a marked up version of the manuscript using track changes that includes minor edits to the text.
Thank you for giving me the opportunity to be involved in such an important process.
I am very impressed with how thorough the document is. You may not have set out to provide an exhaustive review of the scientific literature, but I think that is what you have achieved. A job well done!
The vast majority of my specific comments are suggestions, not corrections, take them or leave them.
Kind Regards,
Sarah

On Wed, May 22, 2019 at 10:22 AM Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov> wrote:

> Great, thanks! If you feel like you're running out of time, let me know, and I can help you prioritize which sections to try to get to.
>
> **From:** Sarah Kupferberg <skupferberg@gmail.com>
> **Sent:** Wednesday, May 22, 2019 10:20 AM
> **To:** Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov>
> **Cc:** Sarah Kupferberg <skupferberg@berkeley.edu>
> **Subject:** Re: Peer Review Request: Foothill Yellow-legged Frog Status Review
>
> Hello Laura-
>
> I just returned from the Eel River and received your email. The timeline of completing my review by June 21 seems quite doable.
>
> Regards,
>
> Sarah
>
> On Tue, May 21, 2019 at 1:52 PM Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov> wrote:
>
>> Good afternoon, Dr. Kupferberg,

Thanks for your patience. We had a couple of loose ends to tie up. Please see the attached letter and draft status review. If you have any questions or concerns with the timeline, please let me know.

Will you please respond to this email to confirm you received it?

Thanks again,

Laura

From: Sarah Kupferberg <skupferberg@gmail.com>
Sent: Tuesday, April 2, 2019 10:07 PM
To: Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov>
Cc: Sarah Kupferberg <skupferberg@berkeley.edu>
Subject: Re: Peer Review Request: Foothill Yellow-legged Frog Status Review

Hello Laura,

I would be happy to participate and help with the review process. I do not have a financial conflict of interest. I will be in and out of the field during that time period, doing my annual breeding surveys but will do my best to ensure rapid turn around.

Regards,

Sarah

On Tue, Apr 2, 2019, 3:25 PM Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov> wrote:

> Dear Dr. Kupferberg,
>
> The Fish and Game Commission (Commission) was petitioned to list the Foothill Yellow-legged Frog as threatened under the California Endangered Species Act (CESA) by the Center for Biological Diversity in December 2016. The California Department of Fish and Wildlife (Department) is tasked with writing a status review and providing a recommendation to the Commission on whether or not the best scientific information available supports the petitioner's position that listing is warranted. Part of the status review process is external peer review of the draft status review.

I am contacting you as a Foothill Yellow-legged Frog subject matter expert to request your participation in the peer review process. The Department expects the draft will be ready on for distribution to peer reviewers on or around May 17th. We would ask that you focus your review on the scientific information available regarding the status of Foothill Yellow-legged Frogs in California. Your peer review of the science and analysis regarding each of the listing factors prescribed in CESA (i.e., present or threatened habitat modification, overexploitation, predation, competition, disease, and other natural occurrences or human-related activities that could affect the species) is particularly valuable. We request that comments be submitted on or before one month from the date of receipt (on or around June 17th).

In addition, per the Department's Peer Review Policy (Department Bulletin 2017-03), I must ensure that you have no financial or other conflict of interest with the outcome or implications of the peer reviewed product.

Please respond to whether you are willing and able to participate in this important part of the listing determination process by Thursday April 11th.

Thank you for your consideration,

Laura

General Comments:

The draft STATUS REVIEW OF THE FOOTHILL YELLOW-LEGGED FROG (*Rana boylii*) IN CALIFORNIA is a scientifically sound and well-written document that very clearly summarizes the natural history of the species and outlines the current and future threats to its persistence throughout the state. The organization and progression of information and ideas are logical and straightforward in presentation. Complex concepts in ecology and population genetics are defined, and the needed background information on environmental change anticipated during an uncertain climate future is well summarized. The document accurately synthesizes knowledge from the scientific literature, reports, conference presentations, with observations from experienced field biologists and regulators who have been working with *Rana boylii* for many years. I have no criticisms with respect to presentation or interpretation of research and scientific information in the document. I have made minor suggestions with respect to wording and noted a few typographical errors in the body of the text. Overall, I find the background information sections titled BIOLOGY AND ECOLOGY, STATUS AND TRENDS IN CALIFORNIA, and FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE, to be comprehensive and insightful. The section covering the threats, SUMMARY OF LISTING FACTORS, is consistent with my knowledge of the species garnered over the past 25 years of field work and the scientific literature. My own research is correctly and accurately represented.

While environmental policy is not my academic area of expertise, I have observed firsthand the effects of water management and dam operations on *Rana boylii*, so am providing some opinions. These are offered as suggestions, not as needed changes. I think that the section entitled "EXISTING MANAGEMENT" could include more information about the shortcomings of the existing laws that contribute to the need for greater protection of *Rana boylii* under the California Endangered Species Act, CESA. One example is when a utility no longer wants to operate a dam and the dam becomes an 'orphaned dam' under FERC. Given the declining profitability of hydropower projects (especially for older dams/reservoirs) and the bankruptcy of PG&E, this may be a growing issue that dams may be operated on a somewhat *ad hoc* basis (i.e. not relicensed). During the limbo period while funds are raised for dam removal or a transfer to a different utility occurs, the needed studies to determine effects of operations on frogs (or other wildlife) don't happen to inform any kind of adaptive management. I am not sure what laws govern the transfers to Dam Removal entities, such as happened with the multiple dams on the Klamath River that are now slated for removal. For example dam operations may proceed in ways known to be harmful to *Rana boylii*, such as pulsed flows after egg-laying has commenced, as is currently the case of Scott Dam on the Eel River now that the Potter Valley Project is an 'orphan'.

With respect to the section titled LISTING RECOMMENDATION, I find that parsing designation by geographic region / clade is justified by the data presented. Because there are marked differences in the number of known populations, the range of populations' sizes from sparse to robust, and the level of genetic differentiation across the state, I concur with the statement that listing "by genetic clade is the prudent approach due to the disparate degrees of imperilment". I agree with the designation of 'endangered' for the West/Central Coast, the South/Southwest Coast, and the Southern Sierra clade because there are several risk factors at play, so few known populations in these regions, the remaining populations are small, and they are genetically distinct. I also agree with a special designation for the Feather, given the uniqueness of this clade and the extensive fragmentation due to the development of hydropower projects in the area.

In comparison, the abundance of large populations in the extended geographic area of the North Coast indicates that this clade is not at immediate risk of extirpation. Consequently, the decision to maintain the present designation of Species of Special Concern is reasonable. This strategy does have a drawback at the perimeter of such a large geographic region, where populations are sparser and disconnected. The option for a greater level of protection is lost. I suppose this trade-off is unavoidable, but I am concerned about the fate of populations in peripheral places like streams on Mt. Tamalpais in Marin County and the McCloud River in Shasta / Siskyou counties. My hope is that the efforts being made in Marin County to protect the populations there will continue without an elevation of the listing designation. The docent program and habitat restoration (e.g. canopy thinning) undertaken by the Marin Municipal Water District are excellent examples of stewardship.

Unfortunately, some utilities are less transparent and responsible than others. A book could be written about the ways in which the San Francisco Public Utilities Commission operates its facilities in the Alameda Creek watershed without making modifications or changes to protect the frogs and exploiting weaknesses in the regulatory framework. Over $40 million dollars were spent to build the fish passage structure mentioned on p. 68, while funds have yet to be allocated to improve habitat or conditions for frogs as was called for in the EIR for the Calaveras Dam replacement project. Furthermore, studies conducted on frogs that would have been useful in the preparation of this Status Review and that predicted negative impacts were never disseminated or made public, only retrievable through Public Records Act requests. The fish passage structure was built upstream of a natural barrier to fish passage, the steep bedrock canyon reach of Alameda Creek known as Little Yosemite. In order for steelhead to reach the large concrete structure, the frog breeding sites in Little Yosemite would have to be destroyed by construction of weirs and altering the water surface elevations of pools. SFPUC tried to exploit loopholes in the CEQA process by making a negative declaration of impact for the Little Yosemite project.

Another chapter in such a book would cover how the protected status / and unrealistic recovery plan for one species can endanger another. I am not sure how it would be incorporated into this document (and perhaps it is more appropriate during the public comment period), but an important question is how will biological conflicts between anadromous fish and frogs and jurisdictional conflicts between agencies (e.g. NMFS and CDFW) be resolved when salmonids are not the only endangered species in a river. Because *Rana boylii* occupy whole dendritic networks of streams, and their life cycle is so entwined with the hydrologic an geomorphic processes of fluvial habitats, an added benefit of protecting them is that there will likely be more thoughtful consideration made when multiple riverine species require accommodation in the same reach. I believe that protection of *Rana boylii* recommended in this Status Review will eventually lead to a more holistic management philosophy for California rivers and streams in the future.

Specific comments:

1. p. vi. The illustrations of Kevin Wiseman's pen and ink drawing and Isaac Chellman's photograph are beautiful – nice choices. I am curious where the frog is from, I have never seen one so overall golden in color. Maybe include the general location when giving credit for the photo?

2. **p. 5** This is trivial, but maybe worth mentioning that for a period of time species name was spelled *boylei*?

3. p. 10 Figure 4. For this figure's legend I think there are a couple of pieces of information that need adding. First, please specify what the numbers are next to each symbol. Is it numbers of pairs of individuals at the river distance on the x axis within the same river? Also I am assuming that these are all data from various rivers within the American River drainage. If not please include info from Ryan's thesis that would specify.

4. Table of predators. If you would like to add another pers comm. observation I have seen otters (a mom and a couple of her young) eating tadpoles on the Angelo Reserve where the tadpoles were concentrated in a side pool.

5. Figures 8, 9. There are very few blue dots (2010-present) for San Benito County, and several extirpated populations (black squares). So, out of curiosity I looked on i-naturalist and there were several. Problem is that the platform obscures the location / coordinates, so it is hard to know how the recent sightings jive with the ones in this map. Do you think that there is a way to reach out to the amateur naturalists to determine where the extant populations are in the region sparsely occupied by the West/Central Coast clade?

6. p. 26. Moraga Creek observation. This record came under scrutiny / was questioned when I was conducting surveys for East Bay Regional Park District not too many miles from Moraga Creek for a stream daylighting project they are planning for Alder and Leatherwood Cks, tributaries to San Leandro Creek. Marcia Grefsrud was going to reach out to the person (Jeff Drier) who made the sighting to see if he had photos. Not sure what she found out.

7. p. 26 Coyote Creek news. In spring 2019 I conducted breeding surveys in Coyote Creek in Henry Coe State Park covering a 3 km reach (including the pools where I found dead frogs fall of 2018). Over two visits I counted 80 clutches (ca. 26/km), but there were some already hatched tadpoles on the first visit and it was difficult to attribute how many clutches worth they were, so this count is an underestimate.

My search area was upstream of the reaches covered by Earl Gonsolin in 2004 and 2005, so comparisons are not exact. I checked Table 1 of his Master's thesis and the densities he recorded were

Lower Reach 2004=17.2, 2005=24.8

Upper Reach 2004= 12.6, 2005=17.9

So, in spite of the die-off I observed last fall, the reproductive output in 2019 doesn't necessarily indicate a drastic difference to the density of breeding adults relative to 15 years ago. However, the loss of juvenile frogs may become apparent in the future when that cohort would have reached breeding age.

8. p. 32. Surveys around / near Yosemite. SFPUC has surveyed the Tuolumne River, near Early Intake, which is not too many river miles downstream of the border with Yosemite National Park (in Stanislaus Natl forest). I received an email dated 6/26/18 from Alan Striegle reporting one clutch.

9. p. 54. Road effects. The pattern of fords / vehicle stream crossings being at breeding sites is something I have seen in many locations including in Mendocino National Forest on the Rice Fork Eel. I think this is also the case with trails – I think there is a popular mountain bike trail on MMWD land that crosses a stream at a breeding site.

10. p. 57. Channel modifications associated with temporary swimming holes. In public places, parks, etc. I see this all the time in the parts of Alameda Creek open to the public within the park. People are constantly building little dams across the channel with whatever cobbles and small boulders are available to create better swimming spots.

11. p. 59 paragraph starting with 'Rapidly receding…' I think this paragraph needs a more general topic sentence, because it covers other effects of drought beyond stranding. Maybe a sentence stating that the effects of droughts, and a 'whiplash' climate which vacillates between extremes of droughts and floods, can create a complex mix of positive and negative effects on FYLF. At Coyote Creek I wonder if part of the Bd outbreak dynamics were driven by the high densities associated with stream drying, which would be consistent with the effects of density seen in the Alameda Ck Bd outbreak.

12. p. 59. In reference to the recent drought, you may want to cite Bogan et al 2019 regarding the abundance of FYLF in remnant pools at Coyote Ck.
M. T. Bogan, R. A. Leidy, L. Neuhaus, C. J. Hernandez, S. M. Carlson. 2019. Biodiversity value of remnant pools in an intermittent stream during the great California drought. Aquatic Conservation https://doi.org/10.1002/aqc.3109

13. p. 60 Although salvage logging is discussed further on, it might be worth mentioning in this paragraph when bringing up the topic of erosion post-fire.

14. p. 62. I suggest adding a summary paragraph before moving on to climate change to pull together the implications of all the sources of mortality reviewed in the previous sections and segue to the next section in which the modeled increase in droughts is presented. When considered cumulatively, the sources of mortality that could lead to local extirpations are problematic because the process of re-colonization is short circuited when populations are un-naturally isolated and distant from one another. In many cases the drier and less predictable future, there will likely be no, or only very small source populations that could produce dispersers to found new populations after an extirpation. The management implication of the human modified landscape is that recolonization is going to depend on assisted migration. Generally, there is evidence to support the idea that FYLF are disturbance adapted, having evolved through many millennia of drought and floods and fires, and likely part of their success as a species has been the ability to have rapid population increases when new populations are founded. I think that capacity bodes well for the development of a recovery plan.

15. p. 64, paragraph 3. It might be worth mentioning here the role that local geology / lithology can play in either buffering or accentuating the impact of hydrologic change on FYLF. In basins with a large degree of springs and volcanic rock (like in the Pit River drainage) base flows remain higher than one might expect. Also in places with a lot of faulting, there can be springs that maintain some presence of above ground water. In other places, increased winter flooding / precipitation may not translate into any increase in summer base flows because there is simply limited sub-surface storage. I think this perspective about the importance of rock types may be really helpful in making decisions about recovery planning, and choosing which watersheds might have high likelihood of successful re-introduction or augmentation.

Hahm, W. J., Dralle, D. N., Rempe, D. M., Bryk, A. B., Thompson, S. E., Dawson, T. E., & Dietrich, W. E. (2019). Low subsurface water storage capacity relative to annual rainfall decouples Mediterranean plant productivity and water use from rainfall variability. *Geophysical Research Letters*.

16. p. 65 paragraph 5. I think the point about fragmentation is super important and salient – is there a way to give this idea more prominence? Perhaps as a conclusion to the climate change section? I am afraid it gets buried here in the middle of the section. I think that fragmentation, in addition to thwarting a pole ward range-shift response, will limit any upslope migration within a watershed. For many larger rivers in the Sierra moving to a higher elevation is not an option, the path is blocked by dams and reservoirs.

17. p. 69, bottom. It is tricky to include all State Park lands in the umbrella of land being protected because it includes the Off Highway Vehicular Recreation Areas, which are not truly protected with respect to conserving wildlife. Also the heavy recreation allowed in other state parks can also be an issue, I am thinking about 'Reggae on the River' and other such festivals in which there is very heavy use of river side habitats.

18. p. 70 The statement that **"**a property's management does not necessarily benefit Foothill Yellow-legged Frogs" requires some examples of the types of management being referred to. A general reader might not read between the lines here.

19. p. 73 Second to last paragraph about compliance requirements of Lake and Streambed Alteration Agreements. In my experience working in Alameda Creek, it seems like there are few repercussions when an entity either violates their LSA or lets their LSA expire, yet continues to work in the stream, or affect the stream. Perhaps it is not appropriate here to delve into the problems of lack of 'teeth' for enforcing agreements, but this is one of the shortcomings of existing protections that is relevant to the need for protection under CESA.

20. p. 75 Hetch Hetchy**.** Not sure it is worth mentioning under this section on laws and the Upper Tuolumne River, but SFPUC / Modesto Irrigation District operate outside of FERC scrutiny because of the Raker Act

https://www.nps.gov/yose/blogs/remember-hetch-hetchy-the-raker-act-and-the-evolution-of-the-national-park-idea.htm

21. **p. 75.** For the Chili Bar reference I suggest naming the river reaches, some readers many not know this refers to the reach of the South Fork American River that is a popular white water boating reach with pulsed flows. I think that it is worth noting the fate of the frogs at these sites. I may not be totally up to date about the status of the populations at that at these locations, but I believe they were or have become sparse / teetering on extirpation. One could infer that despite the incorporation of best management practices into the new licenses, the effects of small population size, which are outlined so clearly on p. 69, could not be overcome through BMP's alone.

22. **p. 84**. conservation funds. Would the state listing influence IUCN red list status? I know that there are certain conservation funding opportunities tied to IUCN status. It also might be worth stating here that listing status might improve the situation with respect to interactions with National Marine Fisheries Service, which acts with a singular mission to restore anadromous salmonids in California rivers, a goal which can at times be in conflict with conservation of other native taxa.

23. **p. 87, paragraph 2.** In addition to (or maybe as a component of) habitat suitability assessment, I wonder if it would be appropriate to use surrogates for FYLF. For example could Bd and pesticide residues be assessed in treefrogs or other local amphibians? Or to assess whether hydroperiod might be adequate, surveys to determine newts' ability to successfully reach metamorphosis at the site could serve as a proxy.

24. **p. 87 bottom** – metapopulation dynamics. I think that an element of the research needed on this topic should be to identify upstream and downstream boundaries of populations, to document the conditions where densities dwindle at the periphery of a distribution. I think the difference between marginal and completely unsuitable habitat requires better distinction.

25. **p. 88** off-stream water storage. As long as these water bodies are managed so they don't create habitat for bullfrogs and non-native fish, they are a good idea.

26. p. 89 barrier removal. This is a complicated recovery action that can have unintended consequences. In some cases though, rocks / hydraulic jumps that make a barrier to fish passage may actually create habitat for FYLF, or prevent the upstream migration of non natives like crayfish. Especially in step pool morphology channels, frogs may utilize the sites that are not passable by fish. Removing the barriers could allow non natives to move upstream (Kerby, J.L., Riley, S.P., Kats, L.B. and Wilson, P., 2005. Barriers and flow as limiting factors in the spread of an invasive crayfish (*Procambarus clarkii*) in southern California streams. *Biological Conservation*, *126*(3), pp.402-409.)

27. **p. 89, enforcement**. What about utilities or governmental or state agencies that are causing harm -- How does law enforcement apply to these larger entities when they violate a law or an agreement? For example SFPUC commissioned studies to be done to be incorporated into an HCP, but then did not release the reports that documented the negative impacts to *Rana boylii* and suspended the HCP process. They received their permits and rebuilt the Calaveras Dam, but did not comply or fulfill their obligations under existing environmental law. On p. 76 where HCP's and Natural Community Conservation Plans are discussed, I find that the authorized take does not always lead to an improvement or compensation elsewhere. Who are the HCP police?

STATE OF CALIFORNIA
NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION

A STATUS REVIEW OF THE **FOOTHILL YELLOW-LEGGED FROG** (*Rana boylii*) IN CALIFORNIA

CHARLTON H. BONHAM, DIRECTOR
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

External Peer Review Draft

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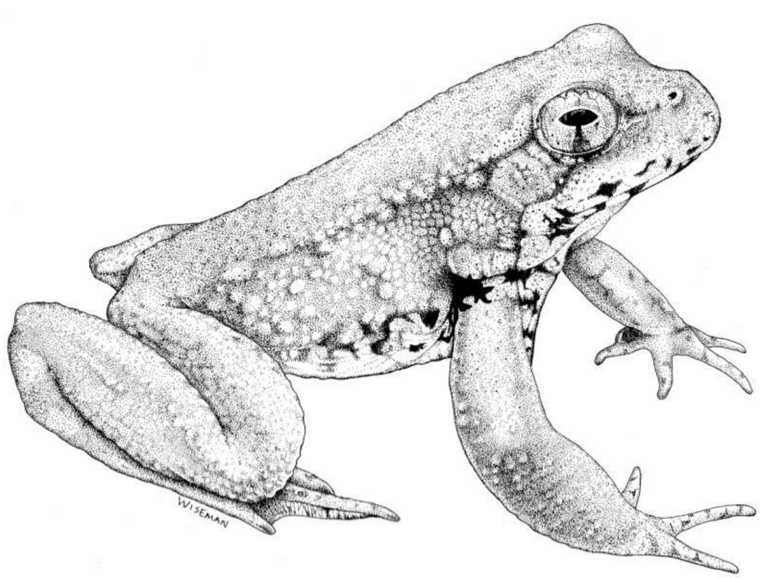

ACKNOWLEDGMENTS

Laura Patterson prepared this report. Stephanie Hogan, Madeleine Wieland, and Margaret Mantor assisted with portions of the report, including the sections on Status and Trends in California and Existing Management. Kristi Cripe provided GIS analysis and figures. Review of a draft document was provided by the following California Department of Fish and Wildlife (Department) staff: Ryan Bourque, Marcia Grefsrud, and Mike van Hattem.

The Department is extremely grateful for the valuable comments provided on this report by the following peer reviewers: Dr. Sarah Kupferberg, Dr. Amy Lind, Dr. Jimmy McGuire, and Dr. Ryan Peek. The conclusions in this report are those of the Department and do not necessarily reflect those of the reviewers.

Cover photograph by Isaac Chellman, used with permission.

Illustration by Kevin Wiseman, used with permission.

EXECUTIVE SUMMARY

[To be completed after external peer review]

REGULATORY SETTING

Petition Evaluation Process

A petition to list the Foothill Yellow-legged Frog (*Rana boylii*) as threatened under the California Endangered Species Act (CESA) was submitted to the Fish and Game Commission (Commission) on December 14, 2016 by the Center for Biological Diversity. Commission staff transmitted the petition to the Department of Fish and Wildlife (Department) pursuant to Fish and Game Code section 2073 on December 22, 2016 and published a formal notice of receipt of the petition on January 20, 2017 (Cal. Reg. Notice Register 2017, No. 3-Z, p. 46). A petition to list or delist a species under CESA must include "information regarding the population trend, range, distribution, abundance, and life history of a species, the factors affecting the ability of the population to survive and reproduce, the degree and immediacy of the threat, the impact of existing management efforts, suggestions for future management, and the availability and sources of information. The petition shall also include information regarding the kind of habitat necessary for species survival, a detailed distribution map, and any other factors that the petitioner deems relevant" (Fish & G. Code, § 2072.3).

On April 17, 2017, the Department provided the Commission with its evaluation of the petition, "Evaluation of the Petition from the Center For Biological Diversity to List the Foothill Yellow-legged Frog (*Rana boylii*) as Threatened under the California Endangered Species Act," to assist the Commission in making a determination as to whether the petitioned action may be warranted based on the sufficiency of scientific information (Fish & G. Code, §§ 2073.5 & 2074.2; Cal. Code Regs., tit. 14, § 670.1, subds. (d) & (e)). Focusing on the information available to the Department relating to each of the relevant categories, the Department recommended to the Commission that the petition be accepted.

At its scheduled public meeting on June 21, 2017, in Smith River, California, the Commission considered the petition, the Department's petition evaluation and recommendation, and comments received. The Commission found that sufficient information existed to indicate the petitioned action may be warranted and accepted the petition for consideration. Upon publication of the Commission's notice of its findings, the Foothill Yellow-legged Frog was designated a candidate species on July 7, 2017 (Cal. Reg. Notice Register 2017, No. 27-Z, p. 986).

Status Review Overview

The Commission's action designating the Foothill Yellow-legged Frog as a candidate species triggered the Department's process for conducting a status review to inform the Commission's decision on whether listing the species is warranted. At its scheduled public meeting on June 21, 2018, in Sacramento, California, the Commission granted the Department a six-month extension to complete the status review and facilitate external peer review.

This status review report is not intended to be an exhaustive review of all published scientific literature relevant to the Foothill Yellow-legged Frog; rather, it is intended to summarize the key points from the best scientific information available relevant to the status of the species. This final report, based upon the best scientific information available to the Department, is informed by independent peer review of a draft report by scientists with expertise relevant to the Foothill Yellow-legged Frog. This review is intended to provide the Commission with the most current information on the Foothill Yellow-legged Frog and to serve as the basis for the Department's recommendation to the Commission on whether the petitioned action is warranted. The status review report also identifies habitat that may be essential to continued existence of the species and provides management recommendations for recovery of the species (Fish & G. Code, § 2074.6). Receipt of this report is to be placed on the agenda for the next available meeting of the Commission after delivery. At that time, the report will be made available to the public for a 30-day public comment period prior to the Commission taking any action on the petition.

Federal Endangered Species Act Review

The Foothill Yellow-legged Frog is currently under review for possible listing as threatened or endangered under the federal Endangered Species Act (ESA) in response to a July 11, 2012 petition submitted by the Center for Biological Diversity. On July 1, 2015, the U.S. Fish and Wildlife Service (USFWS) published its 90-day finding that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted and initiated a status review of the species (USFWS 2015). On March 16, 2016, the Center for Biological Diversity sued the USFWS to compel issuance of a 12-month finding on whether listing under the ESA is warranted. On August 30, 2016, the parties reached a stipulated settlement agreement that the USFWS shall publish its 12-month finding in the Federal Register on or before September 30, 2020 (*Center for Biological Diversity v. S.M.R. Jewell* (D.D.C. Aug. 30, 2016, No. 16-CV-00503)).

BIOLOGY AND ECOLOGY

Species Description and Life History

> *"In its life-history* boylii *exhibits several striking specializations which are in all probability related to the requirements of life of a stream-dwelling species"* – Tracy I. Storer, 1925

The Foothill Yellow-legged Frog is a small- to medium-sized frog; adults range from 38 to 81 mm (1.5-3.2 in) snout to urostyle length (SUL) with females attaining a larger size than males and males possessing paired internal vocal sacs (Zweifel 1955, Nussbaum et al. 1983, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs are typically gray, brown, olive, or reddish with brown-black flecking and mottling, which generally matches the substrate of the stream in which they reside (Nussbaum et al. 1983, Stebbins and McGinnis 2012). They often have a pale triangle between the eyes and snout and broad dark bars on the hind legs (Zweifel 1955, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs have a relatively squat body and granular skin, giving them a rough appearance similar to a toad, and fully webbed feet with slightly expanded toe tips (Nussbaum et al. 1983). The tympanum is also rough

and relatively small compared to congeners at around one-half the diameter of the eye (Zweifel 1955). The dorsolateral folds (glandular ridges extending from the eye area to the rump) in Foothill Yellow-legged Frogs are indistinct compared to other western North American ranids (Stebbins and McGinnis 2012). Ventrally, the abdomen is white with variable amounts of dark mottling on the chest and throat, which are unique enough to be used to identify individuals (Marlow et al. 2016). As their name suggests, the underside of their hind limbs and lower abdomen are often yellow; however, individuals with orange and red have been observed within the range of the California Red-legged Frog (*Rana draytonii*), making hindlimb coloration a poor diagnostic characteristic for this species (Jennings and Hayes 2005).

Adult females likely lay one clutch of eggs per year and may breed every year (Storer 1925, Wheeler et al. 2006). Foothill Yellow-legged Frog egg masses resemble a compact cluster of grapes approximately 45 to 90 mm (1.8-3.5 in) in diameter length-wise and contain anywhere from around 100 to over 3,000 eggs (Kupferberg et al. 2009c, Hayes et al. 2016). The individual embryos are dark brown to black with a lighter area at the vegetative pole and surrounded by three jelly envelopes that range in diameter from approximately 3.9 to 6.0 mm (0.15-0.25 in) (Storer 1925, Zweifel 1955, Hayes et al. 2016).

Foothill Yellow-legged Frog tadpoles hatch out around 7.5 mm (0.3 in) long and are a dark brown or black (Storer 1925, Zweifel 1955). They grow rapidly to 37 to 56 mm (1.5-2.2 in) and turn olive with a coarse brown mottling above and an opaque silvery color below (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012). Their eyes are positioned dorsally when viewed from above (i.e., within the outline of the head), and their mouths are large, downward-oriented, and suction-like with several tooth rows (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012, Hayes et al. 2016). Foothill Yellow-legged Frogs metamorphose at around 14-17 mm (0.55-0.67 in) SUL (Fellers 2005). Sexual maturity is attained at around 30-40 mm (1.2-1.6 in) SUL and 1-2 years for males and around 40-50 mm (1.6-2.0 in) SUL and 3 years for females, although in some populations this has been accelerated by a year (Zweifel 1955, Kupferberg et al. 2009c, Breedveld and Ellis 2018). During the breeding season, males can be distinguished from females by the presence of nuptial pads (swollen darkened thumb bases that aid in holding females during amplexus) and calling, which frequently occurs underwater but sometimes from the surface (MacTague and Northen 1993, Stebbins 2003, Silver 2017).

The reported lifespan of Foothill Yellow-legged Frogs varies widely by study. Storer (1925) and Van Wagner (1996) estimated a maximum age of 2 years for both sexes and the vast majority of the population. Breedveld and Ellis (2018) calculated the typical lifespan of males at 3-4 years and 5-6 years for females. Bourque (2008), using skeletochronology, found an individual over 7 years old and a mean age of 4.7 and 3.6 years for males and females, respectively. Drennan et al. (2015) estimated maximum age at 13 years for both sexes in a Sierra Nevada population and 12 for males and 11 for females in a Coast Range population.

Range and Distribution

Foothill Yellow-legged Frogs historically ranged from the Willamette River drainage in Oregon west of the Sierra-Cascade crest to at least the San Gabriel River drainage in Los Angeles County, California (Figure 1; Zweifel 1955, Stebbins 2003). In addition, a disjunct population was reported from 2,040 m

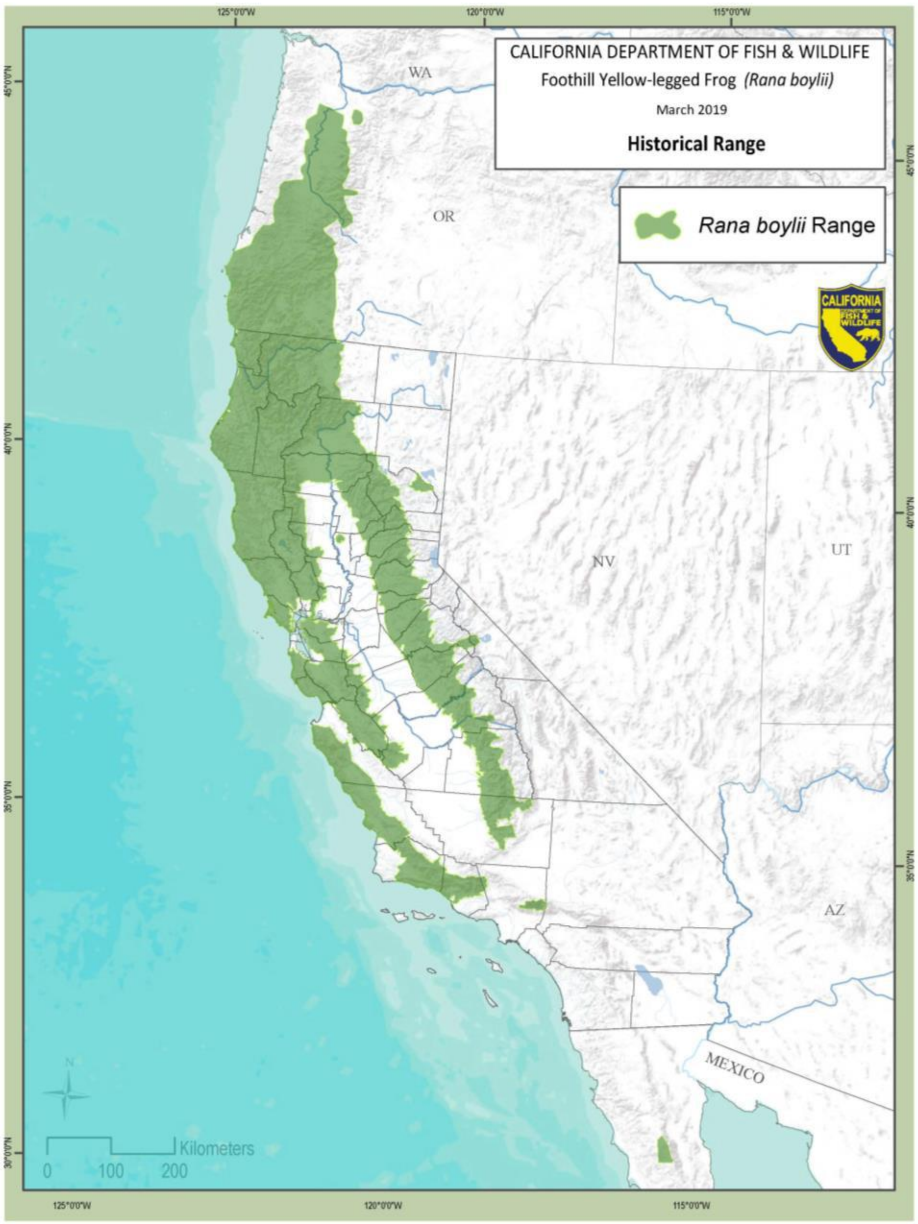

Figure 1. Foothill Yellow-legged Frog historical range (adapted from CWHR, Loomis [1965], Nussbaum et al. [1983])

(6,700 ft) in the Sierra San Pedro Mártir, Baja California Norte, México (Loomis 1965). In California, the species occupies foothill and mountain streams in the Klamath, Cascade, Sutter Buttes, Coast, Sierra Nevada, and Transverse ranges from sea level to 1,940 m (6,400 ft), but generally below 1,525 m (5,000 ft) (Hemphill 1952, Nussbaum et al. 1983, Stebbins 2003, Olson et al. 2016). Zweifel (1955) considered Foothill Yellow-legged Frogs to be present and abundant throughout their range where streams possessed suitable habitat.

Taxonomy and Phylogeny

Foothill Yellow-legged Frogs belong to the family Ranidae (true frogs), which inhabits every continent except Antarctica and contains more than 700 species (Stebbins 2003). The species was first described by Baird (1854) as *Rana boylii*. After substantial taxonomic uncertainty with respect to its relationship to other ranids (frogs in the family Ranidae) and several name changes over the next century, the Foothill Yellow-legged Frog (*R. boylii* with no subspecific epithet) was eventually recognized as a distinct species again by Zweifel (1955, 1968). The phylogenetic relationships among the western North American *Rana* spp. have been revised several times and are still not entirely resolved (Thomson et al. 2016). The Foothill Yellow-legged Frog was previously thought to be most closely related to the higher elevation Mountain Yellow-legged Frog (*R. muscosa*) (Zweifel 1955; Green 1986a,b). However, genetic analyses undertaken by Macey et al. (2001) and Hillis and Wilcox (2005) suggest they are more closely related to Oregon Spotted Frogs (*R. pretiosa*) and Columbia Spotted Frogs (*R. luteiventris*), respectively.

Population Structure and Genetic Diversity

Foothill Yellow-legged Frog populations exhibit varying levels of partitioning and genetic diversity ~~at different~~depending on the spatial ~~scales~~scale of comparison. At the coarse landscape level across the species' extant range, McCartney-Melstad et al. (2018) recovered five deeply divergent, geographically cohesive, genetic clades (Figure 2), while Peek (2018) recovered six (Figure 3). Genetic divergence is the process of speciation; it is a measure of the number of mutations accumulated by populations over time from a shared ancestor that differentiate them from the other populations in a species. When genetic divergence among clades is large enough, it can be used as a tool to define new species or subspecies.

The geographic breaks among the five clades were similar between the studies, but Peek (2018) identified a separate deeply divergent genetic clade in the Feather River watershed that is distinct from the rest of the northern Sierra Nevada clade. The five clades ~~the two studies shared~~(common to both studies) include the following [Note: naming conventions follow McCartney-Melstad et al. (2018) and Peek (2018)]:

(1) Northwest/North Coast: north of San Francisco Bay in the Coast Ranges and east into Tehama County;
(2) Northeast/Northern Sierra: northern El Dorado County (North Fork American River watershed, includes Middle Fork) and north in the Sierra Nevada to southern Plumas County (Upper Yuba River watershed);

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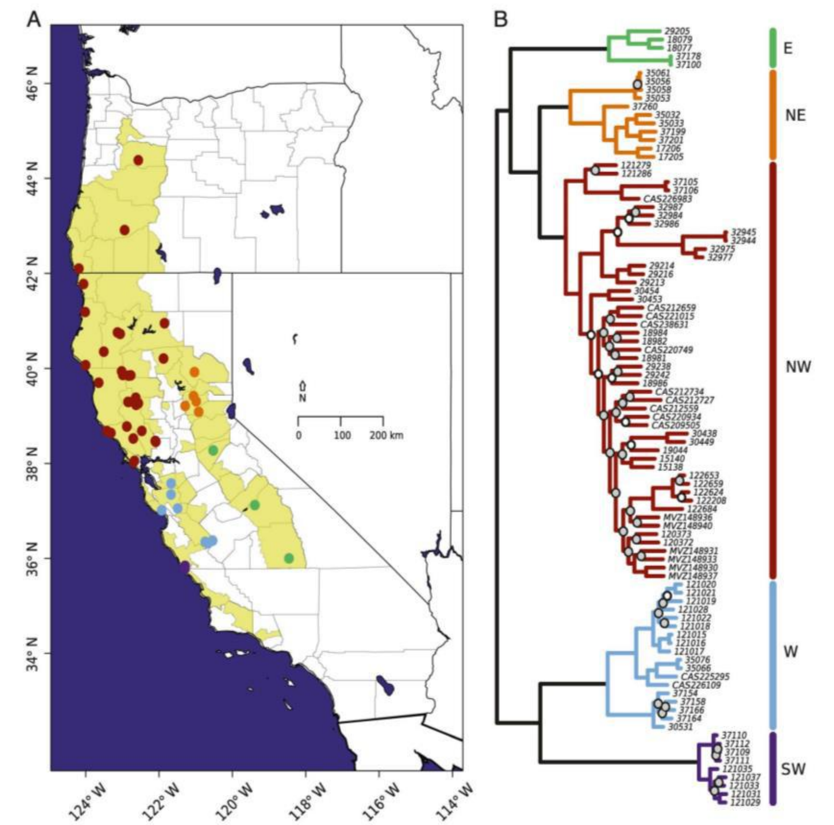

Fig. 1 a Map of *Rana boylii* sample localities. County outlines are shown within California and Oregon. Light yellow indicates the IUCN range map of *R. boylii*, excluding a small disjunct population at Sierra San Pedro Martir, Baja California, Mexico. Dots are colored by major grouping as determined in the b RAxML phylogeny, with midpoint rooting. Nodes without dots received >95% bootstrap support, those with white dots received <95% but greater than or equal to 75% bootstrap support, while nodes with gray dots received <75% bootstrap support

Figure 2. Foothill Yellow-legged Frog clades by McCartney-Melstad et al. (2018)

(3) East/Southern Sierra: El Dorado County (South Fork American River watershed) and south in the Sierra Nevada [no samples from Amador County were tested, but they would most likely fall within this clade because it is located between two other populations that occur within this clade];

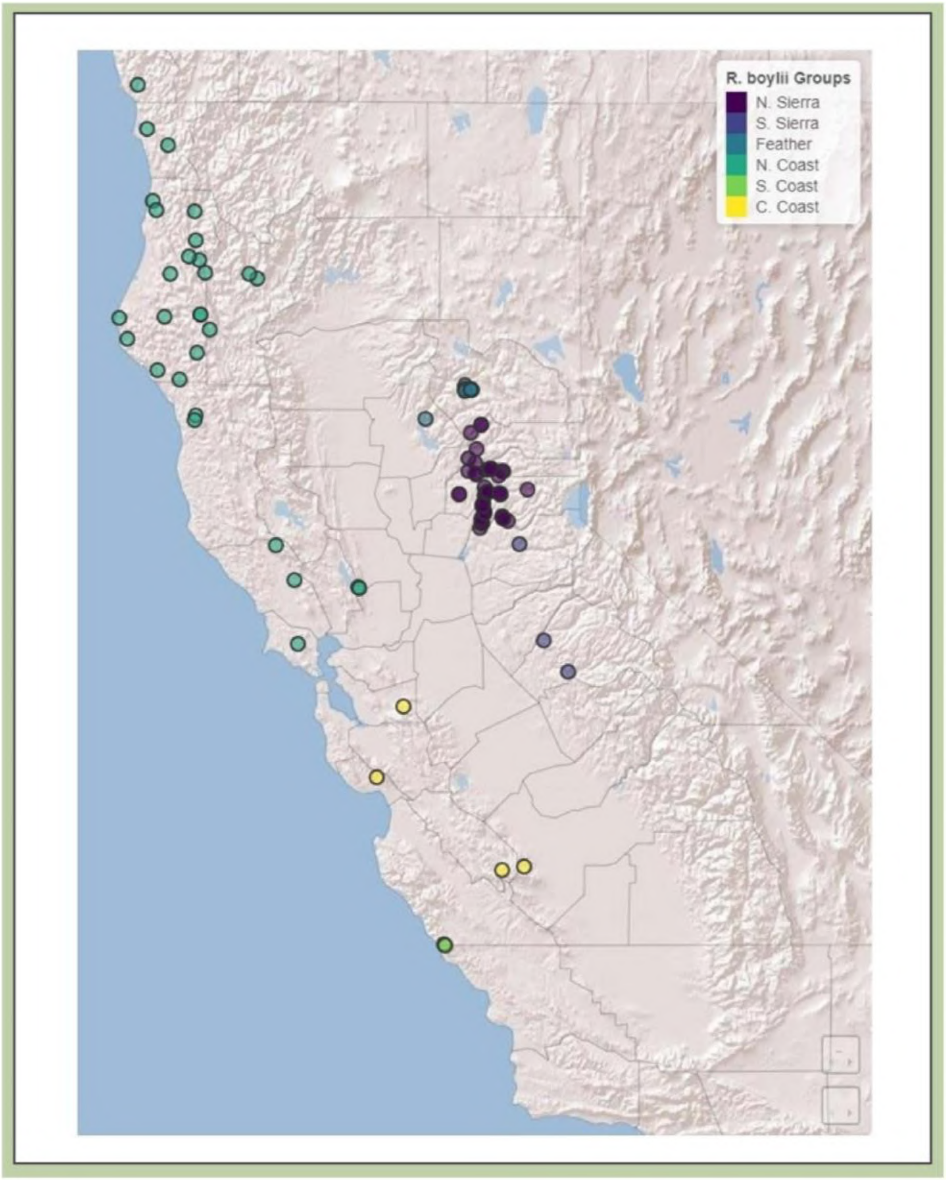

Figure 3. Foothill Yellow-legged Frog clades by Peek (2018)

(4) West/Central Coast: south of San Francisco Bay in the Coast Ranges to San Benito and Monterey counties, presumably east of the San Andreas Fault/Salinas Valley;

(5) Southwest/South Coast presumably west of the San Andreas Fault/Salinas Valley in Monterey County and south in the Coast Ranges.

The Feather River clade is found primarily in Plumas and Butte counties (Peek 2018). Peek's analysis found that this clade is as distinct as the rest of the Sierra Nevada as a cohesive group and all the coastal populations as one group, meaning it was found to be deeply divergent from the rest of the clades. McCartney-Melstad et al. (2018) also recognized the Feather River watershed as distinct from the rest of the northern Sierra but not as deeply divergent from the other clades as Peek. The Feather River watershed is also the only known location where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs (*R. sierrae*) co-occur and where two F1 hybrids (50% ancestry from each species) were found (Peek 2018). In addition, Peek's modeling results only weakly supported dividing the West/Central Coast and Southwest/South Coast groups into separate clades.

Previous work conducted by Lind et al. (2011) found a somewhat similar pattern, that populations on the periphery of the species' range are considerably genetically divergent from the rest of the range. Their results suggested that hydrologic regions and river basins were important landscape features that influenced the genetic structure of Foothill Yellow-legged Frog populations. However, using more modern genomic techniques, McCartney-Melstad et al. (2018) found nearly twice the variation among the five phylogenetic clades than among drainage basins, indicating other factors contributed to current population structure. They report that the depth of genetic divergence among Foothill Yellow-legged Frog clades exceeds that of any anuran (frog or toad) for which similar data are available and recommend using them as management units instead of the previously suggested watershed boundaries.

Levels of genetic diversity within the clades differed significantly. Genetic diversity gives species the ability to adapt to changing conditions (i.e., evolve), and its loss often signals extreme population and range reductions as well as potential inbreeding depression that can reduce survival and reproductive success (Lande and Shannon 1996, Hoffmann and Sgrò 2011, McCartney-Melstad et al. 2018). Loss of genetic diversity in Foothill Yellow-legged Frogs largely follows a north-to-south pattern with the southern clades (Southwest/South Coast and East/Southern Sierra) possessing the least amount (McCartney-Melstad et al. 2018, Peek 2018). In addition, these study results demonstrate that Foothill Yellow-legged Frogs have lost genetic diversity over time across their entire range except for the large Northwest/North Coast clade, which appears to have undergone a relatively recent population expansion (McCartney-Melstad et al. 2018, Peek 2018).

At a watershed scale, Dever (2007) found that tributaries to rivers and streams are important for preserving genetic diversity, and populations separated by more than 10 km (6.2 mi) show signs of genetic isolation. In other words, even in the absence of anthropogenic barriers to dispersal (e.g., dams and reservoirs), individuals located more than 10 km (6.2 mi) are not typically considered part of a single interbreeding population (Olson and Davis 2009). Peek (2011, 2018) reported that at this finer-scale, population structure and genetic diversity appear to be more strongly influenced by river regulation type (i.e., dammed or undammed) than to geographic distance or watershed boundaries. In general, regulated (dammed) rivers had limited gene flow and higher genetic divergence among subpopulations compared with unregulated (undammed) rivers (Peek 2011, 2018). In addition, differences in water flow regimes within regulated rivers affected connectivity (Peek 2011, 2018). Subpopulations in hydropeaking reaches, in which pulsed flows are used for electricity generation or whitewater boating, exhibited significantly lower gene flow than those in bypass reaches where water is diverted from upstream in the basin down to power generating facilities (Figure 4; Peek 2018). River regulation had a greater influence on genetic differentiation among sites than geographic distance in the Alameda Creek watershed as well (Stillwater Sciences 2012). Reduced connectivity among sites leads to lower gene flow and a loss of genetic diversity through genetic drift, which can diminish adaptability to changing environmental conditions (Palstra and Ruzzante 2008). Peek (2011) posits that given the *R. boylii* species group is estimated to be 8 million years old (Macey et al. 2001), the significant reductions in connectivity and genetic diversity over short evolutionary time periods in regulated rivers (often less than 50 years from the time of dam construction) is cause for concern with respect to population viability and persistence, particularly when combined with small population sizes.

Habitat Associations and Use

> *"These frogs are so closely restricted to streams that it is unusual to find one at a greater distance from the water than it could cover in one or two leaps."* – Richard G. Zweifel, 1955

Foothill Yellow-legged Frogs inhabit rivers and streams ranging from primarily rain-fed (coastal populations) to primarily snow-influenced (most Sierra Nevada and Klamath-Cascade populations) from headwater streams to large rivers (Bury and Sisk 1997, Wheeler et al. 2014). Occupied rivers and streams flow through a variety of vegetation types including hardwood, conifer, and valley-foothill riparian forests; mixed chaparral; and wet meadows (Hayes et al. 2016). Because the species is so widespread and can be found in so many types of habitats, the vegetation community is likely less important in determining Foothill Yellow-legged Frog occupancy and abundance than the aquatic biotic and abiotic conditions in the specific river, stream, or reach (Zweifel 1955). The species is an obligate stream-breeder, which sets it apart from other western North American ranids (Wheeler et al. 2014). Foothill Yellow-legged Frog habitat is generally characterized as partly-shaded, shallow, perennial rivers and streams with a low gradient and rocky substrate that is at least cobble-sized (Zweifel 1955, Hayes and Jennings 1988). However, the use of intermittent and ephemeral streams by post-metamorphic Foothill Yellow-legged Frogs may not be all that uncommon in some parts of the species' range in California (R. Bourque pers. comm. 2019). The species has been reported from some atypical habitats as well, including ponds, isolated pools in intermittent streams, and meadows along the edge of streams that lack a rocky substrate (Fitch 1938, Zweifel 1955, J. Alvarez pers. comm. 2017, CDFW 2018a).

As stream-breeding poikilotherms (animals whose internal temperature varies with ambient temperature), appropriate flow velocity, temperature, and water availability are critically important to Foothill Yellow-legged Frogs (Kupferberg 1996a, Van Wagner 1996, Wheeler et al. 2006, Lind et al. 2016). Habitat quality is also influenced by hydrologic regime (regulated vs. unregulated), substrate, presence of non-native predators and competitors, water depth, and availability of high-quality food and basking sites (Lind et al. 1996, Yarnell 2005, Wheeler et al. 2006, Catenazzi and Kupferberg 2017). Habitat suitability and use vary by life stage, sex, geographic location, watershed size, and season and

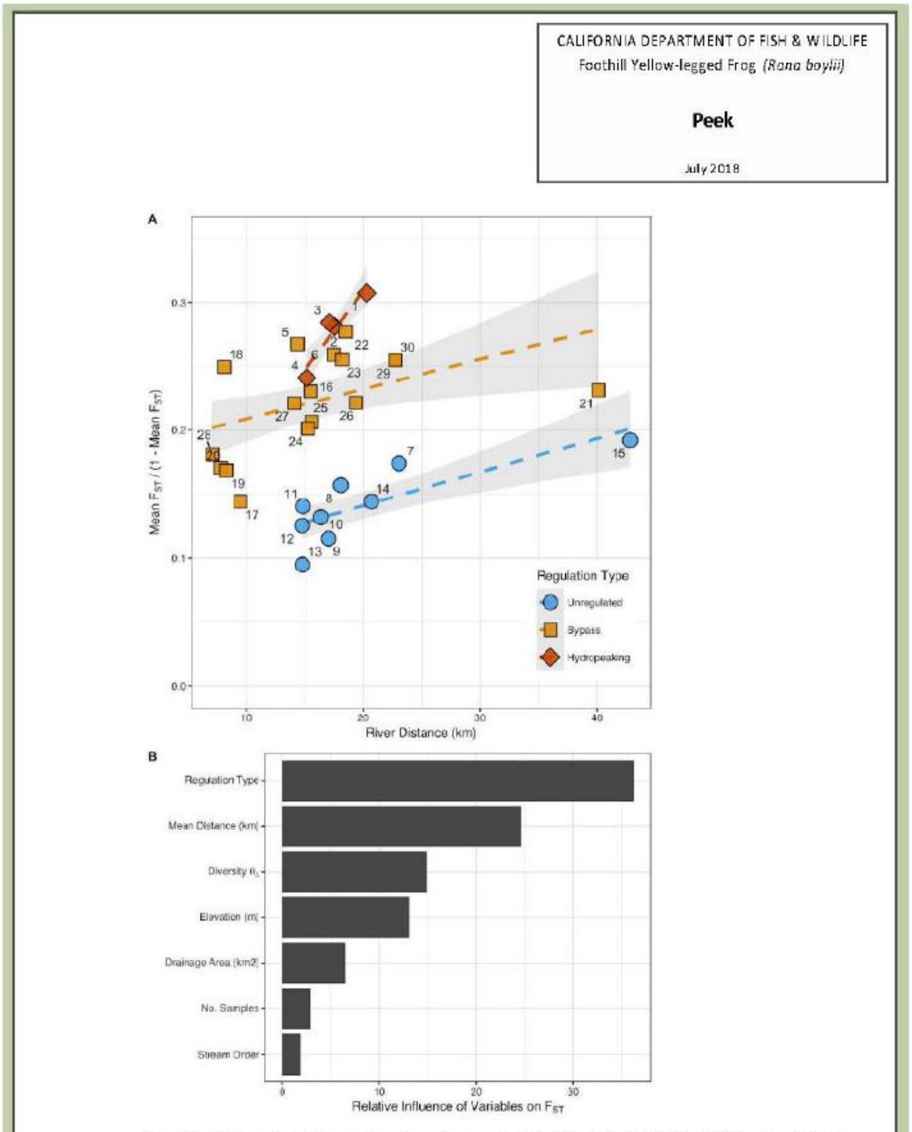

Figure 3. Relationship between river regulation and genetic differentiation in FYLF. A) Mean pairwise F_{ST} vs. mean river distance for each location; B) Relative influence of variables on F_{ST} from boosted regression tree models.

Figure 4. River regulation's relative influence on genetic differentiation from Peek (2018)

can generally be categorized as breeding and rearing habitat, nonbreeding active season habitat, and overwintering habitat (Van Wagner 1996, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011, Hayes et al. 2016, Catenazzi and Kupferberg 2017). Yarnell (2005) located higher densities of Foothill Yellow-legged Frogs in areas with greater habitat heterogeneity and suggested that they were selecting for sites that possessed the diversity of habitats necessary to support each life stage within a relatively short distance.

Breeding and Rearing Habitat

Suitable breeding habitat must be connected to suitable rearing habitat for metamorphosis to be successful. When this connectivity exists, as flows decline through the season, tadpoles can follow the receding shoreline into areas of high productivity and lower predation risk as opposed to becoming trapped in isolated pools with a high risk of overheating, desiccation, and predation (Kupferberg et al. 2009c).

Several studies on Foothill Yellow-legged Frog breeding habitat, carried out across the species' range in California, reported similar findings. Foothill Yellow-legged Frogs select oviposition (egg-laying) sites within a narrow range of depths, velocities, and substrates and exhibit fidelity to breeding sites that consistently possess suitable microhabitat characteristics over time (Kupferberg 1996a, Bondi et al. 2013, Lind et al. 2016). At a coarse-spatial scale, breeding sites in rivers and large streams are often located near the confluence of tributary streams in sunny, wide, shallow reaches (Kupferberg 1996a, Yarnell 2005, GANDA 2008, Peek 2011). These areas are highly productive compared to cooler, deeper, closed-canopy sites (Catenazzi and Kupferberg 2013). At a fine-spatial scale, females prefer to lay eggs in low velocity areas dominated by cobble- and boulder-sized substrates, often associated with sparsely-vegetated point bars (Kupferberg 1996a, Lind et al. 1996, Van Wagner 1996, Bondi et al. 2013, Lind et al. 2016). They tend to select areas with less variable, more stable flows, and in areas with higher flows at the time of oviposition, they place their eggs on the downstream side of large cobblestones and boulders, which protects them from being washed away (Kupferberg 1996a, Wheeler et al. 2006).

Appropriate rearing temperatures are vital for successful metamorphosis. Tadpoles grow faster and larger in warmer water to a point (Zweifel 1955; Catenazzi and Kupferberg 2017, 2018). Zweifel (1955) conducted experiments on embryonic thermal tolerance and determined that the critical low was approximate 6°C (43°F), and the critical high was around 26°C (79°F). Welsh and Hodgson (2011) determined that best the single variable for predicting Foothill Yellow-legged Frog presence was temperature since none were observed below 13°C (55°F), but numbers increased significantly with increasing temperature. Catenazzi and Kupferberg (2013) measured tadpole thermal preference at 16.5-22.2°C (61.7-72.0°F), and the distribution of Foothill Yellow-legged Frog populations across a watershed was consistent within this temperature range. ~~At~~ When the daily average temperatures during the warmest month of the year were below 16°C (61°F), tadpoles were absent under closed canopy and scarce even with an open canopy (Ibid.). Catenazzi and Kupferberg (2017) found regional differences in apparently suitable breeding temperatures. Inland populations from primarily snowmelt-fed systems with relatively cold water were relegated to reaches that are warmer on average during the warmest 30 days of the year than coastal populations in the chiefly rainfall-fed, and thus warmer, systems (17.6-

24.2°C [63.7-75.6°F] vs. 15.7-22.0°C [60.3-71.6°F], respectively). However, experiments on tadpole thermal preference demonstrated that individuals from different source populations selected similar rearing temperatures, which presumably optimized development (Ibid.). In regulated systems, where water released from dams is often colder than normal, suitable rearing temperatures downstream may be limited (Wheeler et al. 2014, Catenazzi and Kupferberg 2017).

Appropriate flow velocities are also critical for survival to metamorphosis. The velocity at which Foothill Yellow-legged Frog egg masses shear away from the substrate they are adhered to varies according to factors such as depth and degree to which the eggs are sheltered (Spring Rivers Ecological Sciences 2003). This critical velocity is expected to decrease as the egg mass ages due to their reduced structural integrity of the protective jelly envelopes (Hayes et al. 2016). Short-duration increases in flow velocity may be tolerated if the egg masses are somewhat sheltered, but sustained high velocities increase the likelihood of detachment (Kupferberg 1996a, Spring Rivers Ecological Sciences 2003). Hatchlings and tadpoles about to undergo metamorphosis are relatively poor swimmers and require especially slow, stable flows during these stages of development (Kupferberg et al. 2011b). Tadpoles respond to increasing flows by swimming against the current to maintain position for a short period of time and eventually swimming to the bottom and seeking refuge in the rocky substrate's interstitial spaces (Ibid.). When tadpoles are exposed to repeated increases in velocities, their growth and development are delayed (Ibid.). Under experimental conditions, the critical velocity at which tadpoles were swept downstream ranged between 20 and 40 cm/s (0.66-1.31 ft/s); however, as they reach metamorphosis it decreases to as low as 10 cm/s (0.33 ft/s) (Ibid.).

Nonbreeding Active Season Habitat

Post-metamorphic Foothill Yellow-legged Frogs utilize a more diverse range of habitats and are much more dispersed during the nonbreeding active season than the breeding season. Microhabitat preferences appear to vary by location and season, but some patterns are common across the species' range. Foothill Yellow-legged Frogs tend to remain close to the water's edge (average < 3 m [10 ft]); select sunny areas with limited canopy cover; and are often associated with riffles and pools (Zweifel 1955, Hayes and Jennings 1988, Van Wagner 1996, Welsh et al. 2005, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011). Adequate water, food resources, cover from predators, ability to thermoregulate (e.g., presence of basking sites and cool refugia), and absence of non-native predators are important components of nonbreeding active season habitat (Hayes and Jennings 1988, Van Wagner 1996, Catenazzi and Kupferberg 2013).

Overwintering Habitat

Overwintering habitat varies depending on local conditions, but as with the rest of the year, Foothill Yellow-legged Frogs are most often found in or near water where they can forage and take cover from predators and high discharge events (Storer 1925, Zweifel 1955). In larger streams and rivers, Foothill Yellow-legged Frogs are often found along tributaries during the winter where the risk of being displaced by heavy flows is reduced (Kupferberg 1996a, Gonsolin 2010). Bourque (2008) found 36.4% of adult females used intermittent and ephemeral tributaries during the overwintering season. Van

Wagner (1996) located most overwintering frogs using pools with cover such as boulders, root wads, and woody debris. During high flow events, they moved to the stream's edge and took cover under vegetation like sedges (*Carex* sp.) or leaf litter (Ibid.). Rombough (2006) found most Foothill Yellow-legged Frogs under woody debris along the high-water line and often using seeps along the stream-edge, which provided them with moisture, a thermally stable environment, and prey.

Exceptions to the pattern of remaining near the stream's edge during winter have been reported. Cook et al. (2012) observed dozens of juvenile Foothill Yellow-legged Frogs traveling over land, as opposed to using riparian corridors. They were found using upland habitats with an average distance of 71.3 m (234 ft) from water (range: 16-331 m [52-1,086 ft]) (Ibid.). In another example, a single subadult that was found adjacent to a large wetland complex 830 m (2,723 ft) straight-line distance from the wetted edge of the Van Duzen River, although it is possible the wetland was connected to the river via a spillway or drainage that may have served as the movement corridor (CDFW 2018a, R. Bourque pers. comm. 2019).

Seasonal Activity and Movements

Because Foothill Yellow-legged Frogs occupy areas with relatively mild winter temperatures, they can be active year-round, although at low temperatures (< 7°C [44 °F], they become lethargic (Storer 1925, Zweifel 1955, Van Wagner 1996, Bourque 2008). They are active both day and night, and during the day adults are often observed basking on warm objects such as sun-heated rocks, although this is also when their detectability is highest (Fellers 2005, Wheeler et al. 2005). By contrast, Gonsolin (2010) tracked radio-telemetered Foothill Yellow-legged Frogs under substrate a third of the time and underwater a quarter of the time, although nearly all his detections of frogs without transmitters were basking.

Adult Foothill Yellow-legged Frogs migrate from their overwintering sites to breeding habitat in the spring, often from a tributary to its confluence with a larger stream or river. In areas where tributaries dry down, juveniles also make this downstream movement (Haggarty 2006). When the tributary itself is perennial and provides suitable breeding habitat, the frogs may not undertake these long-distance movements (Gonsolin 2010). Cues for adults to initiate this migration to breeding sites are somewhat enigmatic and vary by location, elevation, and amount of precipitation (S. Kupferberg and A. Lind pers. comm. 2017). They can also include day length, water temperature, and sex (GANDA 2008, Gonsolin 2010, Yarnell et al. 2010, Wheeler et al. 2018). Males initiate movements to breeding sites where they congregate in leks (areas of aggregation for courtship displays), and females arrive later and over a longer period (Wheeler and Welsh 2008, Gonsolin 2010). Most males utilize breeding sites associated with their overwintering tributaries, but some move substantial distances to other sites and may use more than one breeding site in the same season (Wheeler and Welsh 2006, GANDA 2008).

While the predictable hydrograph in California consists of wet winters with high flows and dry summers with low flows, the timing and quantity of seasonal discharge can vary significantly from year to year. The timing of oviposition can influence offspring growth and survival. Early breeders risk scouring of egg masses from their substrate by late spring storms in wet years or desiccation if waters recede rapidly, but when they successfully hatch, tadpoles benefit from a longer growing season, which can enable them to metamorphose at a larger size and increase their likelihood of survival (Railsback et al. 2016).

Later breeders are less likely to have their eggs scoured away or desiccated because flows are generally more stable, but they have fewer mate choices, and their tadpoles have a shorter growing period before metamorphosis, reducing their chance of survival (Ibid.). Some evidence indicates larger females, who coincidentally lay larger clutches, breed earlier (Kupferberg et al. 2009c, Gonsolin 2010). Consequently, early season scouring or stranding of egg masses or tadpoles can disproportionately impact the population's reproductive output because later breeders produce fewer and smaller eggs per clutch (Kupferberg et al. 2009c, Gonsolin 2010).

Timing of oviposition is often a function of water temperature and flow, but it consistently occurs on the descending limb of the hydrograph which corresponds to high winter discharge gradually receding toward low summer baseflow (Kupferberg 1996a, GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010, Yarnell et al. 2010). Under natural conditions, the timing coincides with intermittent tributaries drying down and increases in algal blooms that provide forage for tadpoles (Haggarty 2006, Power et al. 2008). At lower elevations, breeding can start in late March or early April, and at mid-elevations, breeding typically occurs in mid-May to mid-June (Gonsolin 2010, S. Kupferberg and A. Lind pers. comm. 2017). The time of year a population initiates breeding can vary by a month among water years, occurring later at deeper sites when colder water becomes warmer (Wheeler et al. 2018). In wetter years, delayed breeding into early July can occur in some colder snowmelt systems (S. Kupferberg and A. Lind pers. comm. 2017, GANDA 2018).

A population's period of oviposition can also vary from two weeks to three months, meaning they could be considered explosive breeders at some sites and prolonged breeders at others (Storer 1925, Zweifel 1955, Van Wagner 1996, Ashton et al. 1997, Wheeler and Welsh 2008). Water temperature typically warms to over 10°C (50°F) before breeding commences (GANDA 2008, Gonsolin 2010, Wheeler et al. 2018). Wheeler and Welsh (2008) observed Foothill Yellow-legged Frogs breeding when flows were below 0.6 m/s (2 ft/s), pausing during increased flows until they receded, and GANDA (2008) reported breeding initiated when flow decreased to less than 55% above baseflow.

Male Foothill Yellow-legged Frogs spend more time at breeding sites during the season than females, many of whom leave immediately after laying their eggs (GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010). Daily movements are usually short (< 0.3 m [1 ft]), but some individuals travel substantial distances: median 70.7 m/d (232 ft/d) in spring and 37.1 m/d (104 ft/day) in fall/winter, nearly always using streams as movement corridors (Van Wagner 1996, Bourque 2008, Gonsolin 2010). The maximum reported movement rate is 1,386 m/d (0.86 mi/d), and the longest seasonal (post-breeding) daily distance reported is 7.04 km (4.37 mi) by a female that traveled up a dry tributary and over a ridge before returning to and moving up the mainstem creek (Bourque 2008). Movements during the non-breeding season are typically in response to drying channels or during rain events (Bourque 2008, Gonsolin 2010, Cook et al. 2012).

Hatchling Foothill Yellow-legged Frogs tend to remain with what is left of the egg mass for several days before dispersing into the interstitial spaces in the substrate (Ashton et al. 1997). They often move downstream in areas of moderate flow and will follow the location of warm water in the channel throughout the day (Brattstrom 1962, Ashton et al. 1997, Kupferberg et al. 2011a). Tadpoles usually

metamorphose in late August or early September (S. Kupferberg and A. Lind pers. comm. 2017). Twitty et al. (1967) reported that newly metamorphosed Foothill Yellow-legged Frogs mostly migrated upstream, which may be an evolutionary mechanism to return to their natal site after being washed downstream (Ashton et al. 1997).

Home Range and Territoriality

Foothill Yellow-legged Frogs exhibit a lek-type mating system in which males aggregate at the breeding site and establish calling territories (Wheeler and Welsh 2008, Bondi et al. 2013). The species has a relatively large calling repertoire for western North American ranids with seven unique vocalizations recorded (Silver 2017). Some of these can be reasonably attributed to territory defense and mate attraction communications (MacTeague and Northen 1993, Silver 2017). Physical aggression among males during the breeding season has been reported (Rombough and Hayes 2007, Wheeler and Welsh 2008). In addition, Wheeler and Welsh (2008) observed a non-random mating pattern in which males engaged in amplexus with females were larger than males never seen in amplexus, suggesting either physical competition or female preference for larger individuals. Very little information has been published on Foothill Yellow-legged Frog home range size. Wheeler and Welsh (2008) studied males during a 17-day period during breeding season and classified some of them "site faithful" based on their movements and calculated their home ranges. Two-thirds of males tracked were site faithful, and their mean home range size was 0.58 m^2 (SE = 0.10 m^2; 6.24 ft^2 [SE = 1.08 ft^2]) (Ibid.). In contrast, perhaps because the study took place over a longer time period, Bourque (2008) reported approximately half of the males he tracked during the spring were mobile, and the other half were sedentary. The median distances traveled along the creek (a proxy for home range size since they rarely leave the riparian corridor) for mobile and sedentary males were 149 m (489 ft) and 5.5 m (18 ft), respectively.

Diet and Predators

Foothill Yellow-legged Frog diet varies by life stage and likely body size. Tadpoles graze on periphyton (algae growing on submerged surfaces) scraped from rocks and vegetation and grow faster, and to a larger size, when it contains a greater proportion of epiphytic diatoms with nitrogen-fixing endosymbionts (*Epithemia* spp.), which are high in protein and fat (Kupferberg 1997b, Fellers 2005, Hayes et al. 2016, Caten~~n~~azzi and Kupferberg 2017). Tadpoles may also forage on necrotic tissue from dead bivalves and other tadpoles, or more likely the algae growing on them (Ashton et al. 1997, Hayes et al. 2016). Post-metamorphic Foothill Yellow-legged Frogs primarily feed on a wide variety of terrestrial arthropods but also some aquatic invertebrates (Fitch 1936, Van Wagner 1996, Haggarty 2006). Most of their diet consists of insects and arachnids (Van Wagner 1996, Haggarty 2006, Hothem et al. 2009). Haggarty (2006) did not identify any preferred taxonomic groups, but she noted larger Foothill Yellow-legged Frogs consumed a greater proportion of large prey items compared to smaller individuals, suggesting the species may be gape-limited generalist predators. Hothem et al. (2009) found mammal hair and bones in a Foothill Yellow-legged Frog. Adult Foothill Yellow-legged Frogs, like many other ranids, also cannibalize conspecifics (Wiseman and Bettaso 2007). In the fall when young-of-year are abundant, they may provide an important source of nutrition for adults prior to overwintering (Ibid.).

Foothill Yellow-legged Frogs are preyed upon by several native and introduced species, including each other as described above. Some predators target specific life stages, while others may consume multiple stages. Several species of gartersnakes (genus *Thamnophis*) are the primary and most widespread group of native predators on Foothill Yellow-legged Frogs tadpoles through adults is (Fitch 1941, Fox 1952, Zweifel 1955, Lind and Welsh 1994, Ashton et al. 1997, Wiseman and Bettaso 2007, Gonsolin 2010). Table 1 lists other known and suspected predators of Foothill Yellow-legged Frogs.

Table 1. Confirmed and potential Foothill Yellow-legged Frog predators in California in addition to gartersnakes (*Thamnophis* spp.)

Common Name	Scientific Name	Classification	Native	Prey Life Stage(s)	Sources
Caddisfly (larva)	*Dicosmoecus gilvipes*	Insect	Yes	Embryos (eggs)	Rombough and Hayes 2005
Dragonfly (nymph)	*Aeshna walker*	Insect	Yes	Larvae	Catenazzi and Kupferberg 2018
Waterscorpion	*Ranatra brevicollis*	Insect	Yes	Larvae	Catenaazi and Kupferberg 2018
Signal Crayfish	*Pacifastacus leniusculus*	Crustacean	No	Embryos (eggs) and Larvae	Rombough and Hayes 2005; Wiseman et al. 2005
Speckled Dace	*Rhinichthys osculus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Reticulate Sculpin	*Cottus perplexus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Sacramento Pike Minnow	*Ptychocheilus grandis*	Fish	Yes*	Embryos (eggs) and Adults	Ashton and Nakamoto 2007
Sunfishes	Family Centrachidae	Fish	No	Larvae	Moyle (1973); Hayes and Jennings 1986
Catfishes	Family Ictaluridae	Fish	No	Larvae	Moyle (1973); Hayes and Jennings 1986
Rough-skinned Newt	*Taricha granulosa*	Amphibian	Yes	Embryos (eggs)	Evenden 1948
California Giant Salamander	*Dicamptodon ensatus*	Amphibian	Yes	Larvae	Fidenci 2006
American Bullfrog	*Rana catesbeiana*	Amphibian	No	Larvae to Adults	Crayon 1998; Hothem et al. 2009
California Red-legged Frog	*Rana draytonii*	Amphibian	Yes	Larvae to Adults	Gonsolin 2010
American Robin	*Turdus migratorius*	Bird	Yes	Larvae	Gonsolin 2010
Common Merganser	*Mergus merganser*	Bird	Yes	Larvae	Gonsolin 2010
American Dipper	*Cinclus mexicanus*	Bird	Yes	Larvae	Ashton et al. 1997
Mallard	*Anas platyrhynchos*	Bird	Yes	Adults	Rombough et al. 2005
Raccoon	*Procyon lotor*	Mammal	Yes	Larvae to Adults	Zweifel 1955; Ashton et al. 1997
River Otter	*Lontra canadensis*	Mammal	Yes	Adults	T. Rose pers. comm. 2014

* Introduced to the Eel River, location of documented predation; Foothill Yellow-legged Frogs are extirpated from most areas of historical range overlap

STATUS AND TRENDS IN CALIFORNIA

Administrative Status

Sensitive Species

The Foothill Yellow-legged Frog is listed as a Sensitive Species by the U.S. Bureau of Land Management (BLM) and U.S. Forest Service (Forest Service). These agencies define Sensitive Species as those species that require special management consideration to promote their conservation and reduce the likelihood and need for future listing under the ESA.

California Species of Special Concern

The Department's Species of Special Concern (SSC) designation is similar to the federal Sensitive Species designation. It is administrative, rather than regulatory in nature, and intended to focus attention on animals at conservation risk. The designation is used to stimulate needed research on poorly known species and to target the conservation and recovery of these animals before they meet the CESA criteria for listing as threatened or endangered (Thomson et al. 2016). The Foothill Yellow-legged Frog is listed as a Priority 1 (highest risk) SSC (Ibid.).

Trends in Distribution and Abundance

Range-wide in California

Range is the general geographical area in which an organism occurs. For purposes of CESA and this Status Review, the range is the species' California range (*Cal. Forestry Assn. v. Cal. Fish and Game Com.* (2007) 156 Cal.App.4th 1535, 1551). Systematic, focused, range-wide assessments of Foothill Yellow-legged Frog distribution and abundance are rare, both historically and contemporarily. A detailed account of what has been documented within the National Parks and National Forests in California can be found in Appendix 3 of the *Foothill Yellow-legged Frogs Conservation Assessment in California* (Hayes et al. 2016).

Most Foothill Yellow-legged Frog records are incidental observations made during stream surveys for ESA-listed salmonids and simply document presence at a particular date and location, although some include counts or estimates of abundance by life stage. This makes assessing trends in distribution and abundance difficult despite a relatively large number of observations compared to many other species tracked by the California Natural Diversity Database (CNDDB). The CNDDB contained 2,366 Foothill Yellow-legged Frog occurrences in its March 2019 edition, 500 of which are documented from the past 5 years.

A few wide-ranging survey efforts that included Foothill Yellow-legged Frogs exist. Reports from early naturalists suggest Foothill Yellow-legged Frogs were relatively common in the Coast Ranges as far south as central Monterey County, in eastern Tehama County, and in the foothills in and near Yosemite National Park (Grinnell and Storer 1924, Storer 1925, Grinnell et al. 1930, Martin 1940). In addition to

these areas, relatively large numbers of Foothill Yellow-legged Frogs (17-35 individuals) were collected at sites in the central and southern Sierra Nevada and the San Gabriel Mountains between 1911 and 1950 (Hayes et al. 2016). Widespread disappearances of Foothill Yellow-legged Frog populations were documented as early as the 1970s and 80s in southern California, the southern Coast Range, and the central and southern Sierra Nevada foothills (Moyle 1973, Sweet 1983).

Twenty-five years ago, the Department published the first edition of *Amphibians and Reptile Species of Special Concern in California* (Jennings and Hayes 1994). The authors revisited hundreds of localities that had historically been occupied by Foothill Yellow-legged Frogs between 1988 and 1991 and consulted local experts to determine presumed extant or extirpated status. Based on these survey results and stressors observed on the landscape, they considered Foothill Yellow-legged Frogs endangered in central and southern California south of the Salinas River in Monterey County. They considered the species threatened in the west slope drainages of the Cascade Mountains and Sierra Nevada east of the Central Valley, and they considered the remainder of the range to be of special concern (Ibid.).

Fellers (2005) and his field crews conducted surveys for Foothill Yellow-legged Frogs throughout California. They visited 804 sites across 40 counties with suitable habitat within the species' historical range. They detected at least one individual at 213 sites (26.5% of those surveyed) over 28 counties. They located Foothill Yellow-legged Frogs in approximately 40% of streams in the North Coast, 30% in the Cascade Mountains and south of San Francisco in the Coast Range, and 12% in the Sierra Nevada. Fellers estimated population abundance was 20 or more adults at only 14% of the sites where the species was found and noted the largest and most robust populations occurred along the North Coast. In addition, to determine status of Foothill Yellow-legged Frogs across the species' range and potential causes for declines, Lind (2005) used previously published status accounts, species expert and local biologist professional opinions, and field visits to historically occupied sites between 2000-2002. She determined that Foothill Yellow-legged Frogs had disappeared from 201 of 394 of the sites, representing just over 50%. The coarse-scale trend in California is one of greater population declines and extirpations in lower elevations and latitudes (Davidson et al. 2002).

Few site-specific population trend data are available from which to evaluate status. However, long-term monitoring efforts often use egg mass counts as a proxy to estimate adult breeding females. The results of these studies often reveal extreme interannual variability in number of egg masses laid (Ashton et al. 2010, S. Kupferberg and M. Power pers. comm. 2015, Peek and Kupferberg 2016). In a meta-analysis of egg mass count data collected across the species' range in California over the past 25 years, Peek and Kupferberg (2016) reported declines in two unregulated rivers and an increase in another. Their models did not detect any significant trends in abundance across different locations or regulation type (dammed or undammed); however, high interannual variability can render trend detection difficult. Interannual variability was substantially greater in regulated rivers vs. unregulated; the median coefficient of variation was 66.9% and 41.6%, respectively (Ibid.). The greater variability in regulated rivers decreases the probability of detecting significant declines, and coupled with low abundance, it can lead to populations dropping below a density necessary for persistence without detection, resulting in extirpation.

Regional differences in Foothill Yellow-legged Frog persistence across its range have been recognized for nearly 50 years (i.e., more extirpations documented in the south). Because of these differences and the recent availability of new landscape genomic data, more detailed descriptions of trends in Foothill Yellow-legged Frog population distribution and abundance in California are evaluated by clade below. Figure 5 depicts Foothill Yellow-legged Frog localities across all clades in California by the most recent confirmed sighting in the datasets available to the Department within a Public Lands Survey System (PLSS) section. “Transition Zones” are those areas where the exact clade boundaries are unknown due to a lack of samples. In addition, while not depicted as an area of uncertainty, no genetic samples have been tested south of the extant population in northern San Luis Obispo County, in the Sutter Buttes in Sutter County, or northeastern Plumas County. It is possible there were historically more clades than currently understood.

Caution should be exercised in comparing the following observation data across the species’ range and across time since survey effort and reporting are not standardized. These data can be useful for making some general inferences about distribution, abundance, and trends. For instance, assuming the observation correctly identifies the species, the date on the record is the last time the species was confirmed to have occurred at that location. However, this only works in the affirmative. For example, at a site where the last time the species was seen was 75 years ago, the species may still persist there if no one has surveyed it since the original observation. CNDDB staff use information on land use conversion, follow-up visits, and biological reports to categorize an occurrence location as “extirpated” or “possibly extirpated”.

Northwest/North Coast Clade

This clade extends from north of San Francisco Bay through the Coast Range and Klamath Mountains to the northern limit of the Foothill Yellow-legged Frog’s range and east through the Cascade Range. It includes Del Norte, Siskiyou, Humboldt, Trinity, Shasta, Tehama, Mendocino, Glenn, Colusa, Lake, Sonoma, Napa, Yolo, Solano, and Marin counties. This clade covers the largest geographic area and contains the greatest amount of genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). In addition, it is the only clade with an increasing trend in genetic diversity (Peek 2018).

Early records note the comparatively high abundance of Foothill Yellow-legged Frogs in this area. Storer (1925) described Foothill Yellow-legged Frogs as very common in many of Coast Range streams north of San Francisco Bay, and Cope (1879,1883 as cited in Hayes et al. 2016) noted they were “rather abundant in the mountainous regions of northern California.” In addition, relatively large collections occurred over short periods of time in this region in the late 1800s and the first half of the 20th century (Hayes et al. 2016). Nineteen were taken over two weeks in 1893 along Orrs Creek, a tributary to the Russian River, and 40 from near Willits (both in Mendocino County) in 1911; 112 were collected over three days at Skaggs Spring (Sonoma County) in 1911; 57 were taken in one day along Lagunitas Creek (Marin County) in 1928; and 50 were collected in one day near Denny (Trinity County) in 1955 (Ibid.).

A few long-term Foothill Yellow-legged Frog egg mass monitoring efforts undertaken within this clade’s boundaries found densities vary significantly, often based on river regulation type, and documented

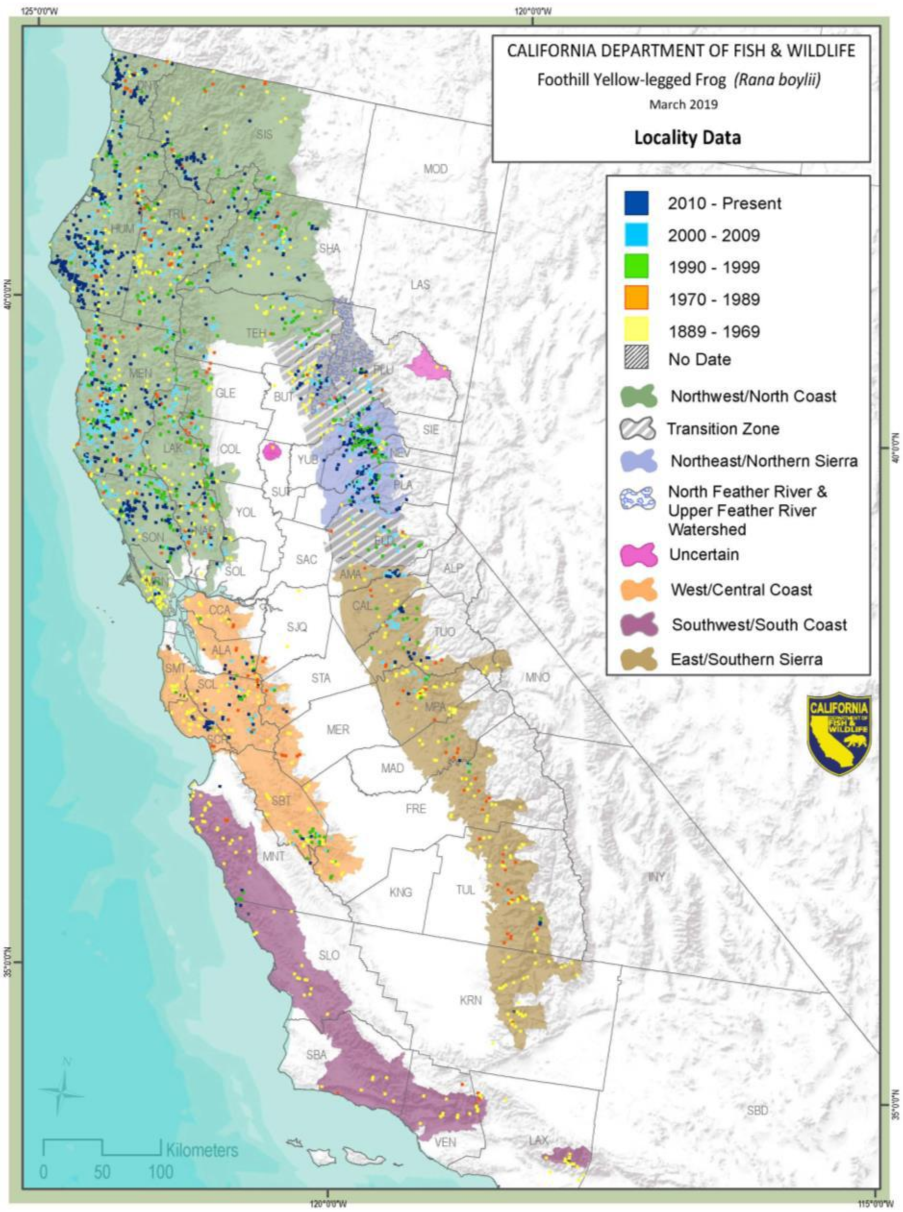

Figure 5. Foothill Yellow-legged Frog occurrence data from 1889-2019 overlaying the six clades by most recent sighting in a Public Lands Survey System section (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

several robust populations. The Green Diamond Resources Company has been monitoring a stretch of the Mad River near Blue Lake (Humboldt County) since 2008 (GDRC 2018). The greatest published density of Foothill Yellow-legged Frog egg masses was documented here in 2009 at 323.6 egg masses/km (520.7/mi) (Bourque and Bettaso 2011). However, in 2017, surveyors counted 625.1 egg masses/km (1,006/mi) along the same reach (GDRC 2018). At its lowest during this period, egg mass density was calculated at 71.54/km (115.1/mi) in 2010, although this count occurred after a flooding even that likely scoured over half of the egg masses laid that season (GDRC 2018, R. Bourque pers. comm. 2019). During a single day survey in 2017 along approximately 2 km (1.3 mi) of Redwood Creek in Redwood National Park (Humboldt County), 2,009 young and 126 adult Foothill Yellow-legged Frogs were found (D. Anderson pers. comm. 2017). Some reaches of the South Fork Eel River (Mendocino County) also support high densities of Foothill Yellow-legged Frogs. Kupferberg (pers. comm. 2018) recorded 206.9 and 106.2 egg masses/km (333 and 171/mi) along two stretches in 2016, and 201.7 and 117.5 egg masses/km (324 and 189/mi) in 2017. However, other reaches yielded counts as low as 6.1 and 8.4 egg masses/km (9.8 and 13.5/mi) (Ibid.). In the Angelo Reserve (an unregulated reach), the 24-year mean density was 109 egg masses/km (175.4/mi) (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015). In contrast, a 10-year mean density of egg masses below Lewiston Dam on the Trinity River (Trinity County) was 0.89/km (1.43/mi) (Ibid.).

Figure 6 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, Biological Information Observation System datasets, and personal communications that are color coded by the most recent date of detection. Within this clade, Foothill Yellow-legged Frogs were observed in at least 343 areas in the past 5 years (CNDDB 2019). The species remains widespread within many watersheds, although most observations only verify presence, or fewer than ten individuals or egg masses are recorded (Ibid.). Documented extirpations are comparatively rare, but also likely undetected or under-reported, and nearly all occurred just north of the high-populated San Francisco Bay area (Figure 7; Ibid.).

West/Central Coast

This clade extends south from the San Francisco Bay through the Diablo Range and down the peninsula through the Santa Cruz and Gabilan Mountains in the Coast Range east of the Salinas Valley. It includes most of Contra Costa, Alameda, San Mateo, Santa Cruz, Santa Clara, and San Benito counties; western San Joaquin, Stanislaus, Merced, and Fresno counties; and a small portion of eastern Monterey County. Records of Foothill Yellow-legged Frogs occurring south of San Francisco Bay did not exist until specimens were collected in 1918 around what is now Pinnacles National Park in San Benito County, and little information exists on historical distribution and abundance within this clade (Storer 1923).

Within this clade, Foothill Yellow-legged Frogs were observed in at least 24 areas in the past five years (Figure 8; CNDDB 2019). Documented and possible extirpations are concentrated around the San Francisco Bay and sites at the southern portion of the clade’s range, although these may not have been resurveyed since their original observations in the 1940s through 1960s, except for a site in Pinnacles National Park that was surveyed in 1994 (Figure 9; Ibid.). In addition, although not depicted,

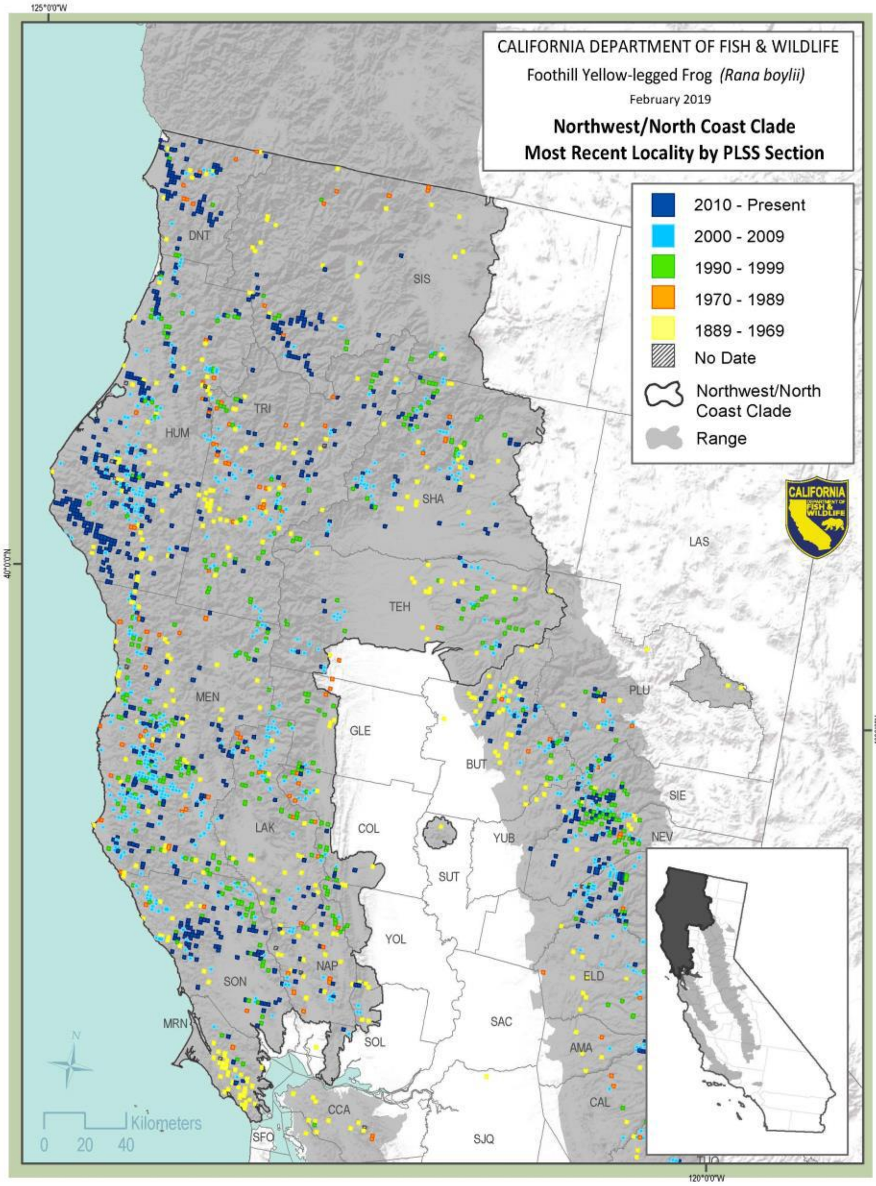

Figure 6. Close-up of Northwest/North Coast Foothill Yellow-legged Frog clade observations from 1889-2019 (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

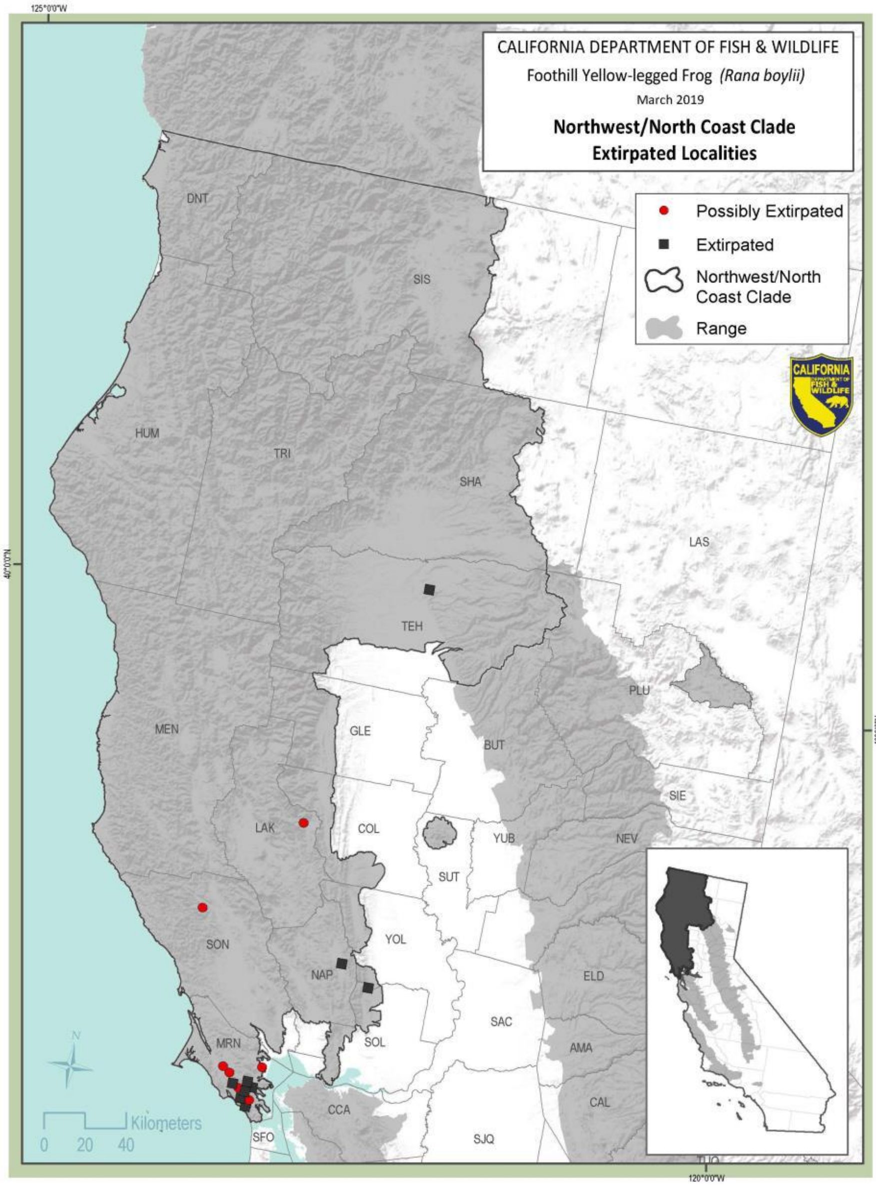

Figure 7. Possibly extirpated and extirpated Northwest/North Coast Foothill Yellow-legged Frog clade sites (CNDDB)

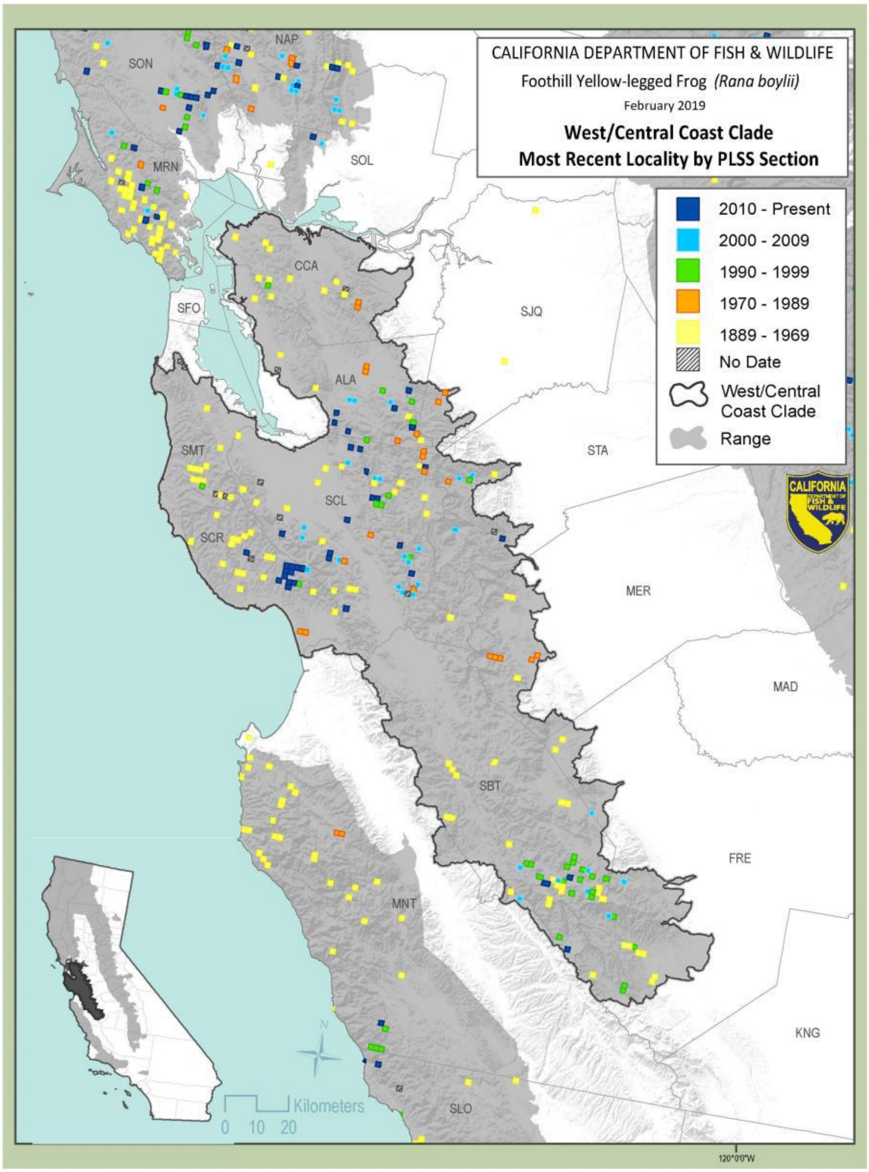

Figure 8. Close-up of West/Central Coast clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

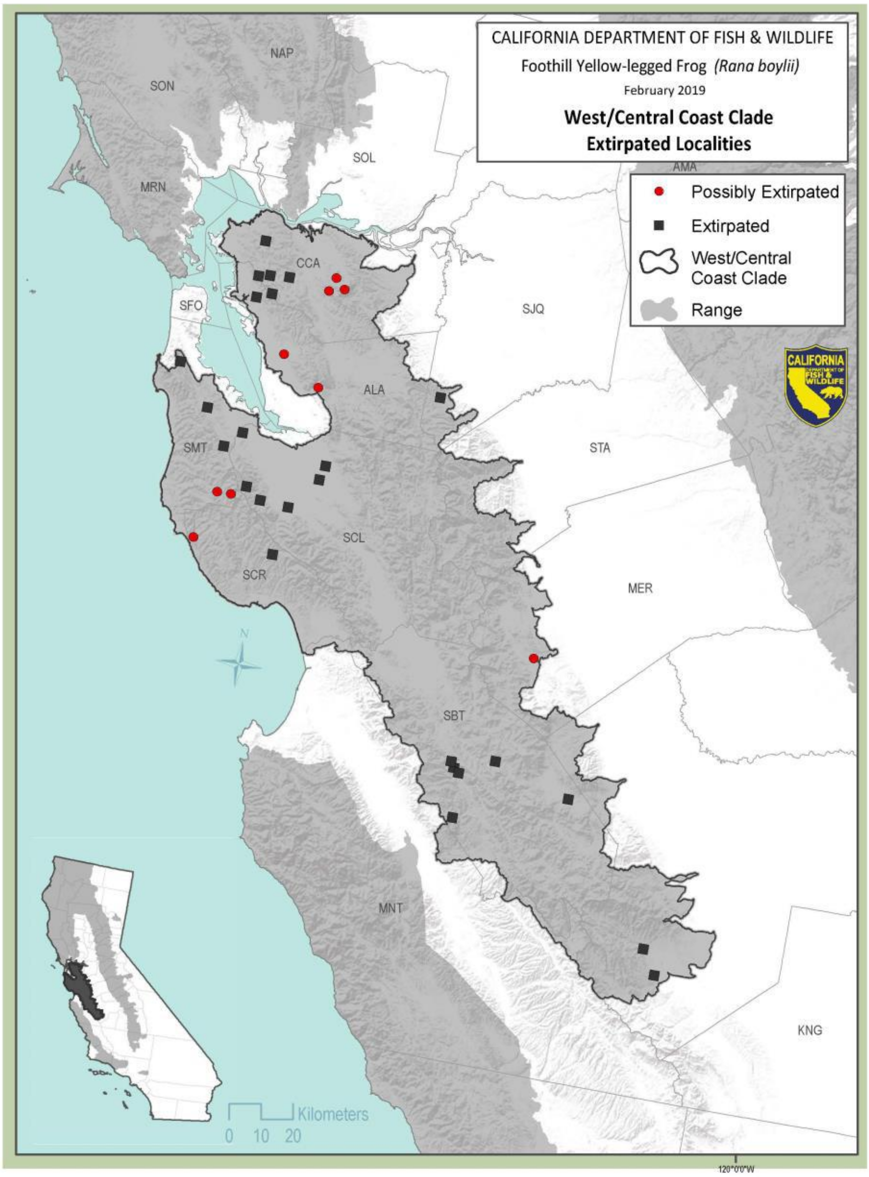

Figure 9. Possibly extirpated and extirpated West/Central Coast Foothill Yellow-legged Frog clade sites (CNDDB)

two populations on Arroyo Mocho and Arroyo Valle south of Livermore (Alameda County) are also likely extirpated (M. Grefsrud pers. comm. 2019).

The San Francisco Bay Area is heavily urbanized. Foothill Yellow-legged Frogs may be gone from Contra Costa County; eight of the nine CNDDB records from the county are museum specimens collected between 1891 and 1953, and the most recent observation was two adults in a plunge pool in an intermittent tributary to Moraga Creek in 1997. No recent (2010 or later) observations exist from San Mateo County (Ibid.). Historically occupied lower-elevation sites surrounding the San Francisco Bay and inland appear to be extirpated, but there are (or were) some moderately abundant breeding populations remaining at higher elevations in Arroyo Hondo (Alameda County), Alameda Creek (Alameda and Santa Clara counties), Coyote and Upper Llagas creeks (Santa Clara County), and Soquel Creek (Santa Cruz County) with some scattered smaller populations also persisting in these counties (J. Smith pers. comm. 2016, 2017; CNDDB 2019). The Alameda Creek and Coyote Creek populations recently underwent large-scale mortality events, so their numbers are likely substantially lower than what is currently reported in the CNDDB (Adams et al. 2017a, Kupferberg and Catenazzi 2019). In addition, the Arroyo Hondo population will lose approximately 1.6 km (1 mi) of prime breeding habitat (i.e., supported the highest density of egg masses on the creek) as the Calaveras Reservoir is refilled following its dam replacement project in 2019 (M. Grefsrud pers. comm. 2019). Foothill Yellow-legged Frogs may be extirpated from Corral Hollow Creek in San Joaquin County, but a single individual was observed five years ago further up the drainage in Alameda County within an Off-Highway Vehicle park (CNDDB 2019). Few recent sightings of Foothill Yellow-legged Frogs in the east-flowing creeks are documented. They may still be extant in the headwaters of Del Puerto Creek (western Stanislaus County), but the records further downstream indicate bullfrogs (known predators and disease reservoirs) are moving up the system (Ibid.). Several locations in southern San Benito, western Fresno, and eastern Monterey counties have relatively recent (2000 and later) detections (Ibid.). However, while many of these sites supported somewhat large populations in the 1990s, the more recent records report fewer than ten individuals (Ibid.). The exception is a Monterey County site where around 25 to 30 were observed in 2012 (Ibid.).

Southwest/South Coast

Widespread extirpations occurred decades ago, primarily in the 1960s and 1970s, in this area (Adams et al. 2017b). As a result, genetic samples were largely unavailable, and the boundaries are speculative. The clade is presumed to include the Coast Range from Monterey Bay south to the Transverse Range across to the San Gabriel Mountains. This clade includes portions of Monterey, San Luis Obispo, Santa Barbara, Ventura, and Los Angeles counties. Storer (1923) reported that Foothill Yellow-legged Frogs were collected for the first time in Monterey County in 1919 and that a specimen collected by Cope in 1889 in Santa Barbara and listed as *Rana temporaria pretiosa* may refer to the Foothill Yellow-legged Frog because as previously mentioned, the taxonomy of this species changed several times over the first century after it was named.

Foothill Yellow-legged Frogs had been widespread and fairly abundant in this area until the late 1960s (Figure 10) but were rapidly extirpated throughout the southern Coast Ranges and western Transverse

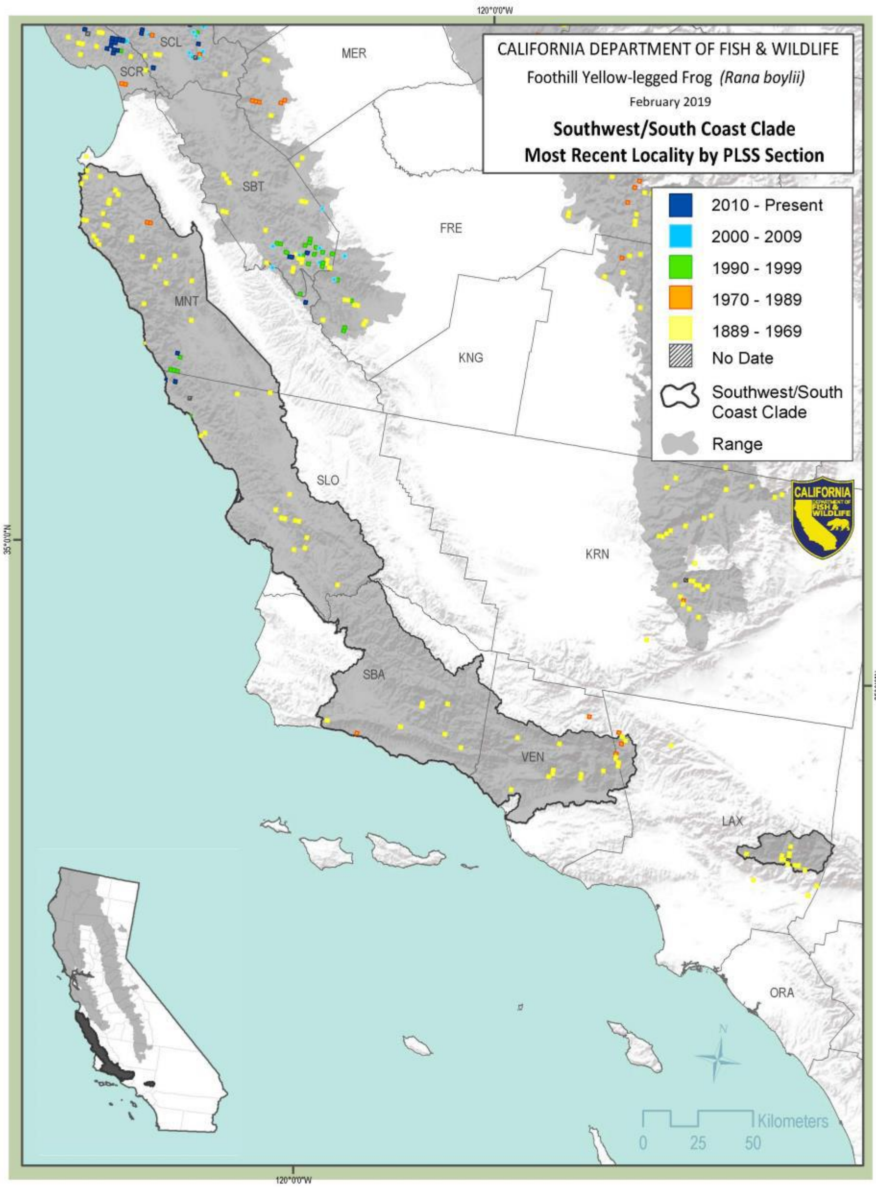

Figure 10. Close-up of Southwest/South Coast clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

Ranges by the mid-1970s (Figure 11; Sweet 1983, Adams et al. 2017b). Only two known extant populations exist from this clade, located near the border of Monterey and San Luis Obispo counties (S. Sweet pers. comm. 2017, McCartney-Melstad et al. 2018, Peek 2018, CNDDB 2019). They appear to be extremely small and rapidly losing genetic diversity, making them at high risk of extirpation (McCartney-Melstad et al. 2018, Peek 2018).

Northeast/Feather River and Northern Sierra

The exact clade boundaries in the Sierra Nevada are unclear and will require additional sampling and testing to define (Figure 12). The Northeast clade presumably encompasses the Feather River and Northern Sierra clades. The Feather River clade is located primarily in Plumas and Butte counties. The Northern Sierra clade roughly extends from the Feather River watershed south to the Middle Fork American River. It includes portions of El Dorado, Placer, Nevada, Sierra, and Plumas counties. It may also include portions of Amador, Butte, and eastern Tehama counties. No genetic samples were available to test in the Sutter Buttes or the disjunct population in northeastern Plumas County to determine which clades they belonged to before they were extirpated (Figure 13; Olson et al. 2016, CNDDB 2019).

In general, there is a paucity of historical Foothill Yellow-legged Frog data for west-slope Sierra Nevada streams, particularly in the lower elevations of the Sacramento Valley, and no quantitative abundance data exist prior to major changes in the landscape (i.e., mining, dams, and diversions) or the introduction of non-native species (Hayes et al. 2016). Foothill Yellow-legged Frogs have been collected frequently from the Plumas National Forest area in small numbers from the turn of the 20th century through the 1970s (Ibid.). Estimates of relative abundance are not clear from the records, but they suggest the species was somewhat widespread in this area.

More recently, Foothill Yellow-legged Frog populations in the Sierra Nevada have been the subject of a substantial number of surveys and focused research associated with recent and ongoing relicensing of hydroelectric power generating dams by the Federal Energy Regulatory Commission (FERC). Consequently, Foothill Yellow-legged Frogs have been observed in at least 30 areas in Plumas and Butte counties (roughly the Feather River clade) over the past five years (CNDDB 2019). As with the rest of the range, most records are observations of only a few individuals; however, many observations occurred over multiple years, and in some cases all life stages were observed over multiple years (Ibid). The populations appear to persist even with the small numbers reported. The only long-term consistent survey effort has been occurring on the North Fork Feather River along the Cresta and Poe reaches (GANDA 2018). The Cresta reach's subpopulation declined significantly in 2006 and never recovered despite modification of the flow regime to reduce egg mass and tadpole scouring and some habitat restoration (Ibid.). A pilot project to augment the Cresta reach's subpopulation through in situ captive rearing was initiated in 2017 (Dillingham et al. 2018). It resulted in the highest number of young-of-year Foothill Yellow-legged Frogs recorded during fall surveys since researchers started keeping count (Ibid.). The number of egg masses laid in the Poe reach varies substantially year-to-year from a low of 26 in 2001 to a high of 154 in 2015 and back down to 36 in 2017 (GANDA 2018).

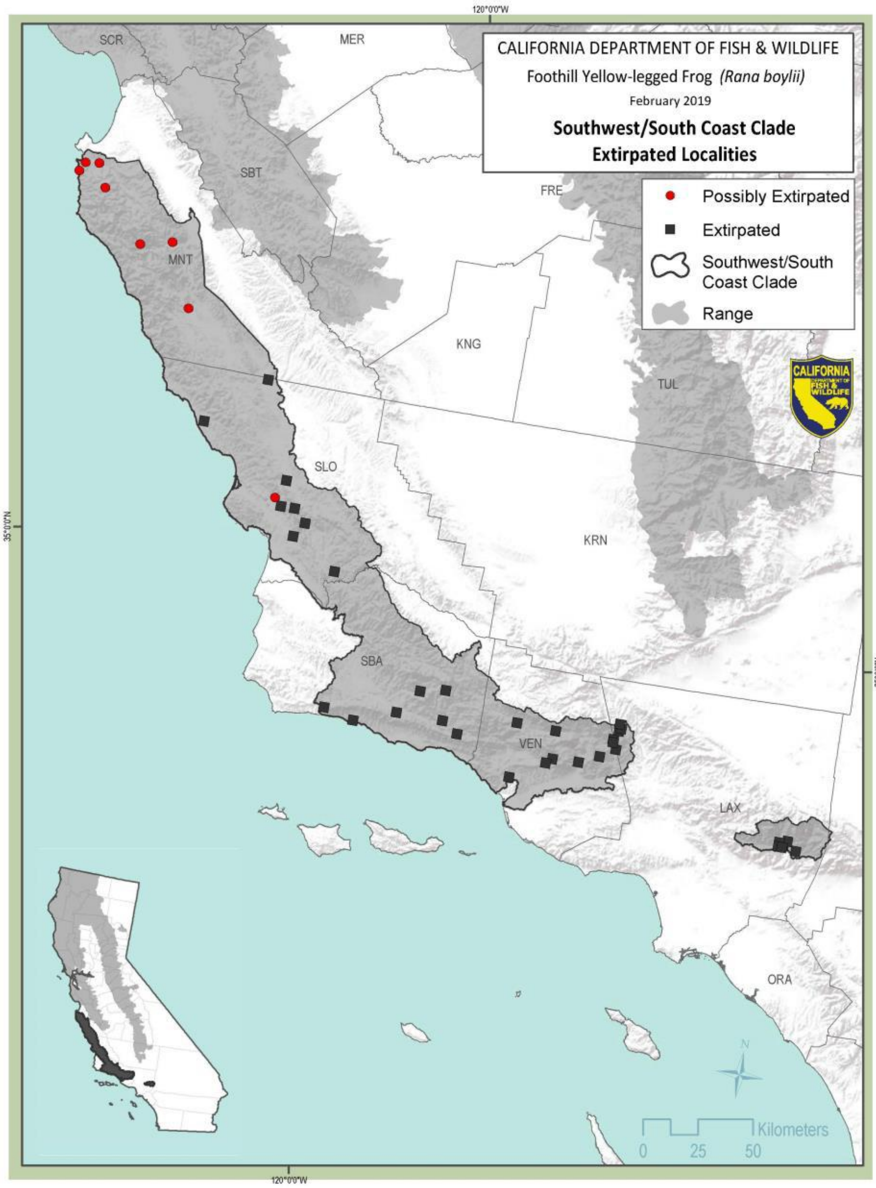

Figure 11. Possibly extirpated and extirpated Southwest/South Coast Foothill Yellow-legged Frog clade sites (CNDDB)

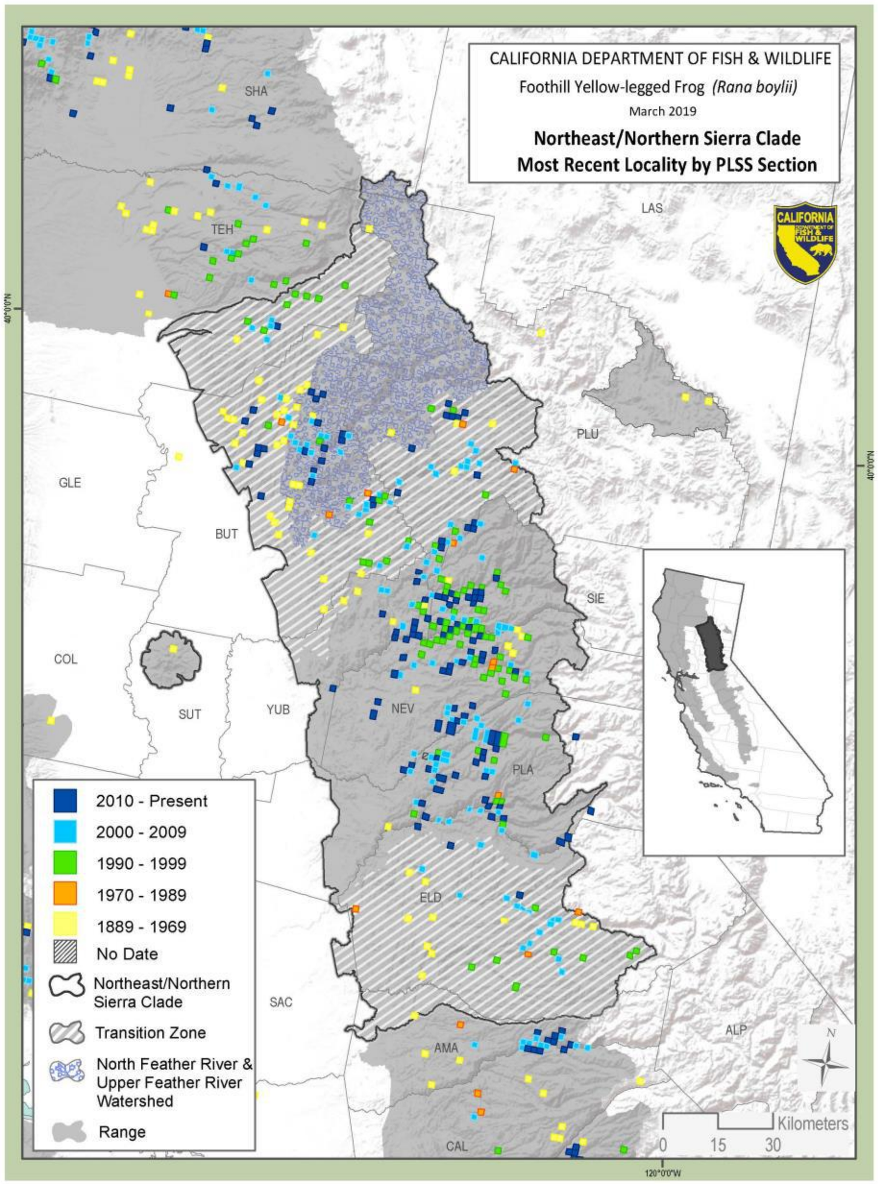

Figure 12. Close-up of Northeast/Feather River and Northern Sierra clades observations from 1889-2019 (ARSSC, BIOS, CNDDB)

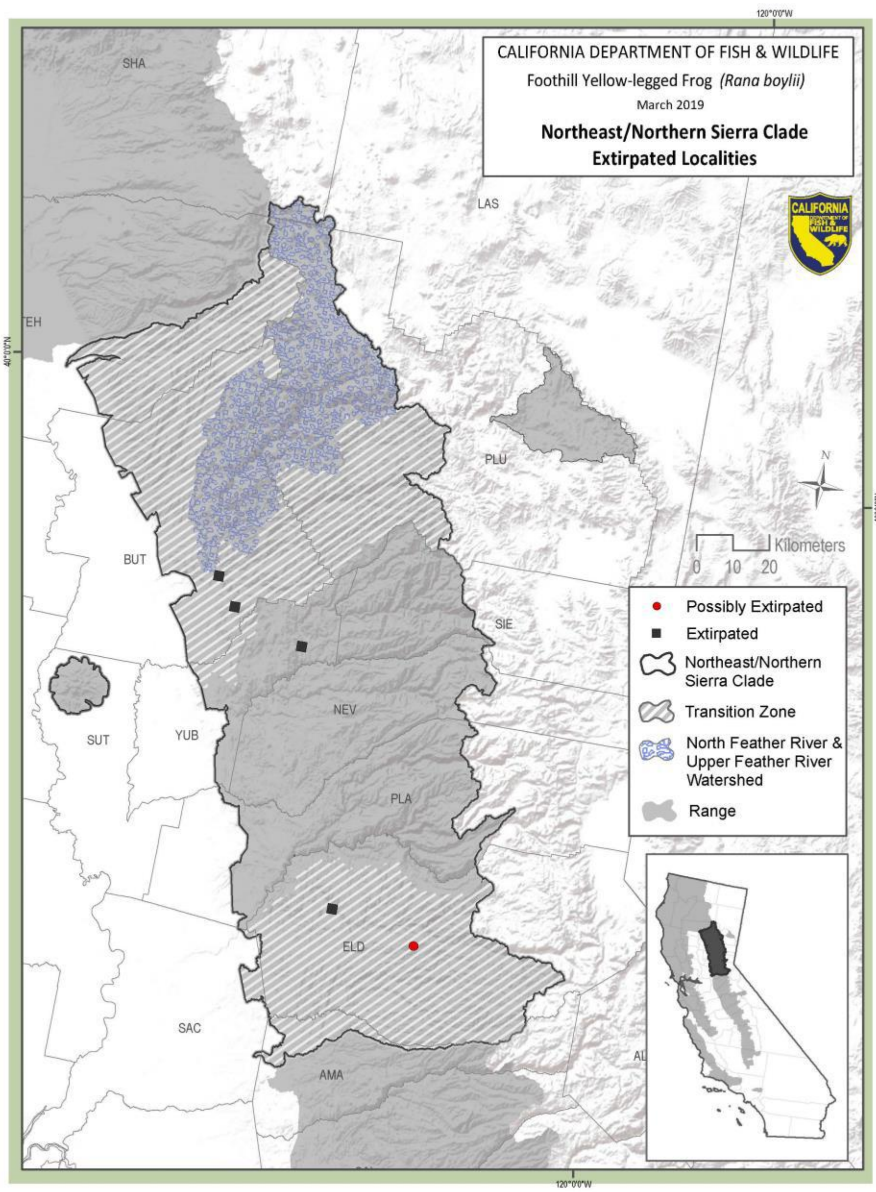

Figure 13. Possibly extirpated and extirpated Northeast/Feather River and Northern Sierra Foothill Yellow-legged Frog clades sites (CNDDB)

Foothill Yellow-legged Frogs have been observed in at least 71 areas in the past 5 years in the presumptive Northeast/Northern Sierra clade. The general pattern in this clade, and across the range for that matter, is that unregulated rivers or reaches have more areas that are occupied more consistently and in larger numbers than regulated rivers or reaches (CNDDB 2019, S. Kupferberg pers. comm. 2019). Foothill Yellow-legged Frogs were rarely observed in the hydropeaking reach of the Middle Fork American River and were observed in low numbers in the bypass reach, but they were present and breeding in small tributary populations (PCWA 2008). Relatively robust populations appear to inhabit the North Fork American River and Lower Rubicon River (Gaos and Bogan 2001, PCWA 2008, Hogan and Zuber 2012, K. Kundargi pers. comm. 2014, S. Kupferberg pers. comm. 2019). Additional apparently sufficiently large and relatively stable populations occur on Clear Creek, South Fork Greenhorn Creek, and Shady Creek (Nevada County) and the North and Middle Yuba River (Sierra County), but the remaining observations are of small numbers in tributaries with minimal connectivity among them (CNDDB 2019, S. Kupferberg pers. comm. 2019).

East/Southern Sierra

The East/Southern Sierra clade is presumed to range from the South Fork American River watershed, the northernmost site where individuals from this clade were collected, south to where the Sierra Nevada meets the Tehachapi Mountains. It likely includes El Dorado, Amador, Calaveras, Tuolumne, Mariposa, Madera, Fresno, Tulare, and Kern counties (Figure 14; Peek 2018). The proportion of extirpated sites in this clade is second only to the Southwest/South Coast and follows the pattern of greater losses in the south (Figure 15). Like the southern coastal clade, the southern Sierra clade has low genetic variability and a trajectory of continued loss of diversity (Ibid.).

Historical collections of small numbers of Foothill Yellow-legged Frogs occurred in every major river system within this clade beginning as early as the turn of the 20th century, indicating widespread distribution but little information on abundance (Hayes et al. 2016). By the early 1970s, declines in Foothill Yellow-legged Frog populations from this area were already apparent; Moyle (1973) found them at 30 of 95 sites surveyed in 1970. Notably bullfrogs inhabited the other 65 sites formerly occupied by Foothill Yellow-legged Frogs, and they co-occurred at only 3 sites (Ibid.). In 1992, Drost and Fellers (1996) revisited the sites around Yosemite National Park (Tuolumne and Mariposa counties) that Grinnell and Storer (1924) surveyed in 1915 and 1919. Foothill Yellow-legged Frogs had disappeared from all seven historically occupied sites and were not found at any new sites surveyed surrounding the park (Ibid.). Resurveys of previously occupied sites on the Stanislaus (Tuolumne County), Sierra (Fresno County), and Sequoia (Tulare County) National Forests were also undertaken (Lind et al. 2003b). Foothill Yellow-legged Frogs were absent from the sites in Sierra and Sequoia National Forests, six at each forest; however, a new population was discovered in the Sierra and two in the Sequoia forests (Ibid.). These populations remain extant but are small and isolated (CNDDB 2019). Two of the six sites on the Stanislaus were still occupied, and 19 new populations were found with evidence of breeding at seven of them (Lind et al. 2003b). Twenty of the 24 populations extant at the time inhabited unregulated waterways (Ibid.). Most of the CNDDB (2019) records of Foothill Yellow-legged Frogs on the Stanislaus are at least a decade old and are represented by low numbers.

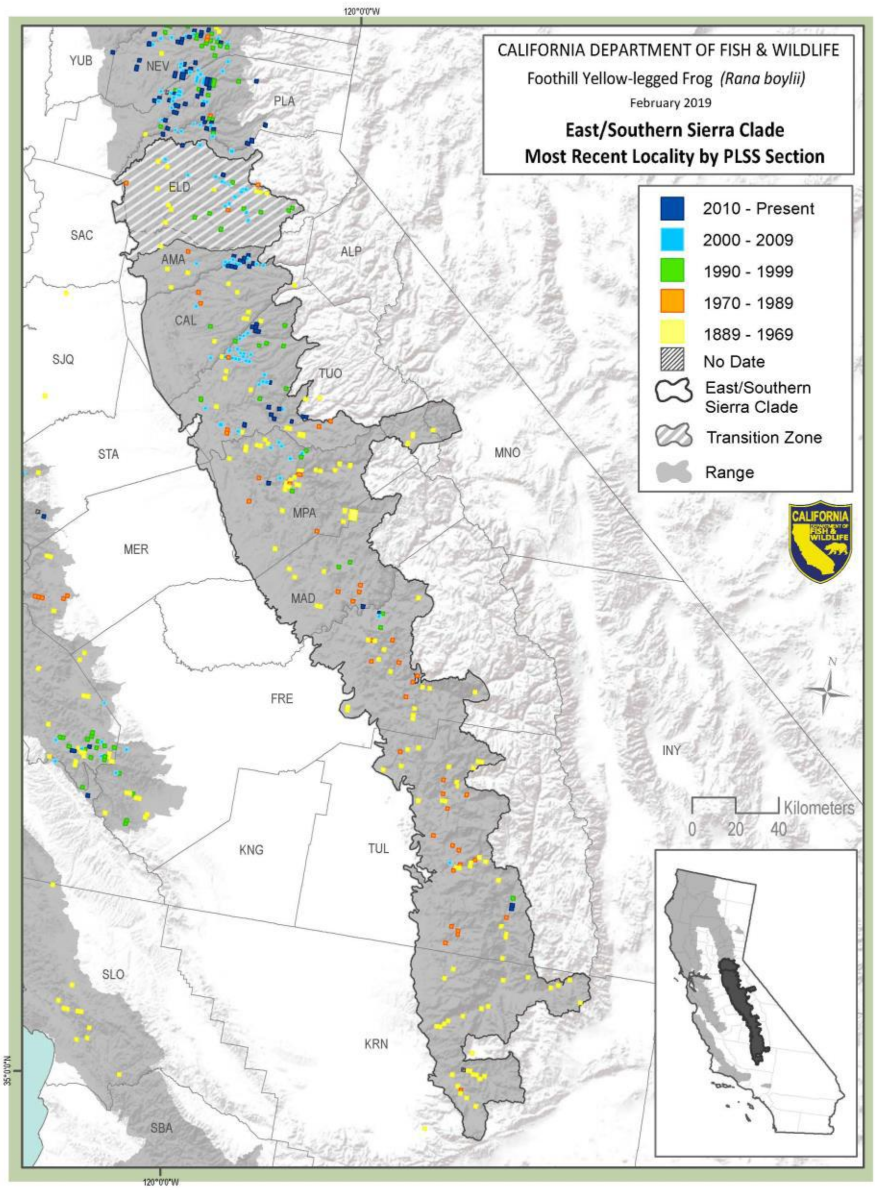

Figure 14. Close-up of East/Southern Sierra clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

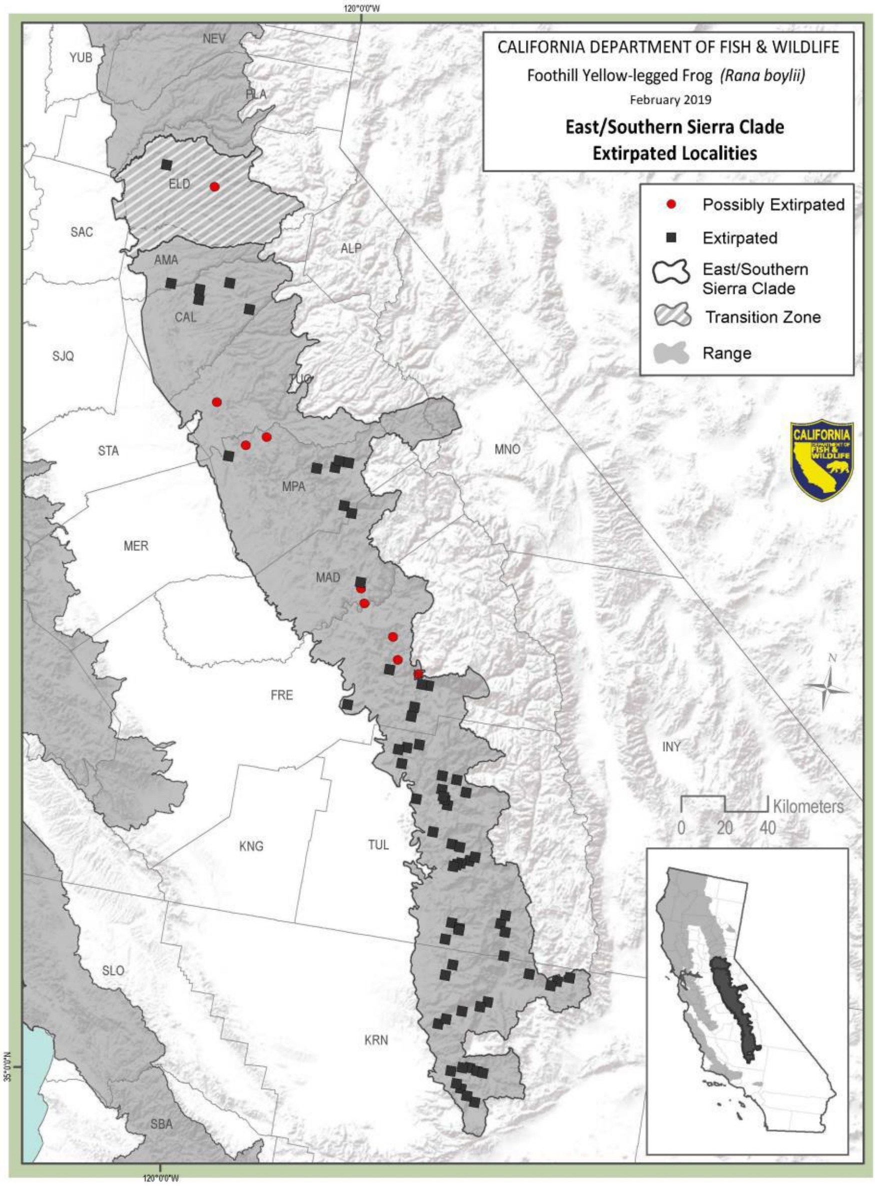

Figure 15. Possibly extirpated and extirpated East/Southern Sierra Foothill Yellow-legged Frog clade sites (CNDDB)

More recently, surveys for Foothill Yellow-legged Frogs were conducted along the South Fork American River as part of the El Dorado Hydroelectric Project's FERC license amphibian monitoring requirements (GANDA 2017). Between 2002 and 2016 counts of different life stages varied significantly by year but the trend for every life stage was a decline over that period (Ibid.). There appears to be a small population persisting along the North Fork Mokelumne River (Amador and Calaveras counties), but it was only productive during the 2012-2014 drought years (Ibid.). Small numbers have also been observed recently in several locations on private timberlands in Tuolumne County (CNDDB 2019).

FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE

"The fortunes of the boylii *population fluctuate with those of the stream"* - Tracy I. Storer, 1925

Several past and ongoing activities have changed the watersheds upon which Foothill Yellow-legged Frogs depend, and many interact with each other exacerbating their adverse impacts. With such an expansive range in California, the degree and severity of these impacts on the species often vary by location. To the extent feasible based on the best scientific information available, those differences are discussed below.

Dams, Diversions, and Water Operations

Foothill Yellow-legged Frogs evolved in a Mediterranean climate with predictable cool, wet winters and hot, dry summers~~,~~; ~~with~~ their life cycle is adapted to these conditions. In California and other areas with a Mediterranean climate, human demands for water are at the highest when runoff and precipitation are lowest, and annual water supply varies significantly but always follows the general pattern of peak discharge declining to baseflow in the late spring or summer (Grantham et al. 2010). The Foothill Yellow-legged Frog's life cycle depends on this discharge pattern and the specific habitat conditions it produces (see the Breeding and Rearing Habitat section). Dams are ubiquitous, but not evenly distributed, in California. Figure 16 depicts the locations of dams under the jurisdiction of the Army Corps of Engineers (ACOE) and the California Department of Water Resources (DWR). Figure 17 depicts the number of surface diversions per PLSS section within the Foothill Yellow-legged Frog's range (eWRIMS 2019).

Dam operations frequently change the amount and timing of water availability; its temperature, depth, and velocity; and its capacity to transport sediment ~~transport~~ and alter channel morphology ~~altering functions~~, all of which can result in dramatic consequences on the Foothill Yellow-legged Frog's ability to survive and successfully reproduce. Several studies comparing Foothill Yellow-legged Frog populations in regulated and unregulated reaches within the same watershed investigate potential dam-effects. These studies demonstrated that dams and their operations can result in several factors that contribute to population declines and possible extirpation. These factors include confusing breeding cues, scouring and stranding of egg masses and tadpoles, reduced quality and quantity of breeding and rearing habitat, reduced tadpole growth rate, barriers to gene flow, and establishment and spread of non-native species (Hayes et al. 2016). In addition, as previously discussed in the Population Structure and Genetic Diversity section, subpopulations of Foothill Yellow-legged Frogs on regulated rivers are more isolated, and the

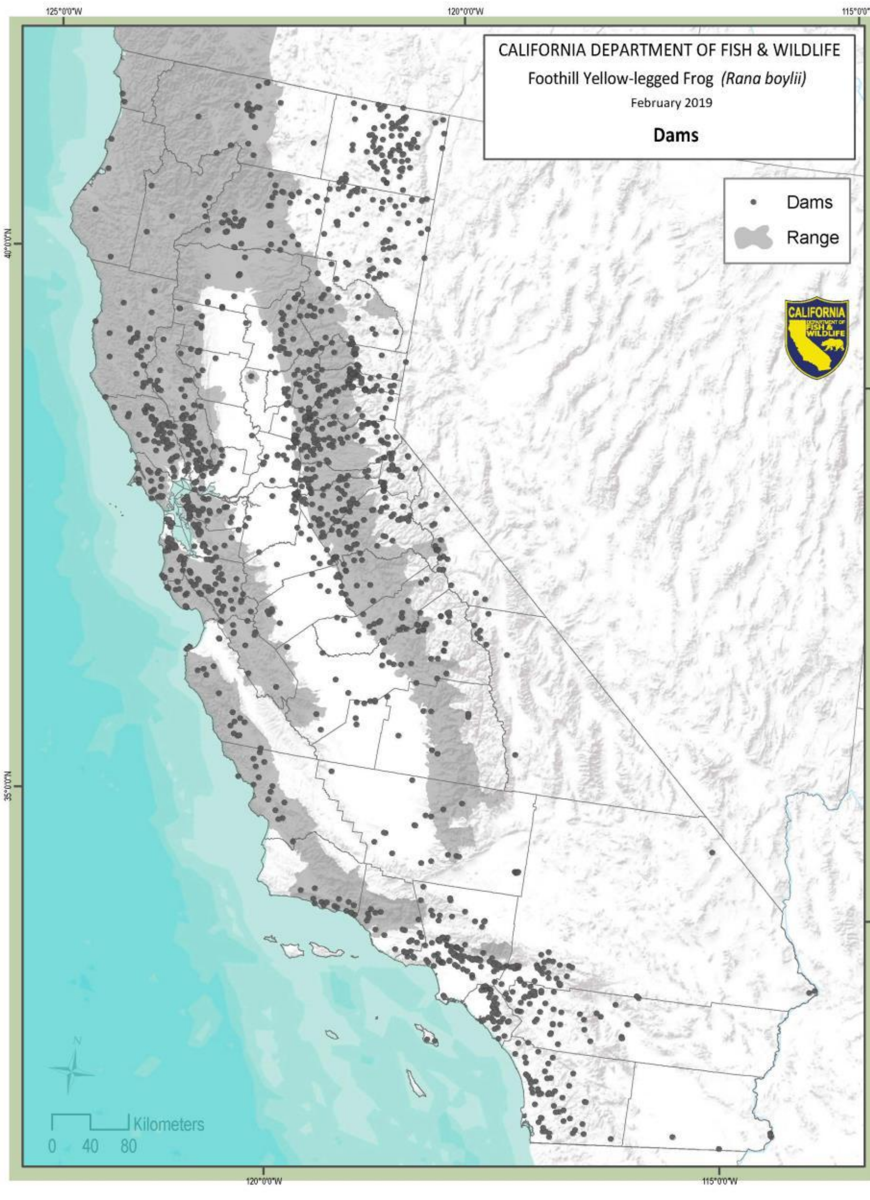

Figure 16. Locations of ACOE and DWR jurisdictional dams (DWR, FRS)

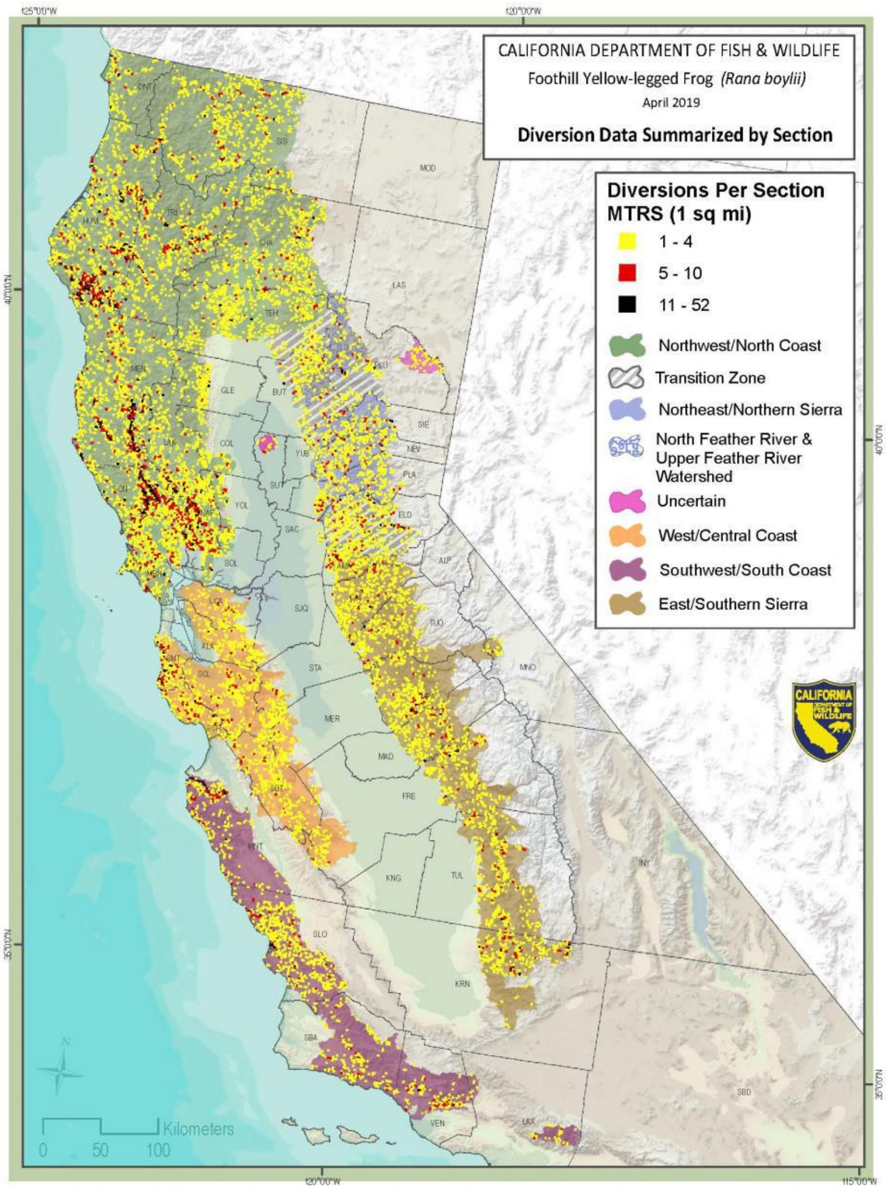

Figure 17. Number of surface water diversions per Public Lands Survey System section within the Foothill Yellow-legged Frog's range in California (eWRIMs)

type of water operations (hydropeaking vs. bypass flows) significantly affects the degree of gene flow loss among them (Peek 2011, 2018). Figure 18 depicts the locations of hydroelectric power plants.

As discussed in the Seasonal Activity and Movements section, cues for Foothill Yellow-legged Frogs to start breeding appear to involve water temperature and velocity, two features altered by dams. Dam operations typically result in reduced flows that are more stable over the course of a year than unimpaired conditions, and dam managers are frequently required to maintain thermally appropriate water temperatures and flows for cold-water-adapted salmonids (USFWS and Hoopa Valley Tribe 1999, Wheeler et al. 2014). For example, late-spring and summer water temperatures on the mainstem Trinity River below Lewiston Dam have been reported to be up to 10°C (20°F) cooler than average pre-dam temperatures, while average winter temperatures are slightly warmer (USFWS and Hoopa Valley Tribe 1999). As a result, Foothill Yellow-legged Frogs breed later on the mainstem Trinity River compared to six nearby tributaries, and some mainstem reaches may never attain the minimum required temperature for breeding (Wheeler et al. 2014, Snover and Adams 2016). In addition, annual discharges past Lewiston Dam have been 10-30% of pre-dam flows and do not mimic the natural hydrograph (Lind et al. 1996).

Aseasonal discharges from dams occur for several reasons including increased flow in late-spring and early summer to facilitate outmigration of salmonids, channel maintenance pulse flows, short-duration releases for recreational whitewater boating, rapid reductions after a spill (uncontrolled flows released down a spillway when reservoir capacity is exceeded) to retain water for power generation or water supply later in the year, peaking flows for hydroelectric power generation, and sustained releases to maintain the seismic integrity of the dam (Lind et al. 1996, Jackman et al. 2004, Kupferberg et al. 2011b, Kupferberg et al. 2012, Snover and Adams 2016). The results of a Foothill Yellow-legged Frog population viability analysis (PVA) suggest that the likelihood a population will persist is very sensitive to early life stage mortality; the 30-year probability of extinction increases significantly with high levels of egg or tadpole scouring or stranding (Kupferberg et al. 2009c). For instance, in 1991 and 1992, all egg masses laid before high flow releases to encourage outmigration of salmonids on the Trinity River were scoured away (Lind et al. 1996). According to the PVA, even a single annual pulse flow such as this or for recreational boating, can result in a three- to five-fold increase in the 30-year extinction risk based on amount of tadpole mortality experienced (Kupferberg et al. 2009c). Management after natural spills can also lead to substantial mortality. For example, in 2006, Foothill Yellow-legged Frogs on the North Fork Feather River bred during a prolonged spill, and the rapid recession below Cresta Dam that followed stranded and desiccated all the eggs laid (Kupferberg et al. 2009b). Rapid flows can also increase predation risk if tadpoles are forced to seek shelter under rocks where crayfish and other invertebrate predators are more common or if they are displaced into the water column where their risk of predation by fish is greater (Ibid.).

The overall reduction of flows and frequency of large winter floods below dams can produce extensive changes to Foothill Yellow-legged Frog habitat quality. They reduce the formation of river bars that are regularly used as breeding habitat, and they create deeper and steeper channels with less complexity and fewer warm, calm, shallow edgewater habitats for tadpole rearing (Lind et al. 1996, Wheeler and Welsh 2008, Kupferberg et al. 2011b, Wheeler et al. 2014). For example, 26 years after construction of

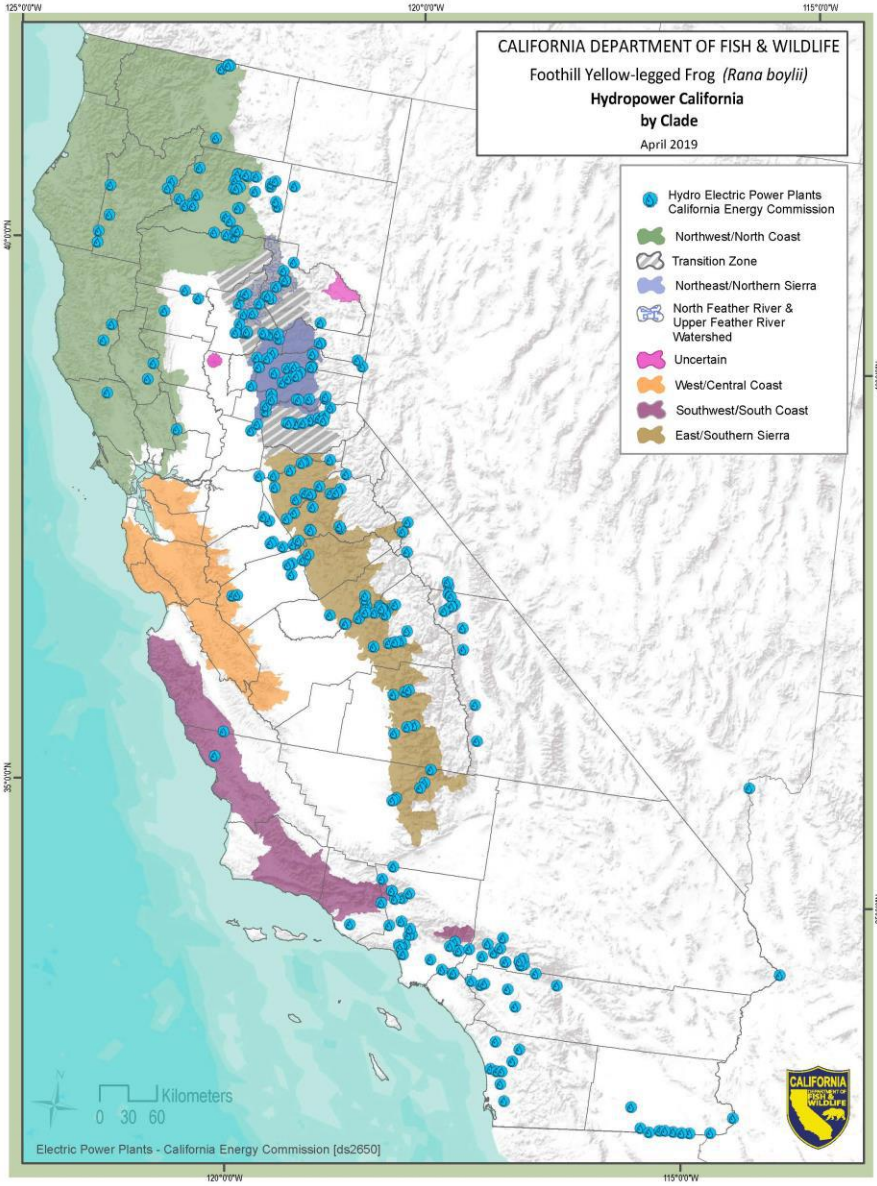

Figure 18. Locations of hydroelectric power generating dams (BIOS)

the Lewiston Dam on the Trinity River, habitat changes in a 63 km (39 mi) stretch from the dam downstream were evaluated (Lind et al. 1996). Riparian vegetation went from covering 30% of the riparian area pre-dam to 95% (Ibid.). Additionally, river bars made up 70% of the pre-dam riparian area compared to 4% post-dam, amounting to a 94% decrease in available Foothill Yellow-legged Frog breeding habitat (Ibid.).

Several features of riverine habitat below dams can decrease tadpole growth rate and other measures of fitness. As ectotherms, Foothill Yellow-legged Frogs require temperatures that support their metabolism, food conversion efficiency, growth, and development, and these temperatures may not be reached until late in the season, or not at all, when the water released is colder than their lower thermal limit (Kupferberg et al. 2011a, Catenazzi and Kupferberg 2013, Wheeler et al. 2014). Colder temperatures and higher flows reduce time spent feeding and efficiency at food assimilation, resulting in slower growth and development (Kupferberg et al. 2011a,b; Catenazzi and Kupferberg 2018). Large bed-scouring winter floods promote greater *Cladophora glomerate* blooms, the filamentous green alga that dominates primary producer biomass during the tadpole rearing season (Power et al. 2008, Kupferberg et al. 2011a). The period of most rapid tadpole growth often coincides with blooms of highly nutritious and more easily assimilated epiphytic diatoms, so reduced flows can have food-web impacts on tadpole growth and survival (Power et al. 2008, Kupferberg et al. 2011a, Catenazzi and Kupferberg 2018). In addition, colder temperatures and fluctuating summer flows, such as those released for hydroelectric power generation, can reduce the amount of algae available for grazing and can change the algal assemblage to one dominated by mucilaginous stalked diatoms like *Didymosphenia* ~~*geminate*~~ *geminata* that have low nutritional value (Spring Rivers Ecological Sciences 2003, Kupferberg et al 2011a, Furey et al. 2014). Altered temperatures, flows, and food quality can contribute to slower growth and development, longer time to metamorphosis, smaller size at metamorphosis, and reduced body condition, which adversely impact fitness (Kupferberg et al. 2011b, Catenazzi and Kupferberg 2018).

As discussed in more detail in the Population Structure and Genetic Diversity section, both are strongly affected by river regulation (Peek 2011, 2018; Stillwater Sciences 2012). Foothill Yellow-legged Frogs primarily use watercourses as movement corridors, so the reservoirs created behind dams are often uninhabitable and represent barriers to gene flow (Bourque 2008; Peek 2011, 2018). This decreased connectivity can lead to loss of genetic diversity, inducing a species' ability to adapt to changing conditions (Palstra and Ruzzante 2008).

Decreased winter discharge below dams facilitates establishment and expansion of invasive bullfrogs, whose tadpoles require overwintering and are not well-adapted to flooding events (Lind et al. 1996, Doubledee et al. 2003). Where they occur, bullfrogs tend to dominate areas more altered by dam operations than less impaired areas that support a higher proportion of native species (Moyle 1973, Fuller et al. 2011). In addition to downstream effects, the reservoirs created behind dams directly destroy lotic (flowing) Foothill Yellow-legged Frog habitat, typically do not retain natural riparian communities due to fluctuating water levels, are often managed for human activities not compatible with the species' needs, and act as a source of introduced species upstream and downstream (Brode and Bury 1984, PG&E 2018). Moyle and Randall (1998) identified characteristics of sites with low native biodiversity in the Sierra Nevada foothills; they were often drainages that had been dammed and

diverted in lower- to middle-elevations and dominated by introduced fishes and bullfrogs. Even small-scale operations can have significant effects. Some farming operations divert water during periods of high flows and store it in small impoundments for use during low flow-high need times; these ponds can serve as sources for introduced species like bullfrogs to spread into areas where the habitat would otherwise be unsuitable (Kupferberg 1996b).

The mechanisms described above result in the widespread pattern of greater Foothill Yellow-legged Frog density in unregulated rivers and in reaches far enough downstream of a dam to experience minimal effects from it (Lind et al. 1996, Kupferberg 1996a, Bobzien and DiDonato 2007, Peek 2011). Abundance in unregulated rivers averages five times greater than population abundance downstream of large dams (Kupferberg et al. 2012). Figure 19 depicts a comprehensive collection of egg mass density data where at least four years of surveys have been undertaken, showing much lower abundance in regulated (S. Kupferberg pers. comm. 2019). In California, Foothill Yellow-legged Frog presence is associated with an absence of dams or with only small dams far upstream (Lind 2005, Kupferberg et al. 2012). Hydroelectric power generation from Sierra Nevada rivers accounts for nearly half its statewide production and about 9% of all electrical power used in California (Dettinger et al. 2018). Every major stream below 600 m (1968 ft) in the Sierra Nevada has at least one large reservoir (≥ 0.12 km^3 [100,000 ac-ft]), and many have multiple medium and small ones (Hayes et al. 2016). Because of this, Catenazzi and Kupferberg (2017) posit that the dam-effect on Foothill Yellow-legged Frog populations is likely greater in the Sierra Nevada than the Coast Range because dams are more often constructed in a series along a river in the former and spaced close enough together such that suitable breeding temperatures may never occur in the intervening reaches.

Pathogens and Parasites

Perhaps the most widely recognized amphibian disease is chytridiomycosis, which is caused by the fungal pathogen *Batrachochytrium dendroabatidis* (Bd). Implicated in the decline of over 500 amphibian species, including 90 presumed extinctions, it represents the greatest recorded loss of biodiversity attributable to a disease (Scheele et al. 2019). The global trade in American Bullfrogs (primarily for food) is connected to the disease's spread because the species can persist with low-level Bd infections without developing chytridiomycosis (Yap et al. 2018). Previous studies suggested Foothill Yellow-legged Frogs may not be susceptible to Bd-associated mass mortality; skin peptides strongly inhibited growth of the fungus in the lab, and the only detectable difference between Bd+ and Bd- juvenile Foothill Yellow-legged Frogs was slower growth (Davidson et al. 2007). At Pinnacles National Park in 2006, 18% of post-metamorphic Foothill Yellow-legged Frogs tested positive for Bd; all were asymptomatic and at least one Bd+ Foothill Yellow-legged Frog subsequently tested negative, demonstrating an ability to shed the fungus (Lowe 2009). However, recent studies have found historical evidence of Bd contributing to the extirpation of Foothill Yellow-legged Frogs in southern California, an acute die-off in 2013 in the Alameda Creek watershed, and another in 2018 in Coyote Creek (Adams et al. 2017a,b; Kupferberg and Catenazzi 2019). Evaluation of museum specimens indicates lower Bd prevalence (proportion of individuals infected) in Foothill Yellow-legged Frogs than most other co-occurring amphibians in southern California in the first part of the 20th century, but it spiked in the 1970s just prior to the last observation of an individual in 1977 (Adams et al. 2017b). Two museum specimens collected in 1966,

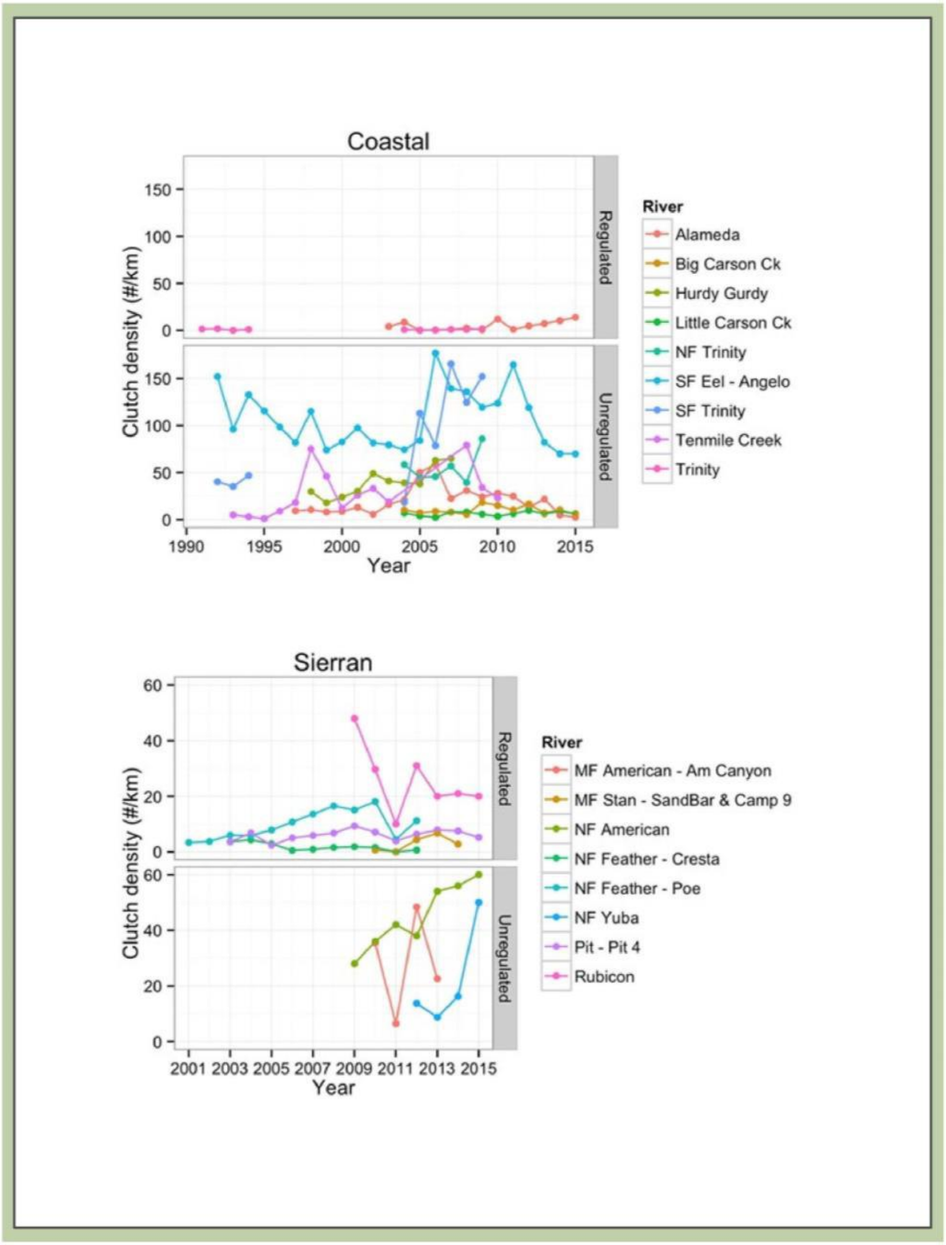

Figure 19. Foothill Yellow-legged Frog Egg mass density estimates along the coast from 1990-2015 and the Sierra Nevada from 2001-2015 from multiple studies compiled by S. Kupferberg (2019)

one from Santa Cruz County and the other from Alameda County, provide the earliest evidence of Bd in Foothill Yellow-legged Frogs in central California (Padgett-Flohr and Hopkins 2009). In contrast to the southern California results, Foothill Yellow-legged Frogs possessed the highest Bd prevalence among all amphibians tested in coastal Humboldt County in 2013 and 2014; however, zoospore (the aquatic dispersal agent) loads were well below the presumed lethal density threshold (Ecoclub Amphibian Group et al. 2016).

In addition to bullfrogs, the native Pacific Treefrog (*Pseudacris regilla*) seems immune to the lethal effects of chytridiomycosis, and owing to its broad ecological tolerances, more terrestrial lifestyle, and relatively large home range size and dispersal ability, the species is ubiquitous across California (Padgett-Flohr and Hopkins 2009). In a laboratory experiment, Bd-infected Pacific Treefrogs shed an average of 68 zoospores per minute, making them the prime candidate for spreading and maintaining Bd in areas where bullfrogs do not occur (Padgett-Flohr and Hopkins 2009, Reeder et al. 2012). In the wild, Pacific Treefrog populations persisted at 100% of sites in the Sierra Nevada (above 1500 m [4920 ft]) where a sympatric ranid species had been extirpated from 72% of its formerly occupied sites due to a Bd outbreak (Reeder et al. 2012). This is consistent with the results of a model that incorporated Bd habitat suitability, host availability, and invasion history in North America, which concluded west coast mountain ranges were at the greatest risk from the disease (Yap et al. 2018).

Several other pathogens and parasites have been encountered with Foothill Yellow-legged Frogs, but none have been ascribed to large-scale mortality events. Another fungus, a water mold (*Saprolegnia* sp.) carried by fish, is an important factor in amphibian embryo mortality in the Pacific Northwest (Blaustein et al. 1994, Kiesecker and Blaustein 1997). Fungal infections of Foothill Yellow-legged Frog egg masses, potentially from *Saprolegnia*, have been observed in the mainstem Trinity River (Ashton et al. 1997). *Saprolegnia* infection is more likely to occur in ponds and lakes, particularly if stocked by hatchery-raised fish into previously fishless areas and when frogs use communal oviposition sites, so it likely does not represent a major source of mortality in Foothill Yellow-legged Frogs (Blaustein et al. 1994, Kiesecker and Blaustein 1997). However, they may be more susceptible to *Saprolegnia* infection when exposed to other environmental stressors that compromise their immune defenses (Blaustein et al. 1994, Kiesecker and Blaustein 1997).

The trematode parasite *Ribeiroia ondatrae* is responsible for limb malformations in ranids (Stopper et al. 2002). *Ribeiroia ondatrae* was detected on a single Foothill Yellow-legged Frog during a study on malformations, but its morphology was normal (Kupferberg et al. 2009a). The results of the study instead linked malformations in Foothill Yellow-legged Frog tadpoles and young-of-year to the Anchor Worm (*Lernaea cyprinacea*), a parasitic copepod from Eurasia (Ibid.). Prevalence of malformations was low, under 4% of the population in both years of study, but there was a pattern of infected individuals metamorphosing at a smaller size, which as previously mentioned can have implications on fitness (Ibid.). Three other species of helminths (parasitic worms) were encountered during the study (*Echinostoma* sp., *Manodistomum* sp., and *Gyrodactylus* sp.); their relative impact on their hosts is unknown, but at least one Foothill Yellow-legged Frog had 700 echinostome cysts in its kidney (Ibid.). Bursey et al. (2010) discovered 13 species of helminths in and on Foothill Yellow-legged Frogs from

Humboldt County. Most are common in anurans, and some are generalists with multiple possible hosts, but studies on their impact on Foothill Yellow-legged Frogs are lacking (Ibid.).

Introduced Species

Species not native to an area, but introduced, can alter food webs and ecosystem processes through predation, competition, hybridization, disease transmission, and habitat modification. Native species lack evolutionary history with introduced species, and early life stages of native anurans are particularly susceptible to predation by aquatic non-native species (Kats and Ferrer 2003). Because introduced species often establish in highly modified habitats, it can be difficult to differentiate between impacts from habitat degradation and the introduced species (Fisher and Shaffer 1996). However, native amphibians have been frequently found successfully reproducing in heavily altered habitats when introduced species were absent, suggesting introduced species themselves can impose an appreciable adverse effect (Ibid.). Numerous introduced species have been documented to adversely impact Foothill Yellow-legged Frogs or are suspected of doing so.

American Bullfrogs were introduced to California from the eastern U.S. around the turn of the 20th century, likely in response to overharvest of native ranids by the frog-leg industry that accompanied the Gold Rush (Jennings and Hayes 1985). Nearly 50 years ago, Moyle (1973) reported that distributions of Foothill Yellow-legged Frogs and bullfrogs in the Sierra Nevada foothills were nearly mutually exclusive. He speculated that bullfrog predation and competition may be causal factors in their disparate distributions in addition to the habitat degradation from dams and diversions that facilitated the bullfrog invasion in the first place. In a study along the South Fork Eel River and one of its tributaries, Foothill Yellow-legged Frog abundance was nearly an order of magnitude lower in reaches where bullfrogs were well established (Kupferberg 1997a). At a site in Napa Valley, after bullfrogs were eradicated, Foothill Yellow-legged Frogs, among other native species, recolonized the area (J. Alvarez pers. comm. 2018). In a mesocosm experiment, Foothill Yellow-legged Frog survival in control enclosures measured half that of enclosures containing bullfrog and Foothill Yellow-legged Frog tadpoles, and they weighed approximately one-quarter lighter at metamorphosis (Kupferberg 1997a). The mechanism for these declines appeared to be the reduction of high quality algae by bullfrog tadpole grazing, as opposed to any behavioral or chemical interference (Ibid.). Adult bullfrogs, which can get very large (9.0-15.2 cm [3.5-6.0 in]), also directly consume Foothill Yellow-legged Frogs, including adults (Moyle 1973, Crayon 1998, Powell et al. 2016). Silver (2017) noted that she never heard Foothill Yellow-legged Frogs calling in areas with bullfrogs, which has implications for breeding success; she speculated the lack of vocalizations may have been a predator avoidance strategy.

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As discussed briefly in the Pathogens and Parasites section, American Bullfrogs act as reservoirs and vectors of the lethal chytrid fungus. In museum specimens from both southern and central California, Bd was detected in bullfrogs before it was detected in Foothill Yellow-legged Frogs in the same area (Padgett-Flohr and Hopkins 2009, Adams et al. 2017b). During a die-off from chytridiomycosis that commenced in 2013, Bd prevalence and load in Foothill Yellow-legged Frogs was positively predicted by bullfrog presence (Adams et al. 2017a). A similar die-off in 2018 from a nearby county appears to be related to transmission by bullfrogs as well (Kupferberg and Catenazzi 2019). In addition, male Foothill

Yellow-legged Frogs have been observed amplexing female bullfrogs, which may not only constitute wasted reproductive effort but could serve to increase their likelihood of contracting Bd (Lind et al. 2003a). In fact, adult males were more likely to be infected with Bd than females or juveniles during the recent die-off in Alameda Creek (Adams et al. 2017a). African Clawed Frogs (*Xenopus laevis*) have also been implicated in the spread of Bd in California because like bullfrogs, they are asymptomatic carriers (Padgett-Flohr and Hopkins 2009). However, African Clawed-Frog distribution only minimally overlaps with the Foothill Yellow-legged Frog's range unlike the widespread bullfrog (Stebbins and McGuinness 2012).

Hayes and Jennings (1986) observed a negative association between the abundance of introduced fish and Foothill Yellow-legged Frogs. Rainbow trout (*Onchorynchus mykiss*) and green sunfish (*Lepomis cyanellus*) are suspected of destroying egg masses (Van Wagner 1996). Bluegill sunfishes (*L. macrochirus*) are likely predators; in captivity when offered eggs and tadpoles of two ranid species, they consumed both life stages but a significantly greater number of tadpoles (Werschkul and Christensen 1977). Common hatchery-stocked fish like brook (*Salvelinus fontinalis*) and rainbow trout commonly carry ~~of~~ *Saprolegnia* (Blaustein et al. 1994). In addition, presence of non-native fish can facilitate bullfrog invasions by reducing the density of macroinvertebrates that prey on their tadpoles (Adams et al. 2003). Foothill Yellow-legged Frog tadpoles raised from eggs from sites with and without smallmouth bass (*Micropterus dolomieu*) did not differ in their responses to exposure to the non-native, predatory bass and a native, non-predatory fish (Paoletti et al. 2011). This result suggests that Foothill Yellow-legged Frogs have not yet evolved a recognition of bass as a threat, which makes them more vulnerable to predation (Ibid.).

Introduced into several areas within the Coast Range and Sierra Nevada, signal crayfish have been recorded preying on Foothill Yellow-legged Frog egg masses and are suspected of preying on their tadpoles based on observations of tail injuries that looked like scissor snips (Riegel 1959, Wiseman et al. 2005). The introduced red swamp crayfish (*Procambarus clarkii*) likely also preys on Foothill Yellow-legged Frogs. Because Foothill Yellow-legged Frogs evolved with native crayfish in northern California, individuals from those areas may more effectively avoid crayfish predation than in other parts of the state where they are not native (Riegel 1959, USFWS 1998, Kats and Ferrer 2003). The Foothill Yellow-legged Frog's naiveté ~~naivety~~ to crayfish was demonstrated in a study that showed they did not change behavior when exposed to signal crayfish chemical cues, but once the crayfish was released and consuming Foothill Yellow-legged Frog tadpoles, the survivors, likely reacting to chemical cues from dead tadpoles, did respond (Kerby and Sih 2015).

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Sedimentation

Several anthropogenic activities, some of which are described in greater detail below, can artificially increase sedimentation into waterways occupied by Foothill Yellow-legged Frogs and adversely impact biodiversity (Moyle and Randall 1998). These activities include but are not limited to mining, agriculture, overgrazing, timber harvest, and poorly constructed roads (Ibid.). Increased fine sediments can substantially degrade Foothill Yellow-legged Frog habitat quality. Heightened turbidity decreases light penetration that phytoplankton and other aquatic plants require for photosynthesis (Cordone and Kelley

1961). When silt particles fall out of the water column, they can destroy algae by covering the bottom of the stream (Ibid.). Algae are not only important for Foothill Yellow-legged Frog tadpoles as forage but also oxygen production (Ibid.). Sedimentation may impede attachment of egg masses to substrate (Ashton et al. 1997). The effect of silt accumulation on embryonic development is unknown, but it does make them less visible, which could decrease predation risk (Fellers 2005). Fine sediments can fill interstitial spaces between rocks that tadpoles use for shelter from high velocity flows and cover from predators and that serve as sources for aquatic invertebrate prey for post-metamorphic Foothill Yellow-legged Frogs (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b).

Mining

Current mining practices, as well as legacy effects from historical mining operations, may adversely impact Foothill Yellow-legged Frogs through contaminants, direct mortality, habitat destruction and degradation, and behavioral disruption. While mercury in streams can result from atmospheric deposition, storm-induced runoff of naturally occurring mercury, agricultural runoff, and geothermal springs, runoff from historical mine sites mobilizes a significant amount of mercury (Foe and Croyle 1998, Alpers et al. 2005, Hothem et al. 2010). Beginning in the mid-1800s, extensive mining occurred in the Coast Range to supply mercury for gold mining in the Sierra Nevada, causing widespread contamination of both mountain ranges and the rivers in the Central Valley (Foe and Croyle 1998). Studies on Foothill Yellow-legged Frog tissues collected from the Cache Creek (Coast Ranges) and Greenhorn Creek (Sierra Nevada) watersheds revealed mercury bioaccumulation concentrations as high as 1.7 and 0.3 µg/g (ppm), respectively (Alpers et al. 2005, Hothem et al. 2010). For context, the U.S. Environmental Protection Agency's mercury criterion for issuance of health advisories for fish consumption is 0.3 µg/g; concentrations exceeded this threshold in Foothill Yellow-legged Frog tissues at 62% of sampling sites in the Cache Creek watershed (Hothem et al. 2010). Bioaccumulation of this powerful neurotoxin can cause deleterious impacts on amphibians including inhibited growth, decreased survival to metamorphosis, increased malformations, impaired reproduction, and other sublethal effects (Zillioux et al. 1993, Unrine et al. 2004). In a study measuring Sierra Nevada watershed health, Moyle and Randall (1998) reportedly found very low biodiversity in streams that were heavily polluted by acidic water leaching from historical mines. Acidic drainage measured as low as 3.4 pH from some mined areas in the northern Sierra Nevada (Alpers et al. 2005).

Widespread suction dredging for gold occurred in the Foothill Yellow-legged Frog's California range until enactment of a moratorium on issuing permits in 2009 (Hayes et al. 2016). Suction dredging vacuums up the contents of the streambed, passes them through a sluice box to separate the gold, and then deposits the tailings on the other side of the box (Harvey and Lisle 1998). While most habitat disturbance is localized and minor, it can be especially detrimental if it degrades or destroys breeding and rearing habitat through direct disturbance or sedimentation (Ibid.). In addition, this activity can lead to direct mortality of early life stages through entrainment, and those eggs and tadpoles that do survive passing through the suction dredge may experience greater mortality due to subsequent unfavorable physiochemical conditions and possible increased predation risk (Ibid.). Suction dredging can also reduce the availability of invertebrate prey, although this impact is typically short-lived (Ibid.). Suction dredging alters stream morphology, and relict tailing ponds can serve as breeding habitat for bullfrogs in areas

that would not normally support them (Fuller et al. 2011). However, in some areas these mining holes have reportedly benefited Foothill Yellow-legged Frogs by creating cool persistent pools that adult females appeared to prefer at one Sierra Nevada site (Van Wagner 1996). Senate Bill 637 (2015) directs the Department to work with the State Water Resources Control Board (SWRCB) to develop a statewide water quality permit that would authorize the use of vacuum or suction dredge equipment in California under conditions set forth by the two agencies. SWRCB staff, in coordination with Department staff, are in the process of collecting additional information to inform the next steps that will be taken by the SWRCB (SWRCB 2019).

Instream aggregate (gravel) mining continues today and can have similar impacts to suction dredge mining by removing, processing, and relocating stream substrates (Olson and Davis 2009). This type of mining typically removes bars used as Foothill Yellow-legged Frog breeding habitat and reduces habitat heterogeneity by creating flat wide channels (Kupferberg 1996a). Typically, when listed salmonids are present, mining must be conducted above the wetted edge, but this practice can create perennial off-channel bullfrog breeding ponds (M. van Hattem pers. comm. 2018).

Agriculture

Direct loss of Foothill Yellow-legged Frog habitat from wildland conversion to agriculture is rare because the typically rocky riparian areas they inhabit are usually not conducive to farming, but removal of riparian vegetation directly adjacent to streams for agriculture is more common and widespread. The U.S. Department of Agriculture classifies 3.9 million ha (9.6 million ac) in California as cropland, which amounts to less than 10% of the state's land area, and 70% of this occurs in the Central Valley between Redding and Bakersfield (Martin et al. 2018). In addition, several indirect impacts can adversely affect Foothill Yellow-legged Frogs at substantial distances from agricultural operations such as effects from runoff (sediments and agrochemicals), drift and deposition of airborne pollutants, water diversions, and creation of novel habitats like impoundments that facilitate spread of detrimental non-native species. As sedimentation and introduced species impacts were previously discussed, this section instead focuses on the other possible adverse impacts.

Agrochemicals

Many species of amphibians, particularly ranids, have experienced declines throughout California, but the most dramatic declines have occurred in the Sierra Nevada east of the San Joaquin Valley where 60% of the total pesticide usage in the state was sprayed (Sparling et al. 2001). Agrochemicals applied to crops in the Central Valley can volatilize and travel in the atmosphere and deposit in higher elevations (LeNoir et al. 1999). Pesticide concentrations diminish as elevations increase in the lower foothills but change little from 533 to 1,920 m (1,750-6,300 ft), which coincides with the Foothill Yellow-legged Frog's elevational range (Ibid). Foothill Yellow-legged Frog absence at historically occupied sites in California significantly correlated with agricultural land use within 5 km (3 mi), and a positive relationship exists between Foothill Yellow-legged Frog declines and the amount of upwind agriculture, suggesting airborne agrochemicals may be a contributing factor (Figure 20; Davidson et al. 2002). Cholinesterase-inhibitors (most organophosphates and carbamates), which disrupt nerve impulse transmission, were

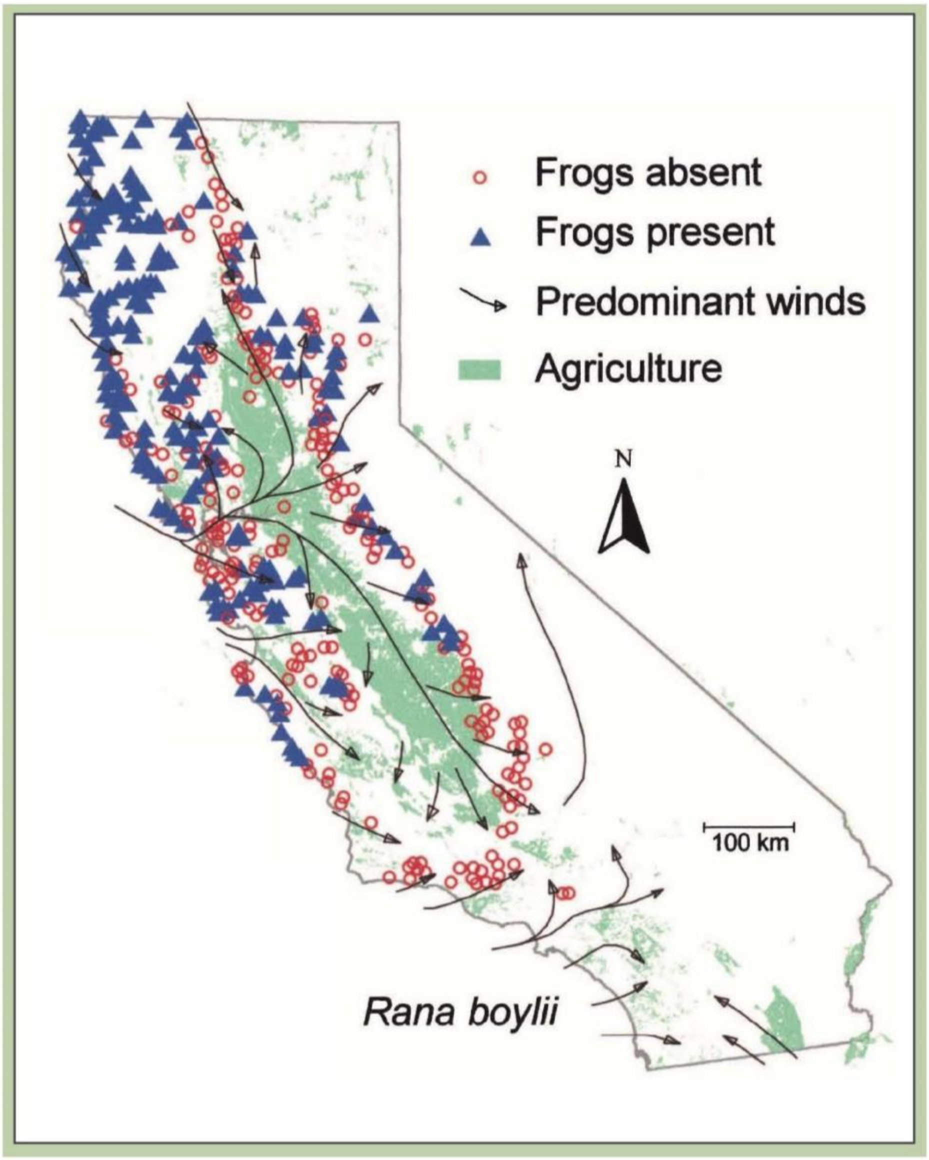


Figure 20. Relationship of Foothill Yellow-legged Frog occupancy to agriculture from Davidson et al. (2002)

more strongly associated with population declines than other pesticide types (Davidson 2004). Olson and Davis (2009) and Lind (2005) also reported a negative correlation between Foothill Yellow-legged Frog presence and proximity and quantity of nearby agriculture in Oregon and across the species' entire range, respectively.

Lethal and sublethal effects of agrochemicals on amphibians can take two general forms: direct toxicity and food-web effects. Sublethal doses of agrochemicals can interact with other environmental stressors to reduce fitness. Foothill Yellow-legged Frog tadpoles showed significantly greater vulnerability to the lethal and sublethal effects of carbaryl than Pacific Treefrogs (Kerby and Sih 2015). An inverse relationship exists between carbaryl concentration and Foothill Yellow-legged Frog activity, and their 72-h LC_{50} (concentration at which 50% die) measured one-fifth that of Pacific Treefrogs (Ibid.). Carbaryl slightly decreased Foothill Yellow-legged Frog development rate, but it significantly increased susceptibility to predation by signal crayfish despite nearly no mortality in the pesticide- and predator-only treatments (Ibid.). Sparling and Fellers (2009) also found Foothill Yellow-legged Frogs were significantly more sensitive to pesticides (chlorpyrifos and endosulfan in this study) than Pacific Treefrogs; their 96-hr LC_{50} was nearly five-times less than for treefrogs. Endosulfan was nearly 121 times more toxic to Foothill Yellow-legged Frogs than chlorpyrifos, and water samples from the Sierra Nevada have contained endosulfan concentrations within their lethal range and sometimes greater than the LC_{50} for the species (Ibid.). Sublethal effects included smaller body size, slower development rate, and increased time to metamorphosis (Ibid.). Sparling and Fellers (2007) determined the organophospates chlorpyrifos, malathion, and diazinon can harm Foothill Yellow-legged Frog populations, and their oxon derivatives (the resultant compounds once they begin breaking down in the body) were 10 to 100 times more toxic than their respective parental forms.

Extrapolating the results of studies on other ranids to Foothill Yellow-legged Frogs should be undertaken with caution; however, those studies can demonstrate additional potential adverse impacts of exposure to agrochemicals. Relyea (2005) discovered that Roundup®, a common herbicide, could cause rapid and widespread mortality in amphibian tadpoles via direct toxicity, and overspray at the manufacturer's recommended application concentrations would be highly lethal. Atrazine, another common herbicide, has been implicated in disrupting reproductive processes in male Northern Leopard Frogs (*Rana pipiens*) by slowing gonadal development, inducing hermaphroditism, and even oocyte (egg) growth (Hayes et al. 2003). However, recent research on sex reversal in wild populations of Green Frogs (*R. clamitans*) suggests it may be a relatively common natural process unrelated to environmental contaminants, requiring more research (Lambert et al. 2019). Malathion, a common organophosphate insecticide, that rapidly breaks down in the environment, applied at low concentrations caused a trophic cascade that resulted in reduced growth and survival of two species of ranid tadpoles (Relyea and Diecks 2008). Malathion caused a reduction in the amount of zooplankton, which resulted in a bloom of phytoplankton and an eventual decline in periphyton, an important food source for tadpoles (Ibid.). In contrast, Relyea (2005) found that some insecticides increased amphibian tadpole survival by reducing their invertebrate predators. Runoff from agricultural areas can contain fertilizers that input nutrients into streams and increase productivity, but they can also result in harmful algal blooms (Cordone and

Kelley 1961). In addition, exposure to pesticides can result in immunosuppression and reduce resistance to the parasites that cause limb malformations (Kiesecker 2002, Hayes et al. 2006).

Cannabis

An estimated 60-70% of the cannabis (*Cannabis indica* and *C. sativa*) used in the U.S. from legal and illegal sources is grown in California, and most comes from the Emerald Triangle, an area comprised of Humboldt, Mendocino, and Trinity counties (Ferguson 2019). Small-scale illegal cannabis farms have operated in this area since at least the 1960s but have expanded rapidly, particularly trespass grows on public land primarily by Mexican cartels, since the passage of the Compassionate Use Act in 1996 (Mallery 2010, Bauer et al. 2015). Like other forms of agriculture, it involves clearing the land, diverting water, and using herbicides and pesticides; however, in addition, many of these illicit operations use large quantities of fertilizers and highly toxic banned pesticides to kill anything that may threaten the crop, and they leave substantial amounts of non-biodegradable trash and human excrement (Mallery 2010, Thompson et al. 2014, Carah et al. 2015).

Measurements of environmental impacts of illegal cannabis grows have been hindered by the difficult and dangerous nature of accessing many of these sites; however, some analyses have been conducted, often using aerial images and geographic information systems (GIS). An evaluation of 54% of watersheds within and bordering Humboldt County revealed that while cannabis grow sites are generally small (< 0.5 ha [1.2 ac]) and comprised a tiny fraction of the study area (122 ha [301 ac]), they were widespread (present in 83% of watersheds) but unevenly distributed, indicating impacts are concentrated in certain watersheds (Butsic and Brenner 2016, Wang et al. 2017). The results also showed that 68% of grows were > 500 m (0.3 mi) from developed roads, 23% were located on slopes steeper than 30%, and 5% were within 100 m (328 ft) of critical habitat for threatened salmonids (Butsic and Brenner 2016). These characteristics suggest wildlands adjacent to cannabis cultivations are at heightened risk of habitat fragmentation, erosion, sedimentation, landslides, and impacts to waterways critical to imperiled species (Ibid.).

A separate analysis in the same general area estimated potentially significant impacts from water diversions alone. Cannabis requires a substantial amount of water during the growing season, so it is often cultivated near sources of perennial surface water for irrigation, commonly diverting from springs and headwater streams (Bauer et al. 2015). In the least impacted of the study watersheds, Bauer et al. (2015) calculated that diversions for cannabis cultivation could reduce the annual seven-day low flow by up to 23%, and in some of the heavily impacted watersheds, water demands for cannabis could exceed surface water availability. If not regulated carefully, cannabis cultivation could have substantial impacts on sensitive aquatic species like Foothill Yellow-legged Frogs in watersheds in which it is concentrated.

For context, cannabis cultivation was responsible for approximately 1.1% of forest cover lost within study watersheds in Humboldt County from 2000 to 2013, while timber harvest accounted for 53.3% (Wang et al. 2017). Cannabis requires approximately two times as much water per day as wine grapes, the other major irrigated crop in the region (Bauer et al. 2015). Impacts from cannabis cultivation have been observed by Foothill Yellow-legged Frog researchers working on the Trinity River and South Fork

Eel River in the form of lower flows in summer, increased egg stranding, and more algae earlier in the season in recent years (S. Kupferberg and M. Power pers. comm. 2015; D. Ashton pers. comm. 2017; S. Kupferberg, M. van Hattem, and W. Stokes pers. comm. 2017). In addition, Gonsolin (2010) reported illegal cannabis cultivations on four headwater streams that drained into his study area along Coyote Creek, three of which were occupied by Foothill Yellow-legged Frogs. The cultivators had removed vegetation adjacent to the creeks, terraced the slopes, diverted water, constructed small water impoundments, poured fertilizers directly into the impoundments, and applied herbicides and pesticides, as evidenced by leftover empty containers littering the site.

Commercial sale of cannabis for recreational use became legal in California on January 1, 2018, through passage of the Control, Regulate and Tax Adult Use of Marijuana Act (2016), and with it an environmental permitting system and habitat restoration fund was established. The number of applications for temporary licenses per watershed is depicted in Figure 21. Two of the expected outcomes of passage of this law were that the profit-margin on growing cannabis would fall to the point that it would discourage illegal trespass grows and move the bulk of the cultivation out of remote forested areas into existing agricultural areas like the Central Valley (CSOS 2016). However, until cannabis is legalized at the federal level, these results may not occur since banks are reluctant to work with growers due to federal prohibitions subjecting them to prosecution for money laundering (ABA 2019). Additional details on cannabis permitting at the state level can be found under the Existing Management section.

Vineyards

Vineyard operators historically built on-stream dams and removed almost all the riparian vegetation to make room for vines and for ease of irrigation (M. van Hattem pers. comm. 2019). They still divert a substantial amount of water for irrigation, and they build on- and off-stream impoundments that support bullfrogs (Ibid.). The acreage of land planted in wine grapes in California began rising dramatically in the 1970s and now accounts for 90% of wine produced in the U.S. (Geisseler and Horwath 2016, Alston et al. 2018). The number of wineries in California rose from approximately 330 to nearly 2,500 between 1975 and 2006; however, expansion slowed and has reversed slightly recently with 24,300 ha (60,000 ac), or 6.5% of total area planted, removed between 2015 and 2017 (Volpe et al. 2010, CDFA 2018). In 2015, 347,000 ha (857,000 ac) were planted in grapes with 70% located in the San Joaquin Valley; 66%, 21%, and 13% were planted in wine, raisin, and table grapes, respectively (Alston et al. 2018).

Expansion of wineries in the coastal counties converted natural areas such as oak woodlands and forests to vineyards (Merenlender 2000, Napa County 2010). The area of Sonoma County covered in grapes increased by 32% from 1990 to 1997, and 42% of these new vineyards were planted above 100 m (328 ft) with 25% on slopes greater than 18% (Merelender 2000). For context, only 18% of vineyards planted before 1990 occurred above 100 m (328 ft) and less than 6% on slopes greater than 18% (Ibid.). This conversion took place on approximately 773 ha (1,909 ac) of conifer and dense hardwood forest, 149 ha (367 ac) of shrubland, and 2,925 ha (7,229 ac) of oak grassland savanna (Ibid.).

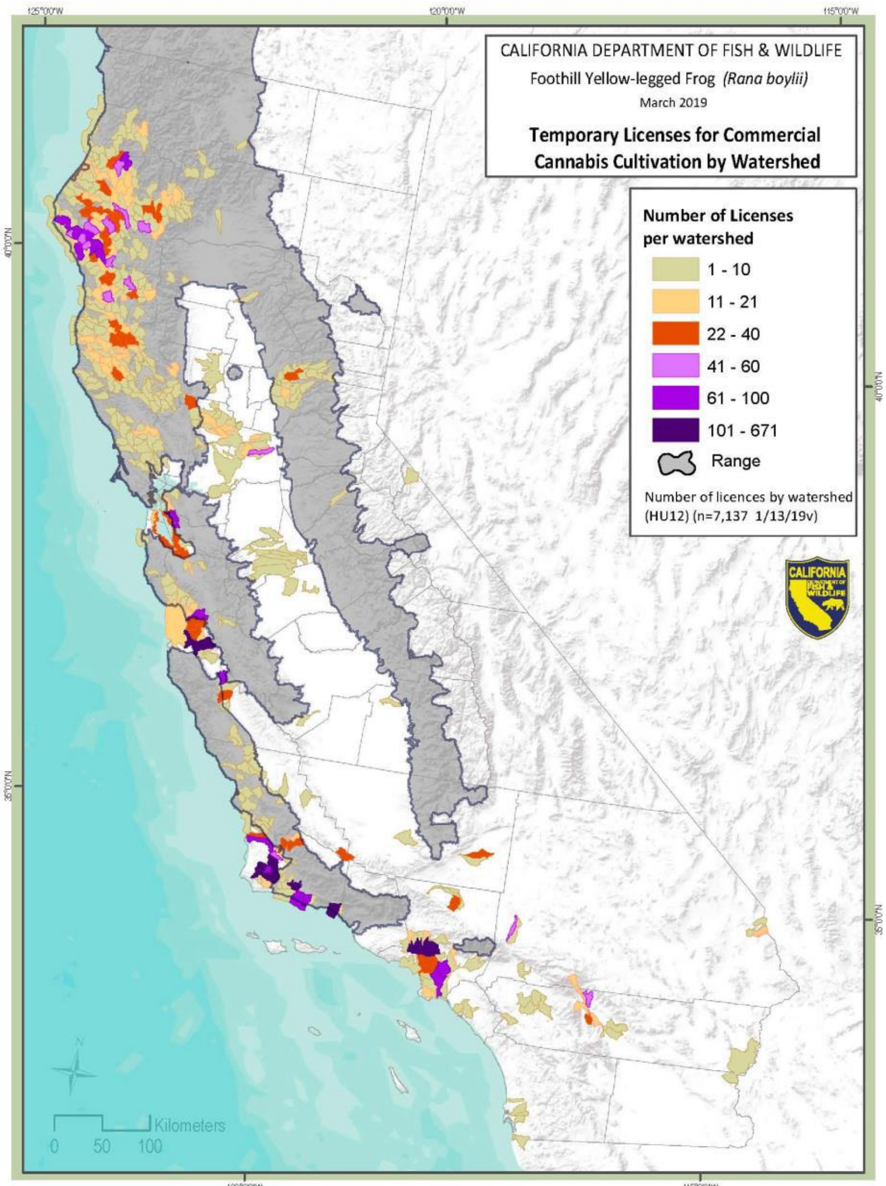


Figure 21. Cannabis cultivation temporary licenses by watershed in California (CDFA, NHD)

Recent expansion of oak woodland conversion to vineyards in Napa County was highest in its eastern hillsides (Napa County 2010). The County estimates that 1,085 and 1,240 ha (2,682-3,065 ac) of woodlands will be converted to vineyards between 2005 and 2030 (Ibid.). For context, 297 ha (733 ac) were converted from 1992 to 2003 (Ibid.). In addition, wine grapes were second only to almonds in terms of overall quantity of pesticides applied in California in 2016, but the quantity per unit area (2.9 kg/ha [2.6 lb/ac]) was 160% greater for the wine grapes (CDPR 2018). Vineyard expansion into hillsides has continued into sensitive headwater areas, and like cannabis cultivation, even small vineyards can have substantial impacts on Foothill Yellow-legged Frog habitat through sedimentation, water diversions, spread of harmful non-native species, and pesticide contamination (Merelender 2000, K. Weiss pers. comm. 2018).

Livestock Grazing

Livestock grazing can be an effective habitat management tool, including control of riparian vegetation encroachment, but overgrazing can significantly degrade the environment (Siekert et al. 1985). Cattle display a strong preference for riparian areas and have been implicated as a major source of habitat damage in the western U.S. where the adverse impacts of overgrazing on riparian vegetation are intensified by arid and semi-arid climates (Behnke and Raleigh 1978, Kauffman and Krueger 1984, Belsky et al. 1999). The severity of grazing impacts on riparian systems can be influenced by the number of animals, duration and time of year, substrate composition, and soil moisture (Benhke and Raleigh 1978, Kauffman et al. 1983, Marlow and Pogacnik 1985, Siekert et al. 1985). In addition to habitat damage, cattle can directly trample any life stage of Foothill Yellow-legged Frog.

Signs of overgrazing include impacts to the streambanks such as increased slough-offs and cave-ins that collapse undercuts used as refuge (Kauffman et al. 1983). Overgrazing reduces riparian cover, increases erosion and sedimentation, which as described above can result in silt degradation of breeding, rearing, and invertebrate food-producing areas (Cordone and Kelley 1961, Behnke and Raleigh 1978, Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). Loss of streamside and instream vegetative cover and changes to channel morphology can increase water temperatures and velocities (Behnke and Raleigh 1978). Water quality can be affected by increased turbidity and nutrient input from excrement, and seasonal water quantity can be impacted through changes to channel morphology (Belsky et al. 1999). In addition, increased nutrients and temperatures can promote blooms of harmful cyanobacteria like *Microcystis aeruginosa*, which releases a toxin when it expires that can cause liver damage to amphibians as well as other animals including humans (Bobzien and DiDonato 2007, Zhang et al. 2013).

While some recent studies indicate livestock grazing continues to damage stream and riparian ecosystems, its impact on Foothill Yellow-legged Frogs in California is unknown (Belsky et al. 1999, Hayes et al. 2016). In Oregon, the species' presence was correlated with significantly less grazing than where they were absent according to Borisenko and Hayes's 1999 report (as cited in Olson and Davis 2009). However, Fellers (2005) reported that apparently some Coast Range foothill populations occupying streams draining east into the San Joaquin Valley were doing well at the time of publication despite being heavily grazed.

Urbanization and Road Effects

Habitat conversion and fragmentation combined with modified environmental disturbance regimes can substantially jeopardize biological diversity (Tracey et al. 2018). This threat is most severe in areas like California with Mediterranean-type ecosystems that are biodiversity hot spots, fire-prone, and heavily altered by human land use (Ibid.). From 1990 to 2010, the fastest-growing land use type in the conterminous U.S. was new housing construction, which rapidly expanded the wildland-urban interface (WUI) where houses and natural vegetation meet or intermix on the landscape (Radeloff et al. 2018).

Of several variables tested, proportion of urban land use within a 5 km (3.1 mi) radius of a site was associated with Foothill Yellow-legged Frog declines (Davidson et al. 2002). Lind (2005) also found significantly less urban development nearby and upwind of sites occupied by Foothill Yellow-legged Frogs, suggesting pollutant drift may be a contributing factor. Changes in wildfires may also contribute to the species' declines; 95% of California's fires are human-caused, and wildfire issues are greatest at the WUI (Syphard et al. 2009, Radeloff et al. 2018). Population density, intermix WUI (where wildland and development intermingle as opposed to an abrupt interface), and distance to WUI explained the most variability in fire frequency (Syphard et al. 2007). In addition to wildfires, habitat loss, and fragmentation, urbanization can impact adjacent ecosystems through non-native species introduction, native predator subsidization, and disease transmission (Bar-Massada et al. 2014).

Projections show growth in California's population to 51 million people by 2060 from approximately 40 million currently (PPIC 2019). This will increase urbanization, the WUI, and habitat fragmentation. The Department of Finance projects the Inland Empire, the San Joaquin Valley, and the Sacramento metropolitan area will be the fastest-growing regions of the state over the next several decades (Ibid.). This puts the greatest pressure in areas outside of the Foothill Yellow-legged Frog's range; however, because the environmental stressors associated with urbanization can span far beyond its physical footprint, they may still adversely affect the species.

Highways are frequently recognized as barriers to dispersal that fragment habitats and populations; however, single-lane roads can pose significant risks to wildlife as well (Cook et al. 2012, Brehme et al. 2018). Foothill Yellow-legged Frogs are at risk of being killed by vehicles when roads are located near their habitat (Cook et al. 2012, Brehme et al. 2018). Fifty-six juvenile Foothill Yellow-legged Frogs were found on a road adjacent to Sulphur Creek (Mendocino County), seven of which had been struck and killed (Cook et al. 2012). When fords (naturally shallow areas) are used as vehicle crossings, they can create sedimentation and poor water quality, and in some cases, the fords are gravel or cobble bars used by Foothill Yellow-legged Frogs for breeding that could result in direct mortality (K. Blanchard pers. comm. 2018, R. Bourque pers. comm. 2018). Construction of culverts under roads to keep vehicles out of the streambed can result in varying impacts. In some cases, they can impede dispersal and create deep scoured pools that support predatory fish and frogs, but when properly constructed, they can facilitate frog movement up and down the channel with reduced road mortality (Van Wagner 1996, GANDA 2008). In areas where non-native species are not a threat, but premature drying is, pools created by culverts can provide habitat in otherwise unsuitable areas (M. Grefsrud pers. comm. 2019). An evaluation of the impact of roads on 166 native California amphibians and reptiles through direct

morality and barriers to movement concluded that Foothill Yellow-legged Frogs, at individual and population levels, were at moderate risk of road impacts in aquatic habitat but very low risk of impacts in terrestrial habitat (Brehme et al. 2018). For context, all chelonids (turtles and tortoises), 72% of snakes, 50% of anurans, 18% of lizards, and 17% of salamander species in California were ranked as having a high or very high risk of negative road impacts in the same evaluation (Ibid.).

Poorly constructed roadways near rivers and streams can result in substantial erosion and sedimentation, leading to reduced amphibian densities (Welsh and Ollivier 1998). Proximity of roads to Foothill Yellow-legged Frog habitat contributes to petrochemical runoff and poses the threat of spills (Ashton et al. 1997). A diesel spill on Hayfork Creek (Trinity County) resulted in mass mortality of Foothill Yellow-legged Frog tadpoles and partial metamorphs (Bury 1972). Roads have also been implicated in the spread of disease and may have aided in the spread of Bd in California (Adams et al. 2017b).

Frogs use auditory and visual cues to defend territories and attract mates, and some studies reveal that realistic levels of traffic noise can impede transmission and reception of these signals (Bee and Swanson 2007). Some male frogs have been observed changing the frequency of their calls to increase the distance they can be heard over traffic noise, but if females have evolved to recognize lower pitched calls as signs of superior fitness, this potential trade-off between audibility and attractiveness could have implications for reproductive success (Parris et al. 2009). In a separate study, traffic noise caused a change in male vocal sac coloration and an increase in stress hormones, which changed sexual selection processes and suppressed immunity (Troïanowski et al. 2017). Because Foothill Yellow-legged Frogs mostly call underwater and are not known to use color displays, communication cues may not be adversely affected by traffic noise, but their stress response is unknown.

Timber Harvest

Because Foothill Yellow-legged Frogs tend to remain close to the water channel (i.e., within the riparian corridor) and current timber harvest practices minimize disturbance in riparian areas for the most part, adverse effects from timber harvest are expected to be relatively low (Hayes et al. 2016, CDFW 2018b). However, some activities have a potential to negatively impact Foothill Yellow-legged Frogs or their habitat, including direct mortality and increased sedimentation during construction and decommissioning of watercourse crossings and infiltration galleries, tree felling, log hauling, and entrainment by water intakes or desiccation of eggs and tadpoles through stranding from dewatering during drafting operations (CDFW 2018b,c). In addition to impacts previously described under the Sedimentation and Road Effects section, when silt runoff into streams is accompanied by organic materials, such as logging debris, impaired water quality can result, including reduced dissolved oxygen, which is important in embryonic and tadpole development (Cordone and Kelley 1961).

Because Foothill Yellow-legged Frogs are heliotherms (i.e, they bask in the sun to raise their body temperature) and sensitive to thermal extremes, some moderate timber harvest may benefit the species (Zweifel 1955, Fellers 2005). Ashton (2002) reported 85% of his Foothill Yellow-legged Frog observations occurred in second-growth forests (37-60 years post-harvest) as opposed to late-seral forests and postulated that the availability of some open canopy areas played a major part in this

disparity. Foothill Yellow-legged Frogs are typically absent in areas with closed canopy (Welsh and Hodgson 2011). Reduced canopy also raises stream temperatures, which could improve tadpole development and promote algal and invertebrate productivity in otherwise cold streams (Olson and Davis 2009; Catenazzi and Kupferberg 2013,2017).

Recreation

Several types of recreation can adversely impact Foothill Yellow-legged Frogs, and some are more severe and widespread than others. One of the main potential factors identified by herpetologists as contributing to disappearance of Foothill Yellow-legged Frogs in southern California was increased and intensified recreation in streams (Adams et al. 2017b). The greater number of people traveling into the backcountry may have facilitated the spread Bd to these areas, and while no evidence shows stress from disturbance or other environmental pressures increases susceptibility to Bd, the stress hormone corticosterone has been implicated in immunosuppression (Hayes et al. 2003, Adams et al. 2017b).

The amount of Foothill Yellow-legged Frog habitat disturbed by off-highway motor vehicles (OHV) throughout its range in California is unknown, but its impacts can be significant, particularly in areas with small isolated populations (Kupferberg et al. 2009c, Kupferberg and Furey 2015). An example is the Carnegie State Vehicular Recreation Area (CVSRA), located in the hills southwest of Tracy in the Corral Hollow Creek watershed (Alameda and San Joaquin counties). The above-described road effects apply: sedimentation, crushing along trail crossings, and potential noise effects (Ibid.). In addition, dust suppression activities employed by CSVRA use magnesium chloride ($MgCl_2$), which has the potential to harm developing embryos and tadpoles (Karraker et al. 2008, Hopkins et al. 2013, OHMVRC 2017). Based on museum records, Foothill Yellow-legged Frogs were apparently abundant in Corral Hollow Creek, but they are extremely rare now and are already extirpated or at risk of extirpation (Kupferberg et al. 2009c, Kupferberg and Furey 2015).

Motorized and non-motorized recreational boating can also impact Foothill Yellow-legged Frogs. The impacts of jet boat traffic were investigated in Oregon; in areas with frequent use and high wakes breaking on shore, Foothill Yellow-legged Frogs were absent (Borisenko and Hayes 1999 as cited in Olson and Davis 2009). This wake action had the potential to dislodge egg masses, strand tadpoles, disrupt adult basking behavior, and erode shorelines (Ibid.). Jet boat tours and races on the Klamath River (Del Norte and Humboldt counties) may have an impact on Foothill Yellow-legged Frog use of the mainstem (M. van Hattem pers. comm. 2019). In addition, using gravel bars as launch and haul out sites for boat trailers, kayaks, or river rafts can result in direct loss of egg masses and tadpoles or damage to breeding and rearing habitat and can disrupt post-metamorphic frog behavior (Ibid.). As described above, pulse flows released for whitewater boating in the late spring and summer can result in scouring and stranding of egg masses and tadpoles (Borisenko and Hayes 1999 as cited in Olson and Davis 2009, Kupferberg et al. 2009b). In addition, the velocities that resulted in stunted growth and increased vulnerability to predation in Foothill Yellow-legged Frog tadpoles were less than the increased velocities experienced in nearshore habitats during intentional release of recreational flows for whitewater boating, as well as hydropeaking for power generation (Kupferberg et al. 2011b).

Hiking, horse-riding, camping, fishing, and swimming, particularly in sensitive breeding and rearing habitat can also adversely impact Foothill Yellow-legged Frog populations (Borisenko and Hayes 1999 in Olson and Davis 2009). Because Foothill Yellow-legged Frog breeding activity was being disturbed and egg masses were being trampled by people and dogs using Carson Falls (Marin County), the land manager established an educational program, including employing docents on weekends that remind people to stay on trails and tread lightly to try to reduce the loss of Foothill Yellow-legged Frog reproductive effort (Prado 2005). In addition, within his study site, Van Wagner (1996) reported that a property owner moved rocks that were being used as breeding habitat to create a swimming hole. The extent to which this is more than a small, local problem is unknown, but as the population of California increases, recreational pressures in Foothill Yellow-legged Frog habitat are likely to increase commensurately.

Drought

Drought is a common phenomenon in California and is characterized by lower than average precipitation. Lower precipitation in general results in less surface water, and water availability is critical for obligate stream-breeding species. Even in the absence of drought, a positive relationship exists between precipitation and latitude within the Foothill Yellow-legged Frog's range in California, and mean annual precipitation has a strong influence on Foothill Yellow-legged Frog presence at historically occupied sites (Davidson et al. 2002, Lind 2005). Figure 22 depicts the recent historical annual average precipitation across the state as well as during the most recent drought and how they differ. Southern California is normally drier than northern California, but the severity of the drought was even greater in the south.

Reduced precipitation can result in deleterious effects to Foothill Yellow-legged Frogs beyond the obvious premature drying of aquatic habitat. When stream flows recede during the summer and fall, sometimes the isolated pools that stay perennially wet are the only remaining habitat. This phenomenon concentrates aquatic species, resulting in several potentially significant adverse impacts. Stream flow volume was negatively correlated with Bd load during a recent chytridiomycosis outbreak in the Alameda Creek watershed (Adams et al. 2017a). The absence of high peak flows in winter coupled with wet years allowed bullfrogs to expand their distribution upstream, and the drought-induced low flows in the fall concentrated them with Foothill Yellow-legged Frogs in the remaining drying pools (Ibid.). This mass mortality event appeared to have been the result of a combination of drought, disease, and dam effects (Ibid.). This die-off occurred in a regulated reach that experiences heavy recreational use and presence of crayfish and bass (Ibid.). Despite these threats, the density of breeding females in this reach was greater in 2014 and 2015 than ~~the~~ in the unregulated reach upstream because the latter dried completely before tadpoles could metamorphose during the preceding drought years (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015).

In addition to increasing the spread of pathogens, drought-induced stream drying can increase predation and competition by introduced fish and frogs in the pools they are forced to share (Moyle 1973, Hayes and Jennings 1988, Drost and Fellers 1996). This concentration in isolated pools can also result in increased native predation as well as facilitate spread of Bd. An aggregation of six adult Foothill

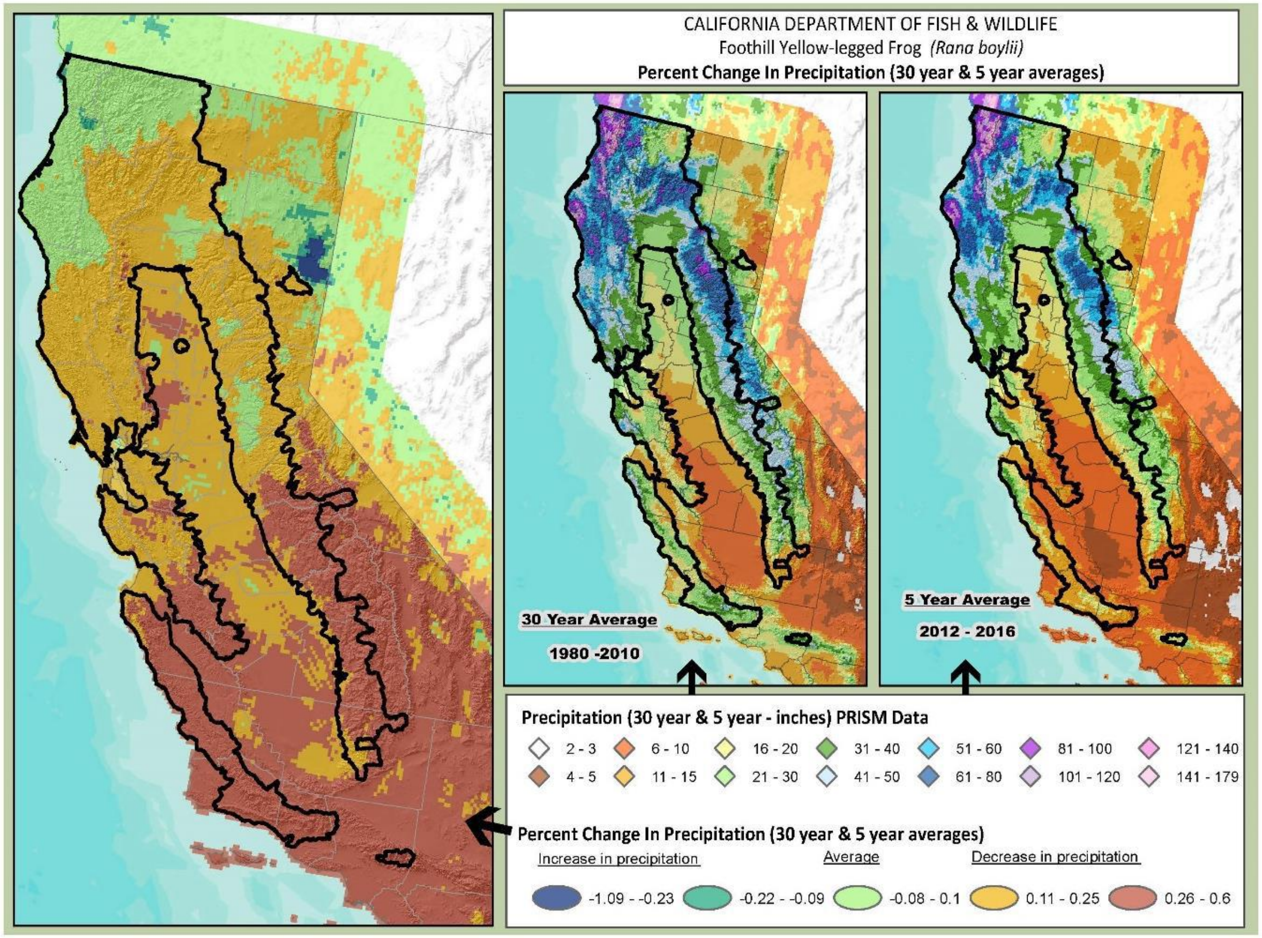


Figure 22. Change in precipitation from 30-year average and during the recent drought (PRISM)

Yellow-legged Frogs was observed perched on a rock above an isolated pool where a gartersnake was foraging on tadpoles during the summer; this close contact may reduce evaporative water loss when they are forced out of the water during high temperatures, but it can also increase disease transmission risk (Leidy et al. 2009.). Gonsolin (2010) also documented a late summer aggregation of juvenile Foothill Yellow-legged Frogs out of water during extremely high temperatures. In addition, drought-induced low flow, high water temperatures, and high densities of tadpoles were associated with outbreaks of malformation-inducing parasitic copepods (Kupferberg et al. 2009a).

Rapidly receding spring flows can result in stranding egg masses and tadpoles. However, this risk is likely less significant when it is drought-induced on an unregulated stream vs. a result of dam operations since Foothill Yellow-legged Frogs have evolved to initiate breeding earlier and shorten the breeding period in drought years (Kupferberg 1996a). If pools stay wet long enough to support metamorphosis, complete drying at the end of the season may benefit Foothill Yellow-legged Frogs if it eliminates introduced species like warm water fish and bullfrogs. Moyle (1973) noted that the only intermittent streams occupied by Foothill Yellow-legged Frogs in the Sierra Nevada foothills had no bullfrogs. At a long-term study site in upper Coyote Creek in 2015, Foothill Yellow-legged Frogs had persisted in reaches that had at least some summer water through the three preceding years of the most severe drought in over a millennium, albeit at much lower abundance than a decade before (Gonsolin 2010, Griffin and Anchokaitis 2014, J. Smith pers. comm. 2015). The population's abundance appeared to have never recovered from the 2007-2009 drought before the 2012-2016 drought began (J. Smith pers. comm. 2015). In 2016, after a relatively wet winter, Foothill Yellow-legged Frogs bred en masse, and only a single adult bullfrog was detected, an unusually low number for that area (CDWR 2016, J. Smith pers. comm. 2016). It appeared the population may rebound; however, in 2018, it experienced lethal chytridiomycosis outbreak, and like the Alameda Creek die-off probably resulted from crowding during drought, presence of bullfrogs as Bd-reservoirs and predators and competitors, and the stress associated with the combination of the two (Kupferberg and Catenazzi 2019).

Drought effects can also exacerbate the effects of other environmental stressors. During the most recent severe drought, tree mortality increased dramatically from 2014 to 2017 and reached approximately 129 million dead trees (OEHHA 2018). Multiple years of high temperatures and low precipitation left them weakened and more susceptible to pathogens and parasites (Ibid.). Vast areas of dead and dying trees are more prone to severe wildfires, and they lose their carbon sequestration function while also emitting methane, which is an extremely damaging greenhouse gas (CNRA 2016). Post-wildfire storms can result in erosion of fine sediments from denuded hillsides into the stream channel (Florsheim et al. 2017). If the storms are short duration and ~~low precipitation~~peak discharges are low in magnitude, as happens during droughts, ~~their magnitude may not~~streamflow may be insufficient to transport the material downstream, ~~resulting in a longer temporal loss or~~extending the duration of ~~degradation of~~ stream habitat degradation (Ibid.). Reduced rainfall may also infiltrate the debris leading to subsurface flows rather than the surface water Foothill Yellow-legged Frogs require (Ibid.). Extended droughts increase risk of the stream being uninhabitable or inadequate for breeding for multiple years, which would result in population-level impacts and possible extirpation (Ibid.).

Wildland Fire and Fire Management

Fire is an important element for shaping and maintaining the species composition and integrity of many California ecosystems (Syphard et al. 2007, SBFFP 2018). Prior to European settlement, an estimated 1.8 to 4.9 million ha (4.5-12 million ac) burned annually (4-11% of total area of the state), ignited both deliberately by Native Americans and through lightning strikes (Keeley 2005, SBFFP 2018). The impacts of wildland fires on Foothill Yellow-legged Frogs are poorly understood and likely vary significantly across the species' range with differences in climate, vegetation, soils, stream-order, slope, frequency, and severity (Olson and Davis 2009). Mortality from direct scorching is unlikely because Foothill Yellow-legged Frogs are highly aquatic, and most wildfires occur during the dry period of the year when the frogs are most likely to be in or near the water (Pilliod et al. 2003, Bourque 2008). Field observations support this presumption; sightings of post-metamorphic Foothill Yellow-legged Frogs immediately after fires in the northern Sierra Nevada and North Coast indicate they are not very vulnerable to the direct effects of fire (S. Kupferberg and R. Peek pers. comm. 2018). Similarly, Foothill Yellow-legged Frogs were observed two months, and again one year, after a low- to moderate-intensity fire burned an area in the southern Sierra Nevada in 2002, and the populations were extant and breeding as recently as 2017 (Lind et al. 2003b, CNDDB 2019). While water may provide a refuge during the fire, it is also possible for temperatures during a fire, or afterward due to increased solar exposure, to near or exceed a threshold resulting lethal or sublethal harm; this would likely impact embryos and tadpoles with limited dispersal abilities (Pilliod et al. 2003).

Intense fires remove overstory canopy, which provides insulation from extreme heat and cold, and woody debris that increases habitat heterogeneity (Pilliod et al. 2003, Olson and Davis 2009). If this happens frequently enough, it can permanently change the landscape. For example, frequent high-severity burning of crown fire-adapted ecosystems can prevent forest regeneration since seeds require sufficient time between fires to mature, and repeated fires can deplete the seed bank (Stephens et al. 2014). Smoke and ash change water chemistry through increased nutrient and heavy metal inputs that can reach concentrations harmful to aquatic species during the fire and for days, weeks, or years after (Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Erosion rates on granitic soils, which make up a large portion of the Foothill Yellow-legged Frog's range, can be over 60 times greater in burned vs. unburned areas and can increase sedimentation for over 10 years (Megahan et al. 1995, Hayes et al. 2016). Post-fire nutrient inputs into streams could benefit Foothill Yellow-legged Frogs through increased productivity and more rapid growth and development (Pilliod et al. 2003). While the loss of leaf litter that accompanies fire alters the food web, insects are expected to recolonize rapidly, and the lack of cover could increase their vulnerability to predation by Foothill Yellow-legged Frogs (Ibid.).

Low-intensity fires likely have no adverse effect on Foothill Yellow-legged Frogs (Olson and Davis 2009). If they occur in areas with dense canopy, wildfires can improve habitat quality for Foothill Yellow-legged Frogs by reducing riparian cover, providing areas to bask, and increasing habitat heterogeneity, which is likely to outweigh any adverse effects from some fire-induced mortality (Russell et al. 1999, Olson and Davis 2009). In a preliminary analysis of threats to Foothill Yellow-legged Frogs in Oregon, proximity to stand-replacing fires was not associated with absence (Olson and Davis 2009).

Euro-American colonization of California significantly altered the pattern of periodic fires with which California's native flora and fauna evolved through fire exclusion, land use practices, and development (OEHHA 2018). Fire suppression can lead to canopy closure, which reduces habitat quality by limiting thermoregulatory opportunities (Olson and Davis 2009). In addition, fire suppression and its subsequent increase in fuel loads combined with expanding urbanization and rising temperatures have resulted in a greater likelihood of catastrophic stand-replacing fires that can significantly alter riparian systems for decades (Pilliod et al. 2003). Firebreaks, in which vegetation is cleared from a swath of land, can result in similar impacts to roads and road construction (Ibid.). Fire suppression can also include bulldozing within streams to create temporary reservoirs for pumping water, which can cause more damage than the fire itself to Foothill Yellow-legged Frogs in some cases (S. Kupferberg and R. Peek pers. comm. 2018). In addition, fire suppression practices can involve applying hundreds of tons of ammonia-based fire retardants and surfactant-based fire suppressant foams from air tankers and fire engines (Pilliod et al. 2003). Some of these chemicals are highly toxic to some anurans (Little and Calfee 2000).

Fire suppression has evolved into fire management with a greater understanding of its importance in ecosystem health (Keeley and Syphard 2016). Several strategies are employed including prescribed burns, mechanical fuels reduction, and allowing some fires to burn instead of necessarily extinguishing them (Pilliod et al. 2003). Like wildfires themselves, fire management strategies have the potential to benefit or harm Foothill Yellow-legged Frogs. Prescribed fires and mechanical fuels removal lessen the likelihood of catastrophic wildfires, but they can also result in loss of riparian vegetation, excessive sedimentation, and increased water temperatures (Ibid.). Salvage logging after a fire may result in similar impacts to timber harvest but with higher rates of erosion and sedimentation (Ibid.). A balanced approach to wildland fires is likely to have the greatest beneficial impact on species and ecosystem health (Stephens et al. 2012).

Floods and Landslides

As previously described, Foothill Yellow-legged Frog persistence is highly sensitive to early life stage mortality (Kupferberg et al. 2009c). While aseasonal dam releases are a major source of egg mass and tadpole scouring, storm-driven floods are also capable of it (Ashton et al. 1997). Van Wagner (1996) concluded that the high discharge associated with heavy rainfall could account for a significant source of mortality in post-metamorphic Foothill Yellow-legged Frogs as well as eggs and tadpoles; he observed two adult females and several juveniles swept downstream with fatal injuries post-flooding. Severe flooding, specifically two 500-year flood events in early 1969 in Evey Canyon (Los Angeles County), resulted in massive riparian habitat destruction (Sweet 1983). Prior to the floods, Foothill Yellow-legged Frogs were widespread and common, but only four subsequent sightings were documented between 1970 and 1974 and none since (Sweet 1983, Adams 2017b). Sweet (1983) speculates that because Foothill Yellow-legged Frogs overwinter in the streambed in that area, the floods may have reduced the population's abundance below an extinction threshold. Four other herpetologists interviewed about Foothill Yellow-legged Frog extirpations in southern California listed severe flooding as a likely cause (Adams et al. 2017b).

As mentioned above, landslides are a frequent consequence of post-fire rainstorms and can result in lasting impacts to stream morphology, water quality, and Foothill Yellow-legged Frog populations. On the other hand, Olson and Davis (2009) suggest that periodic landslides can have beneficial effects by transporting woody debris into the stream that can increase habitat complexity and by replacing sediments that are typically washed downstream over time. Whether a landslide is detrimental or beneficial is likely heavily influenced by amount of precipitation and the underlying system. As previously described, too little precipitation could lead to prolonged loss of habitat through failure to transport material downstream, and too much precipitation can result in large-scale habitat destruction and direct mortality.

Climate Change

Global climate change threatens biodiversity and may lead to increased frequency and severity of drought, wildfires, flooding, and landslides (Williams et al. 2008, Keely and Syphard 2016). Data show a consistent trend of warming temperatures in California and globally; 2014 was the warmest year on record, followed by 2015, 2017, and 2016 (OEHHA 2018). Climate model projections for annual temperature in California in the 21st century range from 1.5 to 4.5°C (2.7-8.1°F) greater than the 1961-1990 mean (Cayan et al. 2008). Precipitation change projections are less consistent than those for temperature, but recent studies indicate increasing variability in precipitation, and increasingly dry conditions in California resulting from increased evaporative water loss primarily due to rising temperatures (Cayan et al. 2005, Williams et al. 2015, OEHHA 2018). Precipitation variability and proportion of dry years were negatively associated with Foothill Yellow-legged Frog presence in a range-wide analysis (Lind 2005). In addition, low precipitation intensified the adverse effects of dams on the species (Ibid.).

California recently experienced the longest drought since the U.S. Drought Monitor began reporting in 2000 (NIDIS 2019). Until March 5, 2019, California experienced drought effects in at least a portion of the state for 376 consecutive weeks; the most intense period occurred during the week of October 28, 2014 when D4 (the most severe drought category) affected 58.4% of California's land area (Figure 23; NIDIS 2019). A recent modeling effort using data on historical droughts, including the Medieval megadrought between 1100 and 1300 CE, indicates the mean state of drought from 2050 to 2099 in California will likely exceed the Medieval-era drought, under both high and moderate greenhouse gas emissions models (Cook et al. 2015). The probability of a multidecadal (35 yr) drought occurring during the late 21st century is greater than 80% in all models used by Cook et al. (2015). If correct, this would represent a climatic shift that not only falls outside of contemporary variability in aridity but would also be unprecedented in the past millennium (Ibid.).

As a result of increasing temperatures, a decreasing proportion of precipitation falls as snow, resulting in more runoff from rainfall during the winter and a shallower snowpack that melts more rapidly (Stewart 2009). A combination of reduced seasonal snow accumulation and earlier streamflow timing significantly reduces surface water storage capacity and increases the risk for winter and spring floods, which may require additional and taller dams and result in alterations to hydroelectric power generation flow regimes (Cayan et al. 2005, Knowles et al. 2006, Stewart 2009). The reduction in snowmelt volume

is expected to impact the northern Sierra (Feather, Yuba, and American River watersheds) to a greater extent than the southern portion (Young et al. 2009). The earlier shift in peak snowmelt timing is predicted to exceed four to six weeks across the entire Sierra Nevada depending on the amount of warming that occurs this century (Ibid.). In addition, the snow water equivalent is predicted to significantly decline by 2070-2099 over the 1961-1990 average in the Trinity, Sacramento, and San Joaquin drainages from -32% to -79%, and effectively no snow is expected to fall below 1000 m (3280 ft) in the high emissions/sensitive model (Cayan et al. 2008).

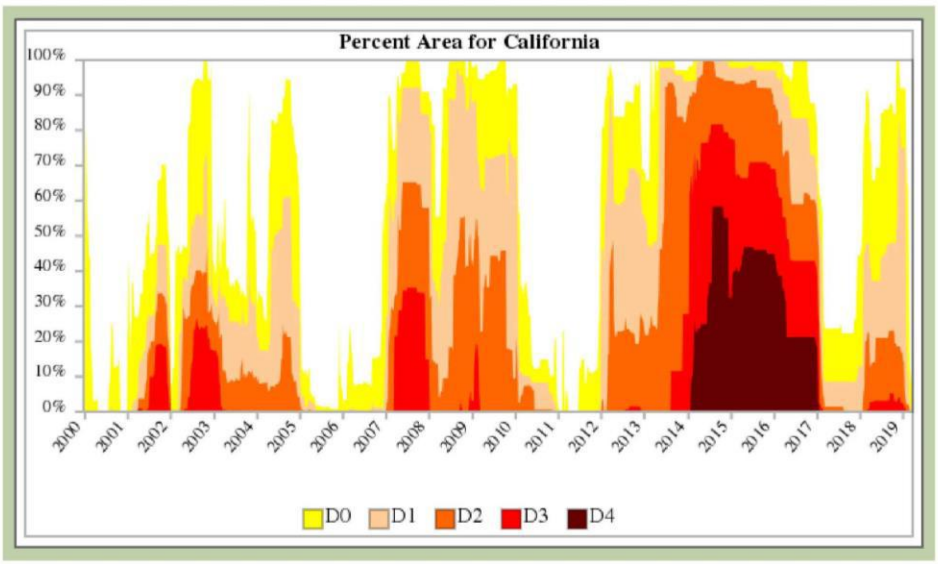


Figure 23. Palmer Hydrological Drought Indices 2000-present (NIDIS)

The earlier shift of snowmelt and lower water content will result in lower summer flows, which will intensify the competition for water among residential, agricultural, industrial, and environmental needs (Field et al. 1999, Cook et al. 2015). In unregulated systems, as long as water is present through late summer, an earlier hydrograph recession that triggers Foothill Yellow-legged Frog breeding could result in a longer time to grow larger prior to metamorphosis, which improves probability of survival (Yarnell et al. 2010, Kupferberg 2011b). However, if duration from peak to base flow shortens, it can result in increased sedimentation and reduced habitat complexity in addition to stranding (Yarnell et al. 2010).

Fire frequency relates to temperature, fuel loads, and fuel moisture (CCSP 2008). Therefore, increasing periods of drought combined with extreme heat and low humidity that stress or kill trees and other vegetation create ideal conditions for wildland fires (Ibid). Not surprisingly, the area burned by wildland fires over the western U.S. increased since 1950 but rose rapidly in the mid-1980s (Westerling et al. 2006, OEHHA 2018). As temperatures warmed and snow melted earlier, large-wildfire frequency and duration increased, and wildfire seasons lengthened (Westerling et al. 2006, OEHHA 2018).

In California, latitude inversely correlates with temperature and annual area burned, but the climate-fire relationship is substantially different across the state, and future wildfire regimes are difficult to predict (Keeley and Syphard 2016). For example, the relationship between spring and summer temperature and area burned in the Sierra Nevada is highly significant but not in southern California (Ibid.). Climate has a greater influence on fire regimes in mesic than arid environments, and the most influential climatological factor (e.g., precipitation, temperature, season, or their interactions) shifts over time (Ibid.). Nine of the 10 largest fires in California since 1932 have occurred in the past 20 years, 4 within the past 2 years (Figure 24; CAL FIRE 2019). However, it is possible this trend will not continue; climate- and wildfire-induced changes in vegetation could reduce wildfire severity in the future (Parks et al. 2016).

Wildfires themselves can accelerate the effects of climate change. Wildfires emit short-lived climate pollutants like black carbon (soot) and methane that are tens to thousands of times greater than carbon dioxide (the main focus of greenhouse gas reduction) in terms of warming effect and are responsible for 40% or more of global warming to date (CNRA 2016). Healthy forests can sequester large amounts of carbon from the atmosphere, but recently carbon emissions from wildfires have exceeded their uptake by vegetation in California (Ackerly et al. 2018).

With increased variability and changes in precipitation type, magnitude, and timing comes more variable and extreme stream flows (Mallakpour et al. 2018). Models for stream flow in California project higher high flows, lower low flows, wetter rainy seasons, and drier dry seasons (Ibid.). The projected water cycle extremes are related to strengthening El Niño and La Niña events, and both severe flooding and intense drought are predicted to increase by at least 50% by the end of the century (Yoon et al. 2015). These changes increase the likelihood of Foothill Yellow-legged Frog egg mass and tadpole scouring and stranding, even in unregulated rivers.

A species' vulnerability to climate change is a function of its sensitivity to climate change effects, its exposure to them, and its ability to adapt its behaviors to survive with them (Dawson et al. 2011). Myriad examples exist of species shifting their geographical distribution toward the poles and to higher elevations and changing their growth and reproduction with increases in temperature over time (Parmesan and Yohe 2003). However, in many places, fragmentation of suitable habitat by anthropogenic barriers (e.g., urbanization, agriculture, and reservoirs) limits a species' ability to shift its range (Pounds et al. 2007). The proportion of sites historically occupied by Foothill Yellow-legged Frogs that are now extirpated increases significantly on a north-to-south latitudinal gradient and at drier sites within California, suggesting climate change may contribute to the spatial pattern of the species' declines (Davidson et al. 2002).

An analysis of the climate change sensitivity of 195 species of plants and animals in northwestern North America revealed that, as a group, amphibians and reptiles were estimated to be the most sensitive (Case et al. 2015). Nevertheless, examples exist of amphibians adjusting their breeding behaviors (e.g., calling and migrating to breeding sites) to occur earlier in the year as global warming increases (Beebee 1995, Gibbs and Breisch 2001). Because of the rapid change in temperature, Beebee (1995) posits these are examples of behavioral and physiological plasticity rather than natural selection. However, for

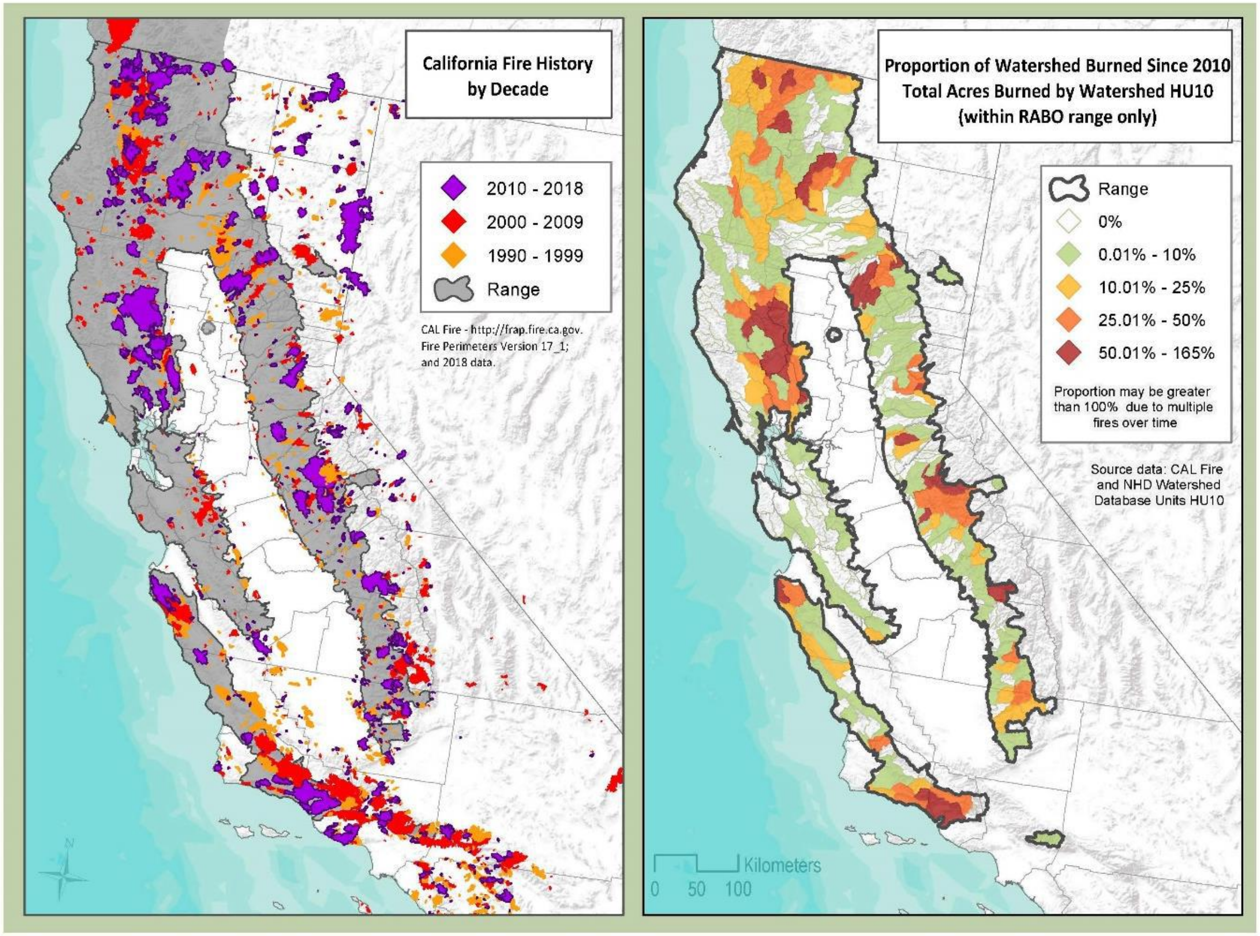


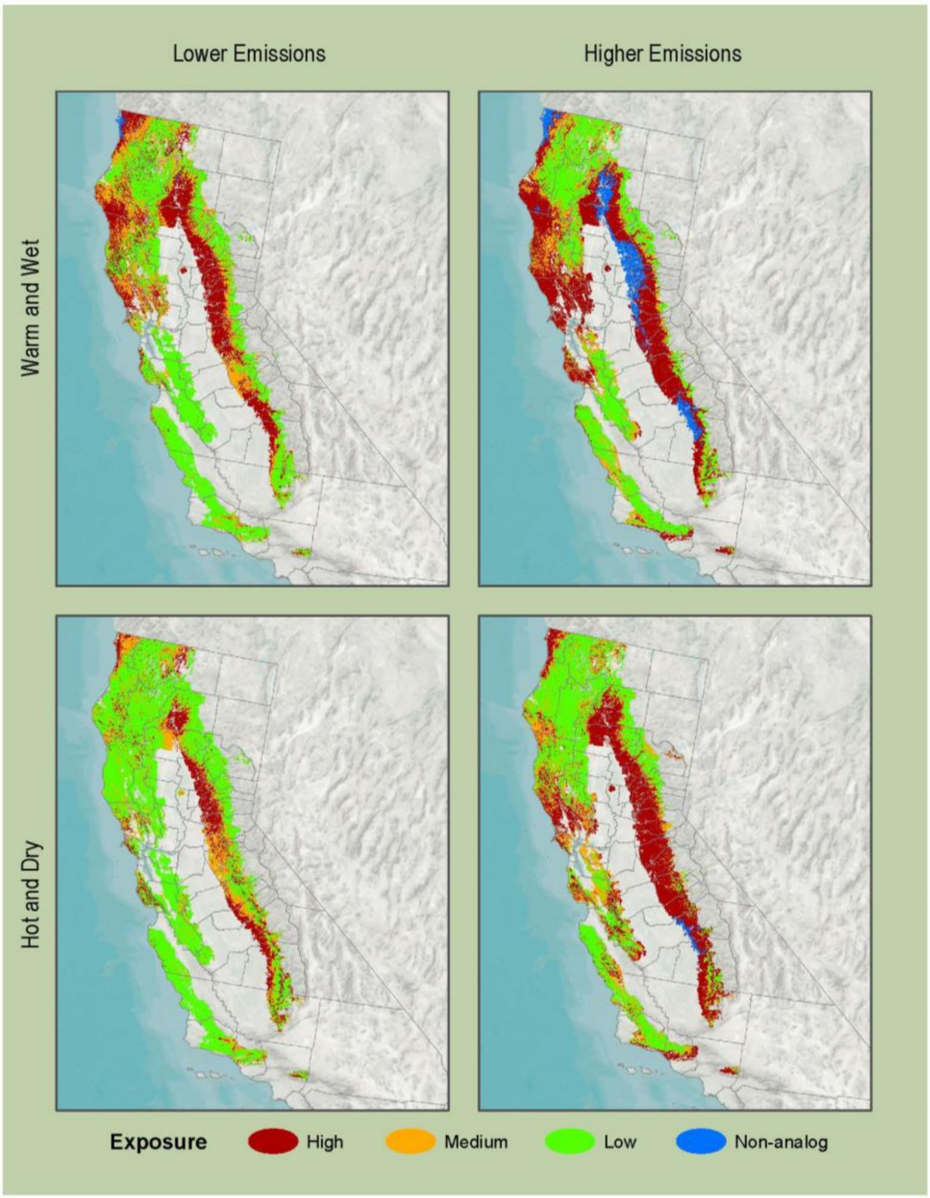
Figure 24. Fire history (1990-2018) and proportion of watershed burned (2010-2018) in California (CAL FIRE, NHD)

species with short generation times or in areas less affected by climate change, populations may be able to undergo evolutionary adaptation to the changing local environmental conditions (Hoffman and Sgrò 2011).

As previously described in the Seasonal Activity and Movements section, Foothill Yellow-legged Frog breeding is closely tied to water temperature, flow, and stage, and the species already adjusts its timing of oviposition by as much as a month in the same location during different water years, so the species may have enough inherent flexibility to reduce their vulnerability. The species appears fairly resilient to drought, fire, and flooding, at least in some circumstances. For example, after the 2012-2016 drought, the Loma Fire in late 2016, and severe winter flooding and landslides in 2016 and 2017, Foothill Yellow-legged Frog adults and metamorphs, as well as aquatic insects and rainbow trout, were abundant throughout Upper Llagas Creek in fall of 2017, and the substrate consisted of generally clean gravels and cobbles with only a slight silt coating in some pools (J. Smith pers. comm. 2017). The frogs and fish likely took refuge in a spring-fed pool, and the heavy rains scoured the fine sediments that eroded downstream (Ibid.). These refugia from the effects of climate change reduce the species' exposure, thereby reducing their vulnerability (Case et al. 2015).

Climate change models that evaluate the Foothill Yellow-legged Frog's susceptibility from a species and habitat perspective yield mixed results. An investigation into the possible effects of climate on California's native amphibians and reptiles used ecological niche models, future climate scenarios, and general circulation models to predict species-specific climatic suitability in 2050 (Wright et al. 2013). The results suggested approximately 90-100% of localities currently occupied by Foothill Yellow-legged Frogs are expected to remain climatically suitable in that time, and the proportion of currently suitable localities predicted to change ranges from -20% to 20% (Ibid.). However, a second study using a subset of these models found that 66.4% of currently occupied cells will experience reduced environmental suitability in 2050 (Warren et al. 2014). This analysis included 90 species of native California mammals, birds, reptiles, and amphibians. For context, over half of the taxa were predicted to experience > 80% reductions, a consistent pattern reflected across taxonomic groups (Ibid.).

A third analysis investigated the long-term risk of climate change by modeling the relative environmental stress a vegetative community would undergo in 2099 given different climate and greenhouse gas emission scenarios (Thorne et al. 2016). This model does not incorporate any Foothill Yellow-legged Frog-specific data; it strictly projects climatic stress levels vegetative communities will experience within the species' range boundaries (Ibid.). Unsurprisingly, higher emissions scenarios resulted in a greater proportion of habitat undergoing climatic stress (Figure 25). Perhaps counterintuitively, the warm and wet scenario resulted in a greater amount of stress than the hot and dry scenario. When high emissions and warm and wet changes are combined, a much greater proportion of the vegetation communities will experience "non-analog" conditions, those outside of the range of conditions currently known in California (Ibid.).



Source - model extracts from -Thorne, J.H. et al. (2016) A climate change vulnerability assessment of California's terrestrial vegetation. CDFW.

Figure 25. Vegetative community exposure to climate change in 2099 based on Thorne et al. (2016).

Habitat Restoration and Species Surveys

Potential conflicts between managing riverine habitat below dams for both cold-water adapted salmonids and Foothill Yellow-legged Frogs was discussed previously. In addition to problems with temperatures and pulse flows, some stream restoration projects aimed at physically creating or improving salmonid habitat can also adversely affect the species. For example, boulder deflectors were placed in Hurdygurdy Creek (Del Norte County) to create juvenile steelhead rearing habitat; deflectors change broad, shallow, low-velocity reaches into narrower, deeper, faster reaches preferred by the fish (Fuller and Lind 1992). Foothill Yellow-legged Frogs were documented using the restoration reach as breeding habitat annually prior to placement of the boulders, but no breeding was detected in the following three years, suggesting this project eliminated the conditions the frogs require (Ibid.). In addition, a fish ~~ladder~~ passage structure to facilitate salmonid migration above the Alameda Creek Diversion Dam was recently constructed on a Foothill Yellow-legged Frog lek site~~,~~; the structure blocks a migratory pathway between overwintering habitat in springs and seeps on a hillside and the creek; and creates a potential trap ~~the~~ for frogs ~~may become trapped~~that fall ~~in~~into the ~~ladder~~ structure (M. Grefsrud pers. comm. 2019). Use of rotenone to eradicate non-native fish as part of a habitat restoration project is rare, but if it is applied in streams occupied by Foothill Yellow-legged Frogs, it can kill tadpoles but is unlikely to impact post-metamorphic frogs (Fontenot et al. 1994). Metamorphosing tadpoles may be able to stay close enough to the surface to breathe air and survive but may display lethargy and experience increased susceptibility to predation (Ibid.).

Commonly when riparian vegetation is removed, regulatory agencies require a greater amount to be planted as mitigation to offset the temporal loss of habitat. This practice can have adverse impacts on habitat suitability Foothill Yellow-legged Frogs, especially where flood suppression by dams has resulted in the active channel being encroached by riparian trees whose roots bind sediment and steepen the slope of the banks. ~~by reducing habitat suitability~~. Foothill Yellow-legged Frogs have been observed moving into areas where trees were recently removed, and they are known to avoid heavily shaded areas (Lind et al. 1996, Welsh and Hodgson 2011, M. Grefsrud pers. comm. 2019).

Biologists and other stream researchers can inadvertently harm Foothill Yellow-legged Frogs. When ~~conducting surveys~~working in Foothill Yellow-legged Frog habitat, in-stream surveyors can trample egg masses or larvae if they are not careful, and those rock-hopping on shore can unknowingly crush post-metamorphic life stages that often take cover under stream-side rocks. One method for sampling fish is electroshocking, which runs a current through the water that stuns the fish temporarily allowing them to be captured. Post-metamorphic frogs are unlikely to be killed by electroshocking; however, at high frequencies (60 Hz), they may experience some difficulty with muscle coordination for a few days (Allen and Riley 2012). This could increase their risk of predation. At 30 Hz, there were no differences between frogs that were shocked and controls (Ibid.). Tadpoles are more similar to fish in tail muscle and spinal structure and are at higher risk of injuries; however, researchers who reported observing stunned tadpoles noted they appeared to recover completely within several seconds (Ibid.). Adverse effects to Foothill Yellow-legged Frogs from electrofishing may only happen at frequencies higher than those typically used for fish sampling (Ibid.)

Commented [SK2]: I think ladder is a misnomer for this massive concrete structure – I think it has 37 rectangular pools, it's huge

Small Population Sizes

Small populations are at greater risk of extirpation, primarily ~~through~~because the effects of demographic, environmental, and genetic stochasticity are disproportionately greater ~~impact of demographic, environmental, and genetic stochasticity on them compared to~~than effects on large populations~~, .~~ ~~so~~ Thus, any of the threats previously discussed will likely have an even greater adverse impact on small populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). This risk of extinction from genetic stochasticity is amplified when connectivity between the small populations, and thus gene flow, is impeded (Fahrig and Merriam 1985, Taylor et al. 1993, Lande and Shannon 1996, Palstra and Ruzzante 2008). Genetic diversity provides capacity to evolve in response to environmental changes, and the "rescue effect" of gene flow is important in minimizing probability of local extinction (Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). However, the rescue effect is diminished in conditions of high local environmental stochasticity of recruitment or survival (Eriksson et al. 2014). In addition, populations living near their physiological limits and lacking adaptive capacity may not be able to evolve in response to rapid changes (Hoffmann and Sgrò 2011). Furthermore, while pathogens or parasites rarely result in host extinction, they can increase its likelihood in small populations by driving the host populations below a critically low threshold beneath which demographic stochasticity can lead to extinction, even if they possess the requisite genetic diversity to adapt to a changed environment (Gomulkiewicz and Holt 1995, Adams et al. 2017b).

A Foothill Yellow-legged Frog PVA revealed that, even with no dam effects considered (e.g., slower growth and increased egg and tadpole mortality), populations with the starting average density of adult females in regulated rivers (4.6/km [2.9/mi]) were four times more likely to go extinct within 30 years than those with the starting average density of adult females from unregulated rivers (32/km [120/mi]) (Kupferberg et al. 2009c). When the density of females in sparse populations was used (2.1/km [1.3/mi], the 30-year risk of extinction increased 13-fold (Ibid.). With dam effects, a number of the risk factors above contribute to the additional probability of local extinction such as living near their lower thermal tolerance and reduced recruitment and survival from scouring and stranding flows, poor food quality, and increased predation and competition (Kupferberg 1997a; Hoffmann and Sgrò 2011; Kupferberg et al. 2011a,b; Kupferberg et al. 2012; Eriksson et al. 2014). These factors act synergistically, contributing in part to the small size, high divergence, and low genetic diversity exhibited by many Foothill Yellow-legged Frog populations located in highly regulated watersheds (Kupferberg et al. 2012, Peek 2018).

EXISTING MANAGEMENT

Land Ownership within the California Range

Using the Department's Foothill Yellow-legged Frog range boundary and the California Protected Areas Database (CPAD), a GIS dataset of lands that are owned in fee title and protected for open space purposes by over 1,000 public agencies or non-profit organizations, the total area of the species' range in California comprises 13,620,447 ha (33,656,857 ac) (CPAD 2019, CWHR 2019). Approximately 37% is owned by federal agencies, 80% of which (4,071,178 ha [10,060,100 ac]) is managed by the Forest Service (Figure 26). Department of Fish and Wildlife-managed lands, State Parks, and other State agency-managed lands constitute around 2.6% of the range. The remainder of the range includes < 1% Tribal lands, 2.3% other conserved lands (e.g., local and regional parks), and 57% private and government-managed lands that are not protected for open space purposes. It is important to note that even if included in the CPAD, a property's management does not necessarily benefit Foothill Yellow-legged Frogs, but in some cases changes in management to conserve the species may be easier to undertake than on private lands or public lands not classified as conserved.

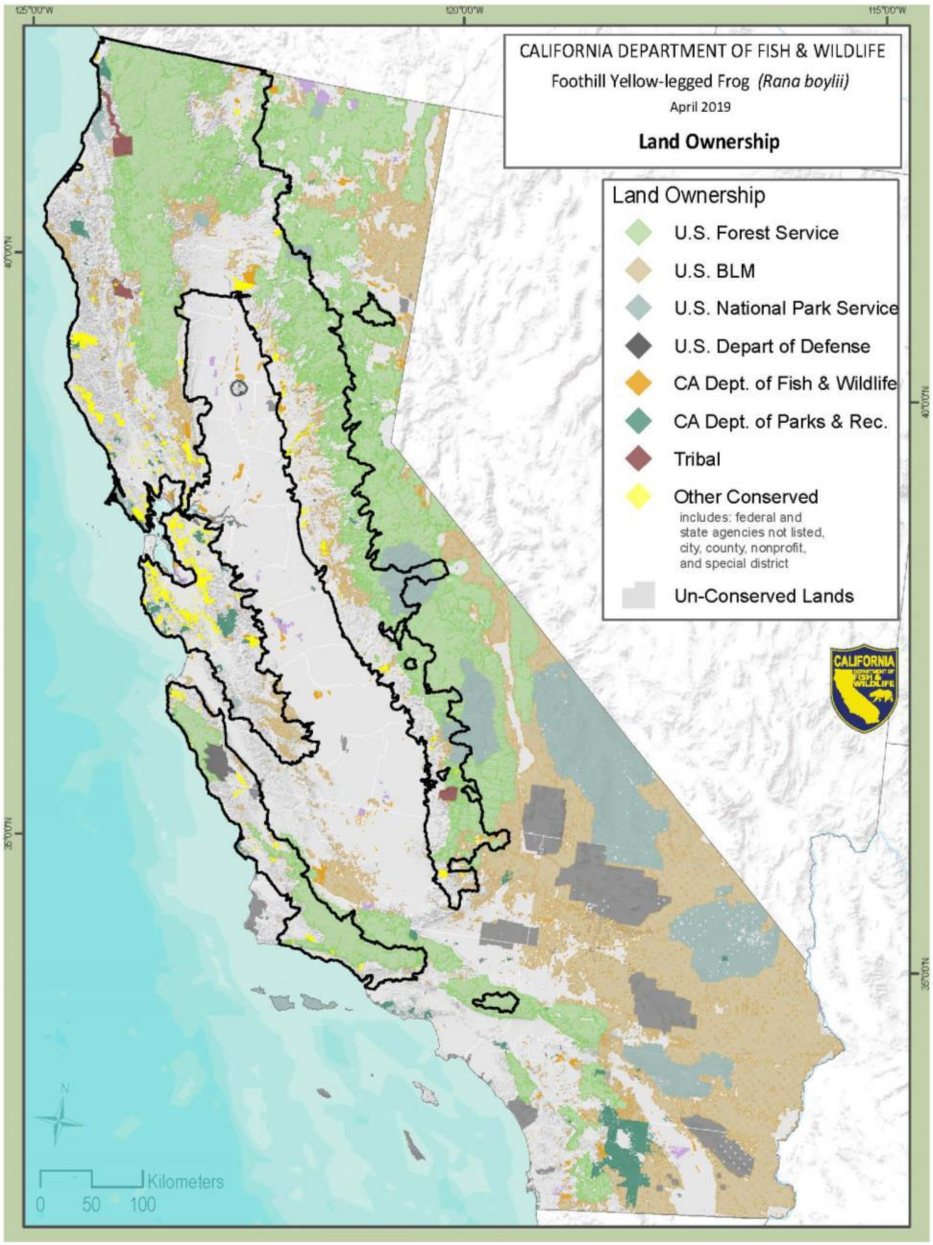


Figure 26. Conserved, Tribal, and other lands (BLM, CMD, CPAD, CWHR, DOD)

Statewide Laws

The laws and regulations governing land management within the Foothill Yellow-legged Frog's range vary by ownership. Several state and federal environmental laws apply to activities undertaken in California that may provide some level of protection for Foothill Yellow-legged Frogs and their habitat. The following is not an exhaustive list.

National Environmental Policy Act and California Environmental Quality Act

Most federal land management actions must undergo National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. § 4321, et seq.) analysis. NEPA requires federal agencies to document, consider alternatives, and disclose to the public the impacts of major federal actions and decisions that may significantly impact the environment. As a BLM and Forest Service Sensitive Species, impacts to Foothill Yellow-legged Legged Frogs are considered during NEPA analysis; however, the law has no requirement to minimize or mitigate adverse effects.

The California Environmental Quality Act (CEQA) is similar to NEPA; it requires state and local agencies to identify, analyze, and consider alternatives, and to publicly disclose environmental impacts from projects over which they have discretionary authority (Pub. Resources Code § 21000 et seq.). CEQA differs substantially from NEPA in requiring mitigation for significant adverse effects to a less than significant level unless overriding considerations are documented. CEQA requires an agency find projects may have a significant effect on the environment if they have the potential to substantially reduce the habitat, decrease the number, or restrict the range of any rare, threatened, or endangered species (Cal. Code Regs., tit. 14, §§ 15065(a)(1), 15380.). CEQA establishes a duty for public agencies to avoid or minimize such significant effects where feasible (Cal. Code regs., tit. 14, § 15021). Impacts to Foothill Yellow-legged Frogs, as an SSC, should be identified, evaluated, disclosed, and mitigated or justified under the Biological Resources section of an environmental document prepared pursuant to CEQA. However, a lead agency is not required to make a mandatory finding of significance conclusion unless it determines on a project-specific basis that the species meets the CEQA criteria for rare, threatened, or endangered.

Clean Water Act and Porter-Cologne Water Quality Control Act

The Clean Water Act originated in 1948 as the Federal Water Pollution Control Act of 1948. It was heavily amended in 1972 and became known as the Clean Water Act (CWA). The purpose of the CWA was to establish regulations for the discharge of pollutants into waters of the United States and establish quality standards for surface waters. Section 404 of the CWA forbids the discharge of dredged or fill material into waters and wetlands without a permit from the ACOE. The CWA also requires an alternatives analysis, and the ACOE is directed to issue their permit for the least environmentally damaging practicable alternative. The definition of waters of the United States has changed substantially over time based on Supreme Court decisions and agency rule changes.

The Porter-Cologne Water Quality Act was established by the State in 1969 and is similar to the CWA in that it establishes water quality standards and regulates discharge of pollutants into state waters, but it

also administers water rights which regulate water diversions and extractions. The SWRCB and nine Regional Water Boards share responsibility for implementation and enforcement of Porter-Cologne as well as the CWA's National Pollutant Discharge Elimination System permitting.

Federal and California Wild and Scenic Rivers Acts

In 1968, the U.S. Congress passed the federal Wild and Scenic Rivers Act (WSRA) (16 U.S.C. § 1271, et seq.) which created the National Wild and Scenic River System. The WSRA requires the federal government to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The WSRA prohibits the federal government from building, licensing, funding or otherwise aiding in the building of dams or other project works on rivers or segments of designated rivers. The WSRA does not give the federal government control of private property including development along protected rivers.

California's Wild and Scenic Rivers Act was enacted in 1972 so rivers that "possess extraordinary scenic, recreational, fishery, or wildlife values shall be preserved in their free-flowing state, together with their immediate environments, for the benefit and enjoyment of the people of the state." (Pub. Res. Code, § 5093.50). Designated waterways are codified in Public Resources Code sections 5093.50-5093.70. In 1981, most of California's designated Wild and Scenic Rivers were adopted into the federal system. Currently in California, 3,218 km (1,999.6 mi) of 23 rivers are protected by the WSRA, most of which are located in the northwest. Foothill Yellow-legged Frogs have been observed in 11 of the 17 designated rivers within their range (CNDDB 2019).

Lake and Streambed Alteration Agreements

Fish and Game Code Section 1602 requires entities to notify the Department of activities that "divert or obstruct the natural flow of, or substantially change or use any material from the bed, channel, or bank of any river, stream, or lake, or deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake." If the activity may substantially adversely affect an existing fish and wildlife resource, the Department may enter into a lake or streambed alteration agreement with the entity that includes reasonable measures necessary to protect the fish or wildlife resource (Fish & G. Code, §1602, subd. (a)(4)(B)). A lake or stream alteration agreement does not authorize take of species listed as candidates, threatened, or endangered under CESA (see Protection Afforded by Listing for CESA compliance requirements).

Medicinal and Adult-Use Cannabis Regulation and Safety Act

The commercial cannabis cultivation industry is unique in that any entity applying for an annual cannabis cultivation license from California Department of Food and Agriculture (CDFA) must include "a copy of any final lake or streambed alteration agreement…or written verification from the California Department of Fish and Wildlife that a lake or streambed alteration agreement is not required" with their license application (Cal. Code Regs., tit. 3, § 8102, subd. (v)). The SWRCB also enforces the laws related to waste discharge and water diversions associated with cannabis cultivation (Cal. Code Regs., tit. 3, § 8102, subd. (p)).

Forest Practice Act

The Forest Practice Act was originally enacted in 1973 to ensure that logging in California is undertaken in a manner that will also preserve and protect the State's fish, wildlife, forests, and streams. This law and the regulations adopted by the California Board of Forestry and Fire Protection (BOF) pursuant to it are collectively referred to as the Forest Practice Rules. The Forest Practice Rules implement the provisions of the Forest Practice Act in a manner consistent with other laws, including CEQA, Porter-Cologne, CESA, and the Timberland Productivity Act of 1982. The California Department of Forestry and Fire Protection (CAL FIRE) enforces these laws and regulations governing logging on private land.

Federal Power Act

The Federal Power Act and its major amendments are implemented and enforced by FERC and require licenses for dams operated to generate hydroelectric power. One of the major amendments required that these licenses "shall include conditions for the protection, mitigation and enhancement of fish and wildlife including related spawning grounds and habitat" (ECPA 1986). Hydropower licenses granted by FERC are usually valid for 30-50 years. If a licensee wants to renew their license, it must file a Notice of Intent and a pre-application document five years before the license expires to provide time for public scoping, any potentially new studies necessary to analyze project impacts and alternatives, and preparation of environmental documents. The applicant must officially apply for the new license at least two years before the current license expires.

As a federal agency, FERC must comply with federal environmental laws prior to issuing a new license or relicensing an existing hydropower project, which includes NEPA and ESA. As a result of environmental compliance or settlement agreements formed during the relicensing process, some operations have been modified and habitat restored to protect fish and wildlife. For example, the Lewiston Dam relicensing resulted in establishment of the Trinity River Restoration Program, which takes an ecosystem-approach to studying dam effects and protecting and restoring fish and wildlife populations downstream of the dam (Snover and Adams 2016). Similarly, relicensing of the Rock Creek-Cresta Project on the North Fork Feather River resulted in establishment of a multi-stakeholder Ecological Resources Committee (ERC). As a result of the ERC's studies and recommendations, pulse flows for whitewater boating were suspended for several years following declines of Foothill Yellow-legged Frogs, and the ERC is currently working toward augmenting the population in an attempt to increase abundance to a viable level.

Administrative and Regional Plans

Forest Plans

NORTHWEST FOREST PLAN

In 1994, BLM and the Forest Service adopted the Northwest Forest Plan to guide the management of over 97,000 km^2 (37,500 mi^2) of federal lands in portions of northwestern California, Oregon, and Washington. The Northwest Forest Plan created an extensive network of forest reserves including

Riparian Reserves. Riparian Reserves apply to all land designations to protect riparian dependent resources. With the exception of silvicultural activities consistent with Aquatic Conservation Strategy objectives, timber harvest is not permitted within Riparian Reserves, which can vary in width from 30 to 91 m (100-300 ft) on either side of streams, depending on the classification of the stream or waterbody (USFS and BLM 1994). Fuel treatment and fire suppression strategies and practices implemented within these areas are designed to minimize disturbance.

Sierra Nevada Forest Plan

Land and Resource Management Plans for forests in the Sierra Nevada were changed in 2001 by the Sierra Nevada Forest Plan Amendment and subsequently adjusted via a supplemental Environmental Impact Statement and Record of Decision in 2004, referred to as the Sierra Nevada Framework (USFS 2004). This established an Aquatic Management Strategy with Goals including maintenance and restoration of habitat to support viable populations of riparian-dependent species; spatial and temporal connectivity for aquatic and riparian species within and between watersheds to provide physically, chemically, and biologically unobstructed movement for their survival, migration, and reproduction; instream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats; the physical structure and condition of streambanks and shorelines to minimize erosion and sustain desired habitat diversity; and prevention of new introductions of invasive species and reduction of invasive species impacts that adversely affect the viability of native species. The Sierra Nevada Framework also includes Riparian Conservation Objectives and associated standards and guidelines specific to aquatic-dependent species, including the Foothill Yellow-legged Frog.

Resource Management Plans

Sequoia, Kings Canyon, and Yosemite National Parks fall within the historical range of the Foothill Yellow-legged Frog, but the species has been extirpated from these areas. The guiding principles for managing biological resources on National Park Service lands include maintenance of animal populations native to park ecosystems (Hayes et al. 2016). They also commit the agency to work with other land managers on regional scientific and planning efforts and maintenance or reintroduction of native species to the parks including conserving Foothill Yellow-legged Frogs in the Sierra Nevada (USDI NPS 1999 as cited in Hayes et al. 2016). A Sequoia and Kings Canyon National Parks Resource Management Plan does not include specific management goals for Foothill Yellow-legged Frogs, but it does include a discussion of the factors leading to the species' decline and measures to restore the integrity of aquatic ecosystems (Ibid.). The Yosemite National Park Resource Management Plan includes a goal of restoring Foothill Yellow-legged Frogs to the Upper Tuolumne River below Hetch Hetchy Reservoir (USDI NPS 2003 as cited in Hayes et al. 2016).

FERC Licenses

Dozens of hydropower dams have been relicensed in California since 1999, and several are in the process of relicensing (FERC 2019). In addition to following the Federal Power Act and other applicable federal laws, Porter-Cologne Water Quality Act requires non-federal dam operators to obtain a Water Quality Certification (WQC) from the SWRCB. Before it can issue the WQC, the SWRCB must consult with

the Department regarding the needs of fish and wildlife. Consequently, SWRCB includes conditions in the WQC that seek to minimize adverse effects to native species, and Foothill Yellow-legged Frogs have received some special considerations due to their sensitivity to dam operations during these licensing processes. As discussed above, the typical outcome is formation of an ERC-type group to implement the environmental compliance requirements and recommend changes to flow management to reduce impacts. Foothill Yellow-legged Frog-specific requirements fall into three general categories: data collection, modified flow regimes, and standard best management practices.

Data Collection

When little is known about the impacts of different flows and temperatures on Foothill Yellow-legged Frog occupancy and breeding success, data are collected and analyzed to inform recommendations for future modifications to operations such as temperature trigger thresholds. These surveys include locating egg masses and tadpoles, monitoring temperatures and flows, and recording their fate (e.g., successful development and metamorphosis, displacement, desiccation) during different flow operations and different water years. Examples of licenses with these conditions include the Lassen Lodge Project (FERC 2018), Rock Creek-Cresta Project (FERC 2009a), and El Dorado Project (EID 2007).

Modified Flow Regimes

When enough data exist to understand the effect of different operations on Foothill Yellow-legged Frog occupancy and success, license conditions may include required minimum seasonal instream flows, specific thermal regimes, gradual ramping rates to reduce the likelihood of early life stage scour or stranding, or freshet releases (winter/spring flooding simulation) to maintain riparian processes, and cancellation or prohibition of recreational pulse flows during the breeding season. Examples of licenses with these conditions include the Poe Hydroelectric Project (SWRCB 2017), Upper American Project (FERC 2014), and Pit 3, 4, 5 Project (FERC 2007b).

Best Management Practices

Efforts to reduce the impacts from maintenance activities and indirect operations include selective herbicide and pesticide application, aquatic invasive species monitoring and control, erosion control, and riparian buffers. Examples of licenses with these conditions include the South Feather Project (SWRCB 2018), Spring Gap-Stanislaus Project (FERC 2009b), and Chili Bar Project (FERC 2007a).

Habitat Conservation Plans and Natural Community Conservation Plans

Non-federal entities can obtain authorization for take of federally threatened and endangered species incidental to otherwise lawful activities through development and implementation of a Habitat Conservation Plan (HCP) pursuant to Section 10 of the ESA. The take authorization can extend to species not currently listed under ESA but which may become listed as threatened or endangered over the term of the HCP, which is often 25-75 years. California's companion law, the Natural Community Conservation Planning Act of 1991, takes a broader approach than either CESA or ESA. A Natural Community Conservation Plan (NCCP) identifies and provides for the protection of plants, animals, and their

habitats, while allowing compatible and appropriate economic activity. There are currently four HCPs that include Foothill Yellow-legged Frogs as a covered species, two of which are also NCCPs.

Humboldt Redwood (formerly Pacific Lumber) Company

The Humboldt Redwood Company (HRC) HCP covers 85,672 ha (211,700 ac) of private Coast Redwood and Douglas-fir forest in Humboldt County (HRC 2015). It is a 50-year HCP/incidental take permit (ITP) that was executed in 1999, revised in 2015 as part of its adaptive management strategy, and expires on March 1, 2049. The HCP includes an Amphibian and Reptile Conservation Plan and an Aquatics Conservation Plan with measures designed to sustain viable populations of Foothill Yellow-legged Frogs and other covered aquatic herpetofauna. These conservation measures include prohibiting or limiting tree harvest within Riparian Management Zones (RMZ), controlling sediment by maintaining roads and hillsides, restricting controlled burns to spring and fall in areas outside of the RMZ, conducting effectiveness monitoring throughout the life of the HCP, and use the data collected to adapt monitoring and management plans accordingly.

Watershed assessment surveys include observations of Foothill Yellow-legged Frogs and have documented their widespread distribution on HRC lands with a pattern of fewer near the coast in the fog belt and more inland (S. Chinnici pers. comm. 2017). The watersheds within the property are largely unaffected by dam-altered flow regimes or non-native species, so aside from the operations described under Timber Harvest above that are minimized to the extent feasible, the focus on suitable temperatures and denser canopy cover for salmonids may reduce habitat suitability for Foothill Yellow-legged Frogs over time (Ibid.).

San Joaquin County Multi-Species Habitat Conservation and Open Space Plan

The San Joaquin County Multi-Species Habitat Conservation and Open Space Plan (SJMSCP) is a 50-year HCP/ITP that was signed by the USFWS on November 14, 2000 (San Joaquin County 2000). The SJMSCP covers almost all of San Joaquin County except federal lands, a few select projects, and some properties with certain land uses, roughly 364,000 ha (900,000 ac). At the time of execution, approximately 70 ha (172 ac) of habitat within the SJMSCP area in the southwest portion of the county were considered occupied by Foothill Yellow-legged Frogs with another 1,815 ha (4,484 ac) classified as potential habitat, but it appears the species had been considered extirpated before then (Jennings and Hayes 1994, San Joaquin County 2000, Lind 2005). The HCP estimates around 8% of the combined modeled habitat would be converted to other uses over the permit term, but the establishment of riparian preserves with buffers around Corral Hollow Creek, where the species occurred historically, was expected to offset those impacts (San Joaquin County 2000, SJCOG 2018). However, the HCP did not require surveys to determine if Foothill Yellow-legged Frogs are benefiting (M. Grefsrud pers. comm. 2019).

East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan

The East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan (ECCC HCP/NCCP) is a multi-jurisdictional 30-year plan adopted in 2007 that covers over 70,423 ha (174,018 ac) in eastern Contra Costa County (Jones & Stokes 2006). The Foothill Yellow-legged Frog appears to be

extirpated from the ECCC HCP/NCCP area (CNDDB 2019). Nevertheless, suitable habitat was mapped, and impacts were estimated at well under 1% of both breeding and migratory habitat (Jones & Stokes 2006). One of the HCP/NCCP's objectives is acquiring high-quality Foothill Yellow-legged Frog habitat that has been identified along Marsh Creek (Ibid.). In 2017, the Viera North Peak 65 ha (160 ac) property was acquired that possesses suitable habitat for Foothill Yellow-legged Frogs (ECCCHC 2018).

Santa Clara Valley Habitat Plan

The Santa Clara Valley Habitat Plan (SCVHP) is a 50-year HCP/NCCP covering over 210,237 ha (519,506 ac) in Santa Clara County (ICF 2012). As previously mentioned, Foothill Yellow-legged Frogs appear to have been extirpated from lower elevation sites, particularly below reservoirs in this area. Approximately 17% of modeled Foothill Yellow-legged Frog habitat, measured linearly along streams, was already permanently preserved, and the SCVHP seeks to increase that to 32%. The maximum allowable habitat loss is 11 km (7 mi) permanent loss and 3 km (2 mi) temporary loss, while 167 km (104 mi) of modeled habitat is slated for protection. By mid-2018, 8% of impact area had been accrued and 3% of habitat protected (SCVHA 2019).

Green Diamond Aquatic Habitat Conservation Plan

Green Diamond Resources Company has an Aquatic Habitat Conservation Plan (AHCP) covering 161,875 ha (400,000 ac) of their land that is focused on cold-water adapted species, but many of the conservation measures are expected to benefit Foothill Yellow-legged Frogs as well (K. Hamm pers. comm. 2017). Examples include slope stability and road management measures to reduce stream sedimentation from erosion and landslides, and limiting water drafting during low flow periods with screens over the pumps to avoid entraining animals (Ibid.). Although creating more open canopy areas and warmer water temperatures is not the goal of the AHCP, the areas that are suitable for Foothill Yellow-legged Frog breeding are likely to remain that way because they are wide channels that receive sufficient sunlight (Ibid.).

SUMMARY OF LISTING FACTORS

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CESA's implementing regulations identify key factors relevant to the Department's analyses and the Fish and Game Commission's decision on whether to list a species as threatened or endangered. A species will be listed as endangered or threatened if the Commission determines that the species' continued existence is in serious danger or is threatened by any one or any combination of the following factors: (1) present or threatened modification or destruction of its habitat; (2) overexploitation; (3) predation; (4) competition; (5) disease; or (6) other natural occurrences or human-related activities (Cal. Code Regs., tit. 14, § 670.1, subd. (i).

This section provides summaries of information from the foregoing sections of this status review, arranged under each of the factors to be considered by the Commission in determining whether listing is warranted.

Present or Threatened Modification or Destruction of Habitat

Most of the factors affecting ability to survive and reproduce listed above involve destruction or degradation of Foothill Yellow-legged Frog habitat. The most widespread, and potentially most significant, threats are associated with dams and their flow regimes, particularly in areas where they are concentrated and occur in a series along a river. Dams and the way they are operated can have up- and downstream impacts to Foothill Yellow-legged Frogs. They can result in confusing natural breeding cues, scouring and stranding of egg masses and tadpoles, reducing quality and quantity of breeding and rearing habitat, reducing tadpole growth rate, impeding gene flow among populations, and establishing and spreading non-native species (Hayes et al. 2016). These impacts appear to be most severe when the dam is operated for the generation of hydropower utilizing hydropeaking and pulse flows (Kupferberg et al. 2009c, Peek 2018). Foothill Yellow-legged Frog abundance below dams is an average of five times lower than in unregulated rivers (Kupferberg et al. 2012). The number, height, and distance upstream of dams in a watershed influenced whether Foothill Yellow-legged Frogs still occurred at sites where they had been present in 1975 in California (Ibid.). Water diversions for agricultural, industrial, and municipal uses also reduce the availability and quality of Foothill Yellow-legged Frog habitat. Dams are concentrated in the Bay Area, Sierra Nevada, and southern California (Figure 17), while hydropower plants are densest in the northern and central Sierra Nevada (Figure 18).

With predicted increases in the human population, ambitious renewable energy targets, higher temperatures, and more extreme and variable precipitation falling increasingly more as rain rather than snow, the need for more and taller dams and water diversions for hydroelectric power generation, flood control, and water storage and delivery is not expected to abate in the future. California voters approved Proposition 1, the Water Quality, Supply and Infrastructure Improvement Act of 2014, which dedicated $2.7 billion to water storage projects (PPIC 2018). In 2018, the California Water Commission approved funding for four new dams in California: expansion of Pacheco Reservoir (Santa Clara County), expansion of Los Vaqueros Reservoir (Contra Costa County), Temperance Flat Dam (new construction) on the San Joaquin River (Fresno County), and the off-stream Sites Reservoir (new construction) diverting the Sacramento River (Colusa County) (CWC 2019). No historical records of Foothill Yellow-legged Frogs from the Los Vaqueros or Sites Reservoir areas exist in the CNDDB, and one historical (1950) collection is documented from the Pacheco Reservoir area (CNDDB 2019). However, the proposed Temperance Flat Dam site is downstream of one of the only known extant populations of Foothill Yellow-legged Frogs in the East/Southern Sierra clade (Ibid.).

The other widespread threat to Foothill Yellow-legged Frog habitat is climate change, although the severity of its impacts is somewhat uncertain. While drought, wildland fires, floods, and landslides are natural and ostensibly necessary disturbance events for preservation of native biodiversity, climate change is expected to result in increased frequency and severity of these events in ways that may exceed species' abilities to adapt (Williams et al. 2008, Hoffmann and Sgrò 2011, Keely and Syphard 2016). These disturbance events which can lead to local extirpations will occur across a landscape of fragmented and small populations and thus the likelihood of natural recolonization will be highly impaired. Climatic~~These c~~hanges in flow regime can lead to increased competition, predation, and disease transmission as species become concentrated in areas that remain wet into the late summer

(Adams et al. 2017a, Kupferberg and Catenazzi 2019). Loss of riparian vegetation from wildland fires can result in increased stream temperatures or concentrations of nutrients and trace heavy metals that inhibit growth and survival (Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Stream sedimentation from landslides following fire or excessive precipitation can destroy or degrade breeding and rearing habitat (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). At least some models predict unprecedented dryness in the latter half of the century (Cook et al. 2015). The effects of climate change will be realized across the Foothill Yellow-legged Frog's range, and their severity will likely differ in ways that are difficult to predict. However, the impacts from extended droughts will likely be greatest in the areas that are naturally more arid, the lower elevations and latitudes of southern California and the foothills surrounding the Central Valley (Figure 21).

While most future urbanization is predicted to occur in areas outside of the Foothill Yellow-legged Frog's range, it has already contributed to the loss and fragmentation of Foothill Yellow-legged Frog habitat in California. In addition, the increased predation, wildland fires, introduced species, road mortality, disease transmission, air and water pollution, and disturbance from recreation that can accompany urbanization expand its impact far beyond its physical footprint (Davidson et al. 2002, Syphard et al. 2007, Cook et al. 2012, Bar-Massada et al. 2014). Within the Foothill Yellow-legged Frog's historical range, these effects appear most significant and extensive in terms of population extirpations in southern California and the San Francisco Bay Area.

Several other activities have the potential to destroy or degrade Foothill Yellow-legged Frog habitat, but they are less common across the range. They also tend to have relatively small areas of impact, although they can be significant in those areas, particularly if populations are already small and declining. These include impacts from mining, cannabis cultivation, vineyard expansion, overgrazing, timber harvest, recreation, and some stream habitat restoration projects (Harvey and Lisle 1998, Belsky et al. 1999, Merelender 2000, Pilliod et al. 2003, Bauer et al. 2015, Kupferberg and Furey 2015).

Overexploitation

Foothill Yellow-legged Frogs are not threatened by overexploitation. There is no known pet trade for Foothill Yellow-legged Frogs (Lind 2005). During the massive frog harvest that accompanied the Gold Rush, some Foothill Yellow-legged Frogs were collected, but because they are relatively small and have irritating skin secretions, there was much less of a market for them (Jennings and Hayes 1985). Within these secretions is a peptide with antimicrobial activity that is particularly potent against *Candida albicans*, a human pathogen that has been developing resistance to traditional antifungal agents (Conlon et al. 2003). However, the peptide's therapeutic potential is limited by its strong hemolytic activity, so further studies will focus on synthesizing analogs that can be used as antifungals, and collection of Foothill Yellow-legged Frogs for lab cultures is unlikely (Ibid.).

Like all native California amphibians, collection of Foothill Yellow-legged Frogs is unlawful without a permit from the Department. They may only be collected for scientific, educational, or propagation reasons through a Scientific Collecting Permit (Fish & G. Code § 1002 et seq.). The Department has the discretion to limit or condition the number of individuals collected or handled to ensure no significant adverse effects. Incidental harm from authorized activities on other aquatic species can be avoided or minimized by the inclusion of special terms and conditions in permits.

Predation

Predation is a likely contributor to Foothill Yellow-legged Frog population declines where the habitat is degraded by one or many other risk factors (Hayes and Jennings 1986). Predation by native gartersnakes can be locally substantial; however, it may only have an appreciable population-level impact if the availability of escape refugia is diminished. For example, when streams dry and only pools remain, Foothill Yellow-legged Frogs are more vulnerable to predation by native and non-native species because they are concentrated in a small area with little cover.

Several studies have demonstrated the synergistic impacts of predators and other stressors. Foothill Yellow-legged Frogs, primarily as demonstrated through studies on tadpoles, are more susceptible to predation when exposed to some agrochemicals, cold water, high velocities, excess sedimentation, and even the presence of other species of predators (Harvey and Lisle 1998, Adams et al. 2003, Olson and Davis 2009, Kupferberg et al. 2011b, Kerby and Sih 2015, Catenazzi and Kupferberg 2018). Foothill Yellow-legged Frog tadpoles appear to be naïve to chemical cues from some non-native predators; they have not evolved those species-specific predator avoidance behaviors (Paoletti et al. 2011). Furthermore, early life stages are often more sensitive to environmental stressors, making them more vulnerable to predation, and Foothill Yellow-legged Frog population dynamics are highly sensitive to egg and tadpole mortality (Kats and Ferrer, 2003, Kupferberg et al. 2009c). Predation pressure is likely positively associated with proximity to anthropogenic changes in the environment, so in more remote or pristine places, it probably does not have a serious population-level impact.

Competition

Intra- and interspecific competition in Foothill Yellow-legged Frogs has been documented. Intraspecific male-to-male competition for females has been reported (Rombough and Hayes 2007). Observations include physical aggression and a non-random mating pattern in which larger males were more often engaged in breeding (Rombough and Hayes 2007, Wheeler and Welsh 2008). A behavior resembling clutch-piracy, where a satellite male attempts to fertilize already laid eggs, has also been documented (Rombough and Hayes 2007). These acts of competition play a role in population genetics, but they likely do not result in serious physical injury or mortality. Intraspecific competition among Foothill Yellow-legged Frog tadpoles was negligible (Kupferberg 1997a).

Interspecific competition appears to have a greater possibility of resulting in adverse impacts. Kupferberg (1997a) did not observe a significant change in tadpole mortality for Foothill Yellow-legged Frogs raised with Pacific Treefrogs compared to single-species controls. However, when reared together, Foothill Yellow-legged Frog tadpoles lost mass, while Pacific Treefrog tadpoles increased mass (Kerby and Sih 2015). As described previously under Introduced Species, Foothill Yellow-legged Frog tadpoles experienced significantly higher mortality and smaller size at metamorphosis when raised with bullfrog tadpoles (Kupferberg 1997a). The mechanism of these declines appeared to be exploitative competition, as opposed to interference, through the reduction of available algal resources from bullfrog tadpole grazing in the shared enclosures (Ibid.).

The degree to which competition threatens Foothill Yellow-legged Frogs likely depends on the number and density of non-native species in the area rather than intraspecific competition, and co-occurrence of Foothill Yellow-legged Frog and bullfrog tadpoles may be somewhat rare since the latter tends to breed in lentic (still water) environments (M. van Hattem pers. comm. 2019). Interspecific competition with other native species may have some minor adverse consequences on fitness.

Disease

Currently, the only disease known to pose a serious risk to Foothill Yellow-legged Frogs is Bd. Until 2017, the only published studies on the impact of Bd on Foothill Yellow-legged Frog suggested it could reduce growth and body condition but was not lethal (Davidson et al. 2007, Lowe 2009, Adams et al. 2017b). However, two recent mass mortality events caused by chytridiomycosis proved they are susceptible to lethal effects, at least under certain conditions like drought-related concentration and presence of bullfrogs (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Some evidence indicates disease may have played a principal role in the disappearance of the species from southern California (Adams et al. 2017b). Bd is likely present in the environment~~al~~ throughout the Foothill Yellow-legged Frog's range, and with bullfrogs and treefrogs acting as carriers, it will remain a threat to the species; however, given the dynamics of the two recent die-offs in the San Francisco Bay area, the probability of future outbreaks may be greater in areas where the species is under additional stressors like drought and introduced species (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Therefore, as with predation, Foothill Yellow-legged Frogs are less likely to experience the adverse impacts of diseases in more remote areas with fewer anthropogenic changes to the environment.

Other Natural Events or Human-Related Activities

Agrochemicals, particularly organophosphates that act as endocrine disruptors, can travel substantial distances from the area of application through atmospheric drift and have been implicated in the disappearance and declines of many species of amphibians in California including Foothill Yellow-legged Frogs (LeNoir et al. 1999, Davidson 2004, Lind 2005, Olson and Davis 2009). Foothill Yellow-legged Frogs appear to be significantly more sensitive to the adverse impacts of some pesticides than other native species (Sparling and Fellers 2009, Kerby and Sih 2015). These include smaller body size, slower development rate, increased time to metamorphosis, immunosuppression, and greater vulnerability to predation and malformations (Kiesecker 2002, Hayes et al. 2006, Sparling and Fellers 2009, Kerby and Sih 2015). Some of the most dramatic declines experienced by ranids in California occurred in the Sierra Nevada east of the San Joaquin Valley where over half of the state's total pesticide usage occurs (Sparling et al. 2001).

Many Foothill Yellow-legged Frog populations are small, isolated from other populations, and possess low genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). Genetic diversity is important in providing a population the capacity to evolve in response to environmental changes, and connectivity among populations is important for gene exchange and in minimizing probability of local extinction

(Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). Small populations are at much greater risk of extirpation primarily through the disproportionate impact of demographic, environmental, and genetic stochasticity than robust populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). Based on a Foothill Yellow-legged Frog PVA, populations in regulated rivers face a 4- to 13-fold greater extinction risk in 30 years than populations in unregulated rivers due to smaller population sizes (Kupferberg et al. 2009c). The threat posed by small population sizes is significant and the general pattern shows increases in severity from north to south; however, many sites, primarily in the northern Sierra Nevada, in watersheds with large hydropower projects are also at high risk.

PROTECTION AFFORDED BY LISTING

It is the policy of the State to conserve, protect, restore and enhance any endangered or threatened species and its habitat (Fish & G. Code, § 2052). The conservation, protection, and enhancement of listed species and their habitat is of statewide concern (Fish & G. Code, § 2051(c)). CESA defines "take" as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill (Fish & G. Code, § 86). The Fish and Game Code provides the Department with related authority to authorize "take" of species listed as threatened or endangered under certain circumstances (see, e.g., Fish & G. Code, §§ 2081, 2081.1, 2086, & 2835).

If the Foothill Yellow-legged Frog is listed under CESA, impacts of take caused by activities authorized through incidental take permits must be minimized and fully mitigated according to state standards (Fish & G. Code, § 2081, subd. (b)). These standards typically include protection of land in perpetuity with an easement, development and implementation of a species-specific adaptive management plan, and funding through an endowment to pay for long-term monitoring and maintenance to ensure the mitigation land meets performance criteria. Obtaining an incidental take permit is voluntary. The Department cannot force compliance; however, any person violating the take prohibition may be criminally and civilly liable under state law.

Additional protection of Foothill Yellow-legged Frogs following listing would be expected to occur through state and local agency environmental review under CEQA. CEQA requires affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on rare, threatened, and endangered species. In common practice, potential impacts to listed species are examined more closely in CEQA documents than potential impacts to unlisted species. Where significant impacts are identified under CEQA, the Department expects project-specific avoidance, minimization, and mitigation measures to benefit the species. State listing, in this respect, and consultation with the Department during state and local agency environmental review under CEQA, would be expected to benefit the Foothill Yellow-legged Frog in terms of reducing impacts from individual projects, which might otherwise occur absent listing.

For some species, CESA listing may prompt increased interagency coordination and the likelihood that state and federal land and resource management agencies will allocate funds toward protection and recovery actions. In the case of the Foothill Yellow-legged Frog, some multi-agency efforts exist, often associated with FERC license requirements, to improve habitat conditions and augment declining populations. The USFWS is leading an effort to develop regional Foothill Yellow-legged Frog conservation strategies, and CESA listing may result in increased priority for limited conservation funds.

LISTING RECOMMENDATION

CESA directs the Department to prepare this report regarding the status of the Foothill Yellow-legged Frog in California based upon the best scientific information available (Fish & G. Code, § 2074.6). CESA also directs the Department based on its analysis to indicate in the status report whether the petitioned action (i.e., listing as threatened) is warranted (Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

Under CESA, an endangered species is defined as "a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease" (Fish & G. Code, § 2062). A threatened species is defined as "a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA]" (Fish and G. Code, § 2067).

The Department includes and makes its recommendation in its status report as submitted to the Commission in an advisory capacity based on the best available science. In consideration of the scientific information contained herein, the Department has determined that listing the Foothill Yellow-legged Frog under CESA by genetic clade is the prudent approach due to the disparate degrees of imperilment among them. In areas of uncertainty, the Department recommends the higher protection status until clade boundaries can be better defined.

NORTHWEST/NORTH COAST: Not warranted at this time.

Clade-level Summary: This is the largest clade with the most robust populations (highest densities) and the greatest genetic diversity. This area is the least densely populated by humans; contains relatively few hydroelectric dams, particularly further north; and has the highest precipitation in the species' California range. The species is still known to occur in most, if not all, historically occupied watersheds; presumed extirpations are mainly concentrated in the southern portion of the clade around the heavily urbanized San Francisco Bay area. The proliferation of cannabis cultivation, particularly illicit grows in and around the Emerald Triangle, the apparent increase in severe wildland fires in the area, and potential climate change effects are cause for concern, so the species should remain a Priority 1 SSC here with continued monitoring for any change in its status.

WEST/CENTRAL COAST: Endangered.

Clade-level Summary: Foothill Yellow-legged Frogs appear to be extirpated from a relatively large proportion of historically occupied sites within this clade, particularly in the heavily urbanized northern portion around the San Francisco Bay. In the northern portion of the clade, nearly all the remaining populations (which may be fewer than a dozen) are located above dams, which line the mountains surrounding the Bay Area, and two are known to have undergone recent disease-associated die-offs. These higher elevation sites are more often intermittent or ephemeral streams than the lower in the watersheds. As a result, the more frequent and extreme droughts that have dried up large areas seem to have contributed to recent declines. Illegal cannabis cultivation, historical mining effects, overgrazing, and recreation likely contributed to declines and may continue to threaten remaining populations.

SOUTHWEST/SOUTH COAST: Endangered.

Clade-level Summary: The most extensive extirpations have occurred in this clade, and only two known extant populations remain. Both are small with apparently low genetic diversity, making them especially vulnerable to extirpation. This is also an area with a large human population, many dams, and naturally arid, fire-prone environments, particularly in the southern portion of the clade. Introduced species are widespread, and cannabis cultivation is rivaling the Emerald Triangle in some areas (e.g., Santa Barbara County). Introduced species, expanded recreation, disease, and flooding appear to have contributed to the widespread extirpations in southern California over 40 years ago.

FEATHER RIVER: Threatened.

Clade-level Summary: This is the smallest clade and has a high density of hydroelectric dams. It also recently experienced one of the largest, most catastrophic wildfires in California history. Despite these threats, Foothill Yellow-legged Frogs appear to continue to be relatively broadly distributed within the clade, although with all the dams in the area, most populations are likely disconnected. The area is more mesic and experienced less of a change in precipitation in the most recent drought than the clades south of it. The clade is remarkable genetically and morphologically as it is the only area where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs overlap and can hybridize. The genetic variation within the clade is greater than the other clades except for the Northwest/North Coast. Most of the area within the clade's boundaries is Forest Service-managed, and little urbanization pressure or known extirpations exist in this area. Recent FERC licenses in this area require Foothill Yellow-legged Frog specific conservation, which to date has included cancelling pulse flows, removing encroaching vegetation, and translocating egg masses and in situ head-starting to augment a population that had recently declined.

NORTHEAST/NORTHERN SIERRA: Threatened.

Clade-level Summary: The Northeast/Northern Sierra clade shares many of the same threats as the Feather River clade (e.g., relatively small area with many hydroelectric dams). The area is also more mesic and experienced less of a change in precipitation during the recent drought than more southern clades. However, this pattern may not continue as some models suggest loss of snowmelt will be greater in the northern Sierra Nevada, and one of the climate change exposure models suggests a comparatively large proportion of the lower elevations will experience climatic conditions not currently known from the area (i.e., non-analog) by the end of the century. Recent surveys suggest the area continues to support several populations of the species, some of which seem to remain robust, with a fairly widespread distribution. However, genetic analyses from several watersheds suggest many of these populations are isolated and diverging, particularly in regulated reaches with hydropeaking flows.

EAST/SOUTHERN SIERRA: Endangered.

Clade-level Summary: Like the Southwest/South Coast clade, widespread extirpations in this area were observed as early as the 1970s. Dams and introduced species were credited as causal factors in these declines in distribution and abundance, and mining and disease may also have contributed. This area is relatively arid, and drought effects appear greater here than in northern areas that exhibit both more precipitation and a smaller difference between drought years and the historical average. There is a relatively high number of hydroelectric power generating dams in series along the major rivers in this clade and at least one new proposed dam near one of the remaining populations. This area is also the most heavily impacted by agrochemicals from the San Joaquin Valley.

MANAGEMENT RECOMMENDATIONS

The Department has evaluated existing management recommendations and available literature applicable to the management and conservation of the Foothill Yellow-legged Frog to arrive at the following recommendations. These recommendations, which represent the best available scientific information, are largely derived the from the Foothill Yellow-legged Frog Conservation Assessment, the California Energy Commission's Public Interest Energy Research Reports, the Recovery Plans of West Coast Salmon and Steelhead, and the California Amphibian and Reptile Species of Special Concern (Kupferberg et al. 2009b,c; 2011a; NMFS 2012, 2013, 2014, 2016; Hayes et al. 2016, Thomson et al. 2016).

Conservation Strategies

Maintain current distribution and genetic diversity by protecting existing Foothill Yellow-legged Frog populations and their habitats and providing opportunities for genetic exchange. Increase abundance to viable levels in populations at risk of extirpation due to small sizes, when appropriate, through in situ or ex situ captive rearing and/or translocations. Use habitat suitability and hydrodynamic habitat models to identify historically occupied sites that may currently support Foothill Yellow-legged Frogs, or they could with minor habitat improvements or modified management. Re-establish extirpated populations in suitable habitat through captive propagation, rearing, and/or translocations. Prioritize areas in the southern portions of the species' range where extirpations and loss of diversity have been the most severe.

If establishing reserves, prioritize areas containing high genetic variation in Foothill Yellow-legged Frogs (and among various native species) and climatic gradients where selection varies over small geographical area because environmental heterogeneity can provide a means of maintaining phenotypic variability which increases the adaptive capacity of populations as conditions change. These reserves should provide connectivity to other occupied areas to facilitate gene flow and allow for ongoing selection to fire, drought, thermal stresses, and changing species interactions.

Research and Monitoring

Attempt to rediscover potentially remnant populations in areas where they are considered extirpated, prioritizing the southern portions of the species' range. Collect environmental DNA in addition to conducting visual encounter surveys to improve detectability. Concurrently assess presence of threats and habitat suitability to determine if future reintroductions may be possible. Collect genetic samples from any Foothill Yellow-legged Frogs captured for use in landscape genomics analyses and possible future translocation or captive propagation efforts. Attempt to better clarify clade boundaries where there is uncertainty. Study whether small populations are at risk of inbreeding depression, whether genetic rescue should be attempted, and if so, whether that results in hybrid vigor or outbreeding depression.

Continue to evaluate how water operations affect Foothill Yellow-legged Frog population demographics. Support, and coordinate existing monitoring and ~~Establish~~ establish more long-term monitoring programs in regulated and unregulated (reference) rivers across the species' range but particularly in areas like the Sierra Nevada where most large hydropower dams in the species' range are concentrated. Assess whether the timing of pulse flows influences population dynamics, particularly whether early releases have a disproportionately large adverse effect by eliminating the reproductive success of the largest, most fecund females, who appear to breed earlier in the season. Investigate survival rates in poorly-understood life stages, such as tadpoles, young of the year, and juveniles. Determine the extent to which pulse flows contribute to displacement and mortality of post-metamorphic life stages.

Collect habitat variables that correlate with healthy populations to develop more site-specific habitat suitability and hydrodynamic models. Study the potential synergistic effect of increased flow velocity and decreased temperature on tadpole fitness. Examine the relationship between changes in flow, breeding and rearing habitat connectivity, and scouring and stranding to develop site-specific benign ramping rates. Incorporate these data and demographic data into future PVAs for use in establishing frog-friendly flow regimes in future FERC relicensing or license amendment efforts and habitat restoration projects. Ensure long-term funding for post-license or restoration monitoring to evaluate attainment of expected results and for use in adapting management strategies accordingly.

Evaluate the distribution of other threats such as cannabis cultivation, vineyard expansion, livestock grazing, mining, timber harvest, and urbanization and roads in the Foothill Yellow-legged Frog's range. Study the short- and long-term effects of wildland fires and fire management strategies. Assess the extent to which these potential threats pose a risk to Foothill Yellow-legged Frog persistence in both regulated and unregulated systems.

Investigate how reach-level or short-distance habitat suitability and hydrodynamic models can be extrapolated to a watershed level. Study habitat connectivity needs such as the proximity of breeding sites and other suitable habitats along a waterway necessary to maintain gene flow and functioning meta-population dynamics.

Habitat Restoration and Watershed Management

Remove or update physical barriers like dams and poorly constructed culverts and bridges to improve connectivity and natural stream processes. Remove anthropogenic features that support introduced predators and competitors such as abandoned mine tailing ponds that support bullfrog breeding. Conduct active eradication and management efforts to decrease the abundance of bullfrogs, non-native fish, and crayfish (where they are non-native). In managed rivers, manipulate stream flows to negatively affect non-native species not adapted to a winter flood/summer drought flow regime.

Adopt a multi-species approach to channel restoration projects and managed flow regimes (thermal, velocity, timing) and mimic the natural hydrograph to the greatest extent possible. When this is impractical or infeasible, focus on minimizing adverse impacts by gradually ramping discharge up and down, creating and maintaining gently sloping and sun-lit gravel bars and warm calm edgewater habitats for tadpole rearing, and mixing hypolimnetic water (from the lower colder stratum in a reservoir) with warmer surface water before release if necessary to ensure appropriate thermal conditions for successful metamorphosis. Promote restoration and maintenance of habitat heterogeneity (different depths, velocities, substrates, etc.) and connectivity to support all life stages and gene flow. Avoid damaging Foothill Yellow-legged Frog breeding habitat when restoring habitat for other focal species like anadromous salmonids.

Regulatory Considerations and Best Management Practices

Develop range-wide minimum summer baseflow requirements that protect Foothill Yellow-legged Frogs and their habitat with appropriate provisions to address regional differences using new more ecologically-meaningful approaches such as modified percent-of-flow strategies for watersheds (e.g., Mierau et al. 2018). Limit water diversions during the dry season and construction of new dams by focusing on off-stream water storage strategies.

Ensure and improve protection of riparian systems. Require maintenance of appropriate riparian buffers and canopy coverage (i.e., partly shaded) around occupied habitat or habitat that has been identified for potential future reintroductions. Restrict instream work to dry periods where possible. Prohibit fording in and around breeding habitat. Avoid working near streams after the first major rains in the fall when Foothill Yellow-legged Frogs may be moving upslope toward tributaries and overwintering sites. Use a 3 mm (0.125 in) mesh screen on water diversion pumps and limit the rate and amount of water diverted such that depth and flow remain sufficient to support Foothill Yellow-legged Frogs of all life stages occupying the immediate area and downstream. Install exclusion fencing where appropriate (being mindful of predators, such as river otters, that may take advantage of fencing to catch frogs). I~~, and i~~f Foothill Yellow-legged Frog relocation is required, conduct it early in the season because moving egg masses is easier than moving tadpoles.

Reduce habitat degradation from sedimentation, pesticides, herbicides, and other non-point source waste discharges from adjacent land uses including along tributaries of rivers and streams. Limit mining to parts of rivers not used for oviposition, such as deeper pools or reaches with few tributaries, and at times of year when frogs are more common in tributaries (i.e., fall and winter). Manage recreational activities in or adjacent to Foothill Yellow-legged Frog habitat (e.g., OHV and hiking trails, camp sites, boating ingress/egress, flows, and speeds) in a way that minimizes adverse impacts. Siting cannabis grows in areas with better access to roads, gentler slopes, and ample water resources could significantly reduce threats to the environment. Determine which, when, and where agrochemicals should be restricted to reduce harm to Foothill Yellow-legged Frogs and other species. Ensure all new road crossings and upgrades to existing crossings (bridges, culverts, fills, and other crossings) accommodate at least 100-year flood flows and associated bedload and debris.

Partnerships and Coordination

Establish collaborative partnerships with agencies, universities, and non-governmental organizations working on salmon and steelhead recovery and stream restoration. Anadromous salmonids share many of the same threats as Foothill Yellow-legged Frogs, and recovery actions such as barrier removal, restoration of natural sediment transport processes, reduction in pollution, and eradication of non-native predators ~~would~~ should be planned so as to benefit frogs as well. Ensure Integrated Regional Water Management Plans and fisheries restoration programs take Foothill Yellow-legged Frog conservation into consideration during design, implementation, and maintenance.

Encourage local governments to place conditions on new developments to minimize negative impacts on riparian systems. Promote and implement initiatives and programs that improve water conservation use efficiency, reduce greenhouse gas emissions, promote sustainable agriculture and smart urban growth, and protect and restore riparian ecosystems. Shift reliance from on-stream storage to off-stream storage, resolve frost protection issues (water withdrawals), and ensure necessary flows for all life stages in all water years.

Establish a Department-coordinated staff and citizen scientist program to systematically monitor occupied stream reaches across the species' range.

Education and Enforcement

Support programs to provide educational outreach and local involvement in restoration and watershed stewardship, such as Project Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land and water use on Foothill Yellow-legged Frog survival.

Provide additional funding for increased law enforcement to reduce ecologically harmful stream alterations and water pollution and to ensure adequate protection for Foothill Yellow-legged Frogs at pumps and diversions. Identify and address illegal water diverters and out-of-compliance diverters, seasons of diversion, off-stream reservoirs, well pumping, and bypass flows to protect Foothill Yellow-legged Frogs. Prosecute violators accordingly.

ECONOMIC CONSIDERATIONS

The Department is charged in an advisory capacity in the present context to provide a written report and a related recommendation to the Commission based on the best scientific information available regarding the status of Foothill Yellow-legged Frog in California. The Department is not required to prepare an analysis of economic impacts (See Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

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Patterson, Laura@Wildlife

From:	Lind, Amy -FS <amy.lind@usda.gov>
Sent:	Wednesday, June 12, 2019 11:08 AM
To:	Patterson, Laura@Wildlife
Subject:	RE: Peer Review Request: Foothill Yellow-legged Frog Status Review
Attachments:	DRAFT FYLF Status Review-2019.05.21_Lind.docx

Laura – I have gotten through a bit of the document and am now out of the office until July 1. I have included my comments as 'track changes' text edits, or margin notes, through page 35, in the attached WORD document. I was unable to just pick and choose sections to read (lost the thread too much), so I did start at the beginning and work forward.

If you would like my comments on the remainder of the document, I may be to work on it again in early July. Let me know.

Overall, I found this to be a comprehensive document on the status of the foothill yellow-legged frog (*Rana boylii*) in California. It is well written with clear logic. The incorporation of new genetic data is a big positive!

A couple of "housekeeping" items:

- Recommend number the Sections/Subsections for ease of referencing and so the reader can better follow the different heading levels (e.g., 1.0, 1.1, 1.1.1, 1.1.2, etc.)
- Check the use of present and past tense throughout the document – I noted a few places where things seems off.
- Figures:
    - For figures taken from other sources, remove the original figure number and legend, describe the figure in your own words in this document's caption, and cite appropriately (e.g., your Figures 2 and 4)
    - Also, some figures are in the figure list, and included in the text, but never referenced in the text.
    - Consider adding more references to figures (you can point to them more than once if they are relevant) – as they say "a picture is worth 1000 words" ☺

I apologize that I was unable to complete the full review on your requested timeline. My upcoming time off has been planned for months.
Best Regards,
Amy

Amy Lind
Hydroelectric Coordinator

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Caring for the land and serving people

Please note my new email, and update your address books.

From: Patterson, Laura@Wildlife [mailto:Laura.Patterson@wildlife.ca.gov]
Sent: Tuesday, May 21, 2019 2:37 PM
To: Lind, Amy -FS <amy.lind@usda.gov>
Subject: RE: Peer Review Request: Foothill Yellow-legged Frog Status Review

Okay, thanks. The letter gives some instruction on what to focus on, but here's how I'd prioritize your review by the major headings in the TOC:

1. Factors Affecting Ability to Survive and Reproduce
2. Status and Trends in California
3. Existing Management
4. Management Recommendations
5. Biology and Ecology
6. Protection Afforded by Listing
7. Summary of Listing Factors
8. Listing Recommendation

If you have very limited time, please try to get through 1, 2, 7 and 8. You can completely ignore the Regulatory Setting and Economic Considerations.

Thanks so much!

From: Lind, Amy -FS <amy.lind@usda.gov>
Sent: Tuesday, May 21, 2019 2:04 PM
To: Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov>
Subject: RE: Peer Review Request: Foothill Yellow-legged Frog Status Review

Laura – I have received the review documents. I will make every effort to meet your deadline, though as I noted previously, a good portion of the review period coincides with previously scheduled out of town travel. I will update you as the requested deadline approaches.
Best,
Amy

Amy Lind
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Please note my new email, and update your address books.

From: Patterson, Laura@Wildlife [mailto:Laura.Patterson@wildlife.ca.gov]
Sent: Tuesday, May 21, 2019 1:55 PM
To: Lind, Amy -FS <amy.lind@usda.gov>
Subject: RE: Peer Review Request: Foothill Yellow-legged Frog Status Review

Good afternoon, Dr. Lind,

Thanks for your patience. We had a couple of loose ends to tie up. Please see the attached letter and draft status review. If you have any questions or concerns with the timeline, please let me know.

Will you please respond to this email to confirm you received it?

Thanks again,
Laura

From: Lind, Amy -FS <alind@fs.fed.us>
Sent: Tuesday, April 9, 2019 2:22 PM
To: Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov>
Subject: RE: Peer Review Request: Foothill Yellow-legged Frog Status Review

Laura – Sorry for the delayed reply. I am happy to respond positively to your request for a peer review of the California status review for the foothill yellow-legged frog and I look forward to seeing the draft document.

My only constraint is timing. I will be out of town during a portion of the proposed review period. I will do my best to respond by mid-June (as described in your email) and I will certainly update you if I need a few more days.

Thank you for including me in this process,
Amy

Amy Lind
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Please note my new email, and update your address books.

From: Patterson, Laura@Wildlife [mailto:Laura.Patterson@wildlife.ca.gov]
Sent: Tuesday, April 2, 2019 3:25 PM
To: Lind, Amy -FS <alind@fs.fed.us>
Subject: Peer Review Request: Foothill Yellow-legged Frog Status Review

Dear Dr. Lind,

The Fish and Game Commission (Commission) was petitioned to list the Foothill Yellow-legged Frog as threatened under the California Endangered Species Act (CESA) by the Center for Biological Diversity in December 2016. The California Department of Fish and Wildlife (Department) is tasked with writing a status review and providing a recommendation to the Commission on whether or not the best scientific information available supports the petitioner's position that listing is warranted. Part of the status review process is external peer review of the draft status review.

I am contacting you as a Foothill Yellow-legged Frog subject matter expert to request your participation in the peer review process. The Department expects the draft will be ready on for distribution to peer reviewers on or around May 17th. We would ask that you focus your review on the scientific information available regarding the status of Foothill Yellow-legged Frogs in California. Your peer review of the science and analysis regarding each of the listing factors prescribed in CESA (i.e., present or threatened habitat modification, overexploitation, predation, competition, disease, and other natural occurrences or human-related activities that could affect the species) is particularly valuable. We request that comments be submitted on or before one month from the date of receipt (on or around June 17th).

In addition, per the Department's Peer Review Policy (Department Bulletin 2017-03), I must ensure that you have no financial or other conflict of interest with the outcome or implications of the peer reviewed product.

Please respond to whether you are willing and able to participate in this important part of the listing determination process by Thursday April 11th.

Thank you for your consideration,
Laura

Laura Patterson
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STATE OF CALIFORNIA
NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION

A STATUS REVIEW OF THE **FOOTHILL YELLOW-LEGGED FROG** (*Rana boylii*) IN CALIFORNIA

CHARLTON H. BONHAM, DIRECTOR
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
External Peer Review Draft

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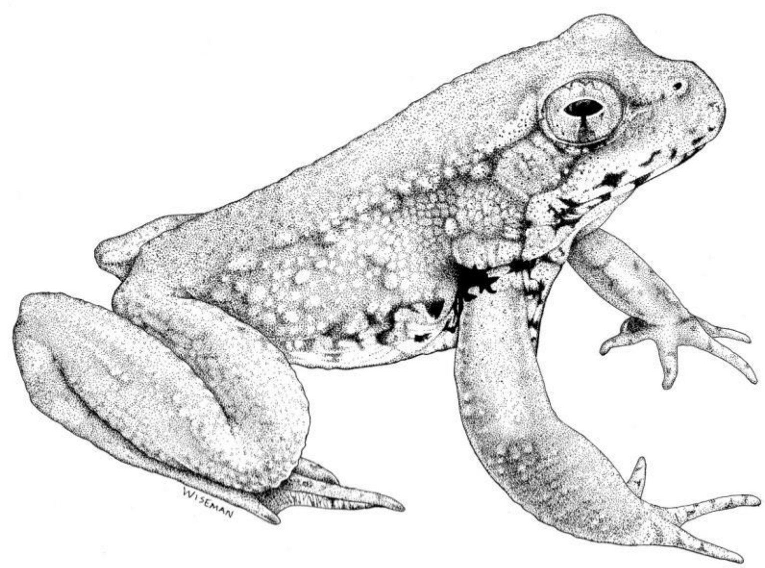

ACKNOWLEDGMENTS

Laura Patterson prepared this report. Stephanie Hogan, Madeleine Wieland, and Margaret Mantor assisted with portions of the report, including the sections on Status and Trends in California and Existing Management. Kristi Cripe provided GIS analysis and figures. Review of a draft document was provided by the following California Department of Fish and Wildlife (Department) staff: Ryan Bourque, Marcia Grefsrud, and Mike van Hattem.

The Department is extremely grateful for the valuable comments provided on this report by the following peer reviewers: Dr. Sarah Kupferberg, Dr. Amy Lind, Dr. Jimmy McGuire, and Dr. Ryan Peek. The conclusions in this report are those of the Department and do not necessarily reflect those of the reviewers.

Cover photograph by Isaac Chellman, used with permission.

Illustration by Kevin Wiseman, used with permission.

EXECUTIVE SUMMARY

[To be completed after external peer review]

REGULATORY SETTING

Petition Evaluation Process

A petition to list the Foothill Yellow-legged Frog (*Rana boylii*) as threatened under the California Endangered Species Act (CESA) was submitted to the Fish and Game Commission (Commission) on December 14, 2016 by the Center for Biological Diversity. Commission staff transmitted the petition to the Department of Fish and Wildlife (Department) pursuant to Fish and Game Code section 2073 on December 22, 2016 and published a formal notice of receipt of the petition on January 20, 2017 (Cal. Reg. Notice Register 2017, No. 3-Z, p. 46). A petition to list or delist a species under CESA must include "information regarding the population trend, range, distribution, abundance, and life history of a species, the factors affecting the ability of the population to survive and reproduce, the degree and immediacy of the threat, the impact of existing management efforts, suggestions for future management, and the availability and sources of information. The petition shall also include information regarding the kind of habitat necessary for species survival, a detailed distribution map, and any other factors that the petitioner deems relevant" (Fish & G. Code, § 2072.3).

On April 17, 2017, the Department provided the Commission with its evaluation of the petition, "Evaluation of the Petition from the Center For Biological Diversity to List the Foothill Yellow-legged Frog (*Rana boylii*) as Threatened under the California Endangered Species Act," to assist the Commission in making a determination as to whether the petitioned action may be warranted based on the sufficiency of scientific information (Fish & G. Code, §§ 2073.5 & 2074.2; Cal. Code Regs., tit. 14, § 670.1, subds. (d) & (e)). Focusing on the information available to the Department relating to each of the relevant categories, the Department recommended to the Commission that the petition be accepted.

At its scheduled public meeting on June 21, 2017, in Smith River, California, the Commission considered the petition, the Department's petition evaluation and recommendation, and comments received. The Commission found that sufficient information existed to indicate the petitioned action may be warranted and accepted the petition for consideration. Upon publication of the Commission's notice of its findings, the Foothill Yellow-legged Frog was designated a candidate species on July 7, 2017 (Cal. Reg. Notice Register 2017, No. 27-Z, p. 986).

Status Review Overview

The Commission's action designating the Foothill Yellow-legged Frog as a candidate species triggered the Department's process for conducting a status review to inform the Commission's decision on whether listing the species is warranted. At its scheduled public meeting on June 21, 2018, in Sacramento, California, the Commission granted the Department a six-month extension to complete the status review and facilitate external peer review.

This status review report is not intended to be an exhaustive review of all published scientific literature relevant to the Foothill Yellow-legged Frog; rather, it is intended to summarize the key points from the best scientific information available relevant to the status of the species. This final report, based upon the best scientific information available to the Department, is informed by independent peer review of a draft report by scientists with expertise relevant to the Foothill Yellow-legged Frog. This review is intended to provide the Commission with the most current information on the Foothill Yellow-legged Frog and to serve as the basis for the Department's recommendation to the Commission on whether the petitioned action is warranted. The status review report also identifies habitat that may be essential to continued existence of the species and provides management recommendations for recovery of the species (Fish & G. Code, § 2074.6). Receipt of this report is to be placed on the agenda for the next available meeting of the Commission after delivery. At that time, the report will be made available to the public for a 30-day public comment period prior to the Commission taking any action on the petition.

Federal Endangered Species Act Review

The Foothill Yellow-legged Frog is currently under review for possible listing as threatened or endangered under the federal Endangered Species Act (ESA) in response to a July 11, 2012 petition submitted by the Center for Biological Diversity. On July 1, 2015, the U.S. Fish and Wildlife Service (USFWS) published its 90-day finding that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted and initiated a status review of the species (USFWS 2015). On March 16, 2016, the Center for Biological Diversity sued the USFWS to compel issuance of a 12-month finding on whether listing under the ESA is warranted. On August 30, 2016, the parties reached a stipulated settlement agreement that the USFWS shall publish its 12-month finding in the Federal Register on or before September 30, 2020 (*Center for Biological Diversity v. S.M.R. Jewell* (D.D.C. Aug. 30, 2016, No. 16-CV-00503)).

BIOLOGY AND ECOLOGY

Species Description and Life History

> *"In its life-history* boylii *exhibits several striking specializations which are in all probability related to the requirements of life of a stream-dwelling species"* – Tracy I. Storer, 1925

The Foothill Yellow-legged Frog is a small- to medium-sized frog; adults range from 38 to 81 mm (1.5-3.2 in) snout to urostyle length (SUL) with females attaining a larger size than males and males possessing paired internal vocal sacs (Zweifel 1955, Nussbaum et al. 1983, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs are typically gray, brown, olive, or reddish with brown-black flecking and mottling, which generally matches the substrate of the stream in which they reside (Nussbaum et al. 1983, Stebbins and McGinnis 2012). They often have a pale triangle between the eyes and snout and broad dark bars on the hind legs (Zweifel 1955, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs have a relatively squat body and granular skin, giving them a rough appearance similar to a toad, and fully webbed feet with slightly expanded toe tips (Nussbaum et al. 1983). The tympanum is also rough

and relatively small compared to congeners at around one-half the diameter of the eye (Zweifel 1955). The dorsolateral folds (glandular ridges extending from the eye area to the rump) in Foothill Yellow-legged Frogs are indistinct compared to other western North American ranids (Stebbins and McGinnis 2012). Ventrally, the abdomen is white with variable amounts of dark mottling on the chest and throat, which are unique enough to be used to identify individuals (Marlow et al. 2016). As their name suggests, the underside of their hind limbs and lower abdomen are often yellow; however, individuals with orange and red have been observed within the range of the California Red-legged Frog (*Rana draytonii*), making hindlimb coloration a poor diagnostic characteristic for this species (Jennings and Hayes 2005).

Adult females likely lay one clutch of eggs per year and may breed every year (Storer 1925, Wheeler et al. 2006). Foothill Yellow-legged Frog egg masses resemble a compact cluster of grapes approximately 45 to 90 mm (1.8-3.5 in) in diameter length-wise and contain anywhere from around 100 to over 3,000 eggs (Kupferberg et al. 2009c, Hayes et al. 2016). The individual embryos are dark brown to black with a lighter area at the vegetative pole and surrounded by three jelly envelopes that range in diameter from approximately 3.9 to 6.0 mm (0.15-0.25 in) (Storer 1925, Zweifel 1955, Hayes et al. 2016).

Foothill Yellow-legged Frog tadpoles hatch out around 7.5 mm (0.3 in) long and are a dark brown or black (Storer 1925, Zweifel 1955). They grow rapidly to 37 to 56 mm (1.5-2.2 in) and turn olive with a coarse brown mottling above and an opaque silvery color below (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012). Their eyes are positioned dorsally when viewed from above (i.e., within the outline of the head), and their mouths are large, downward-oriented, and suction-like with several tooth rows (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012, Hayes et al. 2016). Foothill Yellow-legged Frogs metamorphose at around 14-17 mm (0.55-0.67 in) SUL (Fellers 2005). Sexual maturity is attained at around 30-40 mm (1.2-1.6 in) SUL and 1 year for males and around 40-50 mm (1.6-2.0 in) SUL and 3 years for females, although in some populations this has been accelerated by a year (Zweifel 1955, Kupferberg et al. 2009c, Breedveld and Ellis 2018). During the breeding season, males can be distinguished from females by the presence of nuptial pads (swollen darkened thumb bases that aid in holding females during amplexus) and calling, which frequently occurs underwater but sometimes from the surface (MacTague and Northen 1993, Stebbins 2003, Silver 2017).

The reported lifespan of Foothill Yellow-legged Frogs varies widely by study. Storer (1925) and Van Wagner (1996) estimated a maximum age of 2 years for both sexes and the vast majority of the population. Breedveld and Ellis (2018) calculated the typical lifespan of males at 3-4 years and 5-6 years for females. Bourque (2008), using skeletochronology, found an individual over 7 years old and a mean age of 4.7 and 3.6 years for males and females, respectively. Drennan et al. (2015) estimated maximum age at 13 years for both sexes in a Sierra Nevada population and 12 for males and 11 for females in a Coast Range population.

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Range and Distribution

Foothill Yellow-legged Frogs historically ranged from the Willamette River drainage in Oregon west of the Sierra-Cascade crest to at least the San Gabriel River drainage in Los Angeles County, California (Figure 1; Zweifel 1955, Stebbins 2003). In addition, a disjunct population was reported from 2,040 m

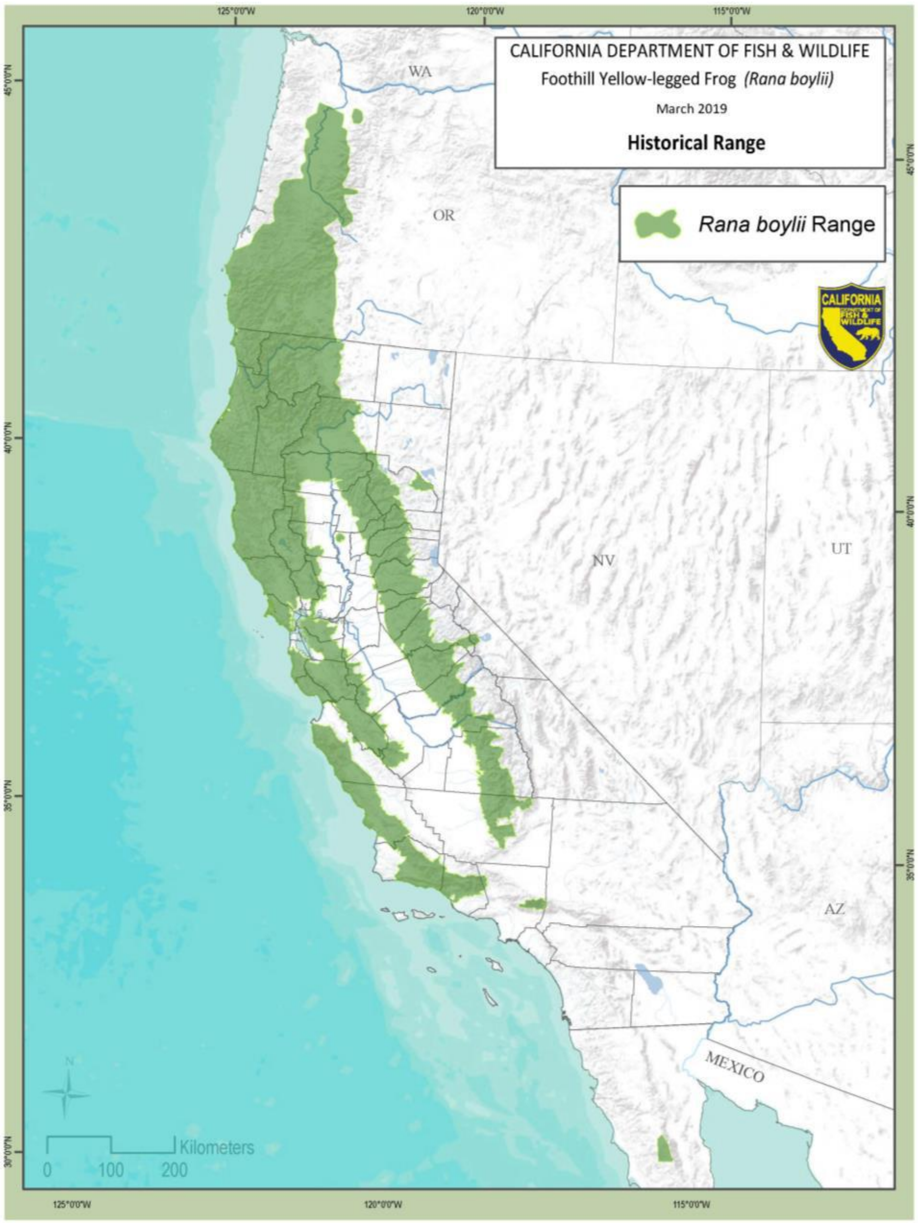

Figure 1. Foothill Yellow-legged Frog historical range (adapted from CWHR, Loomis [1965], Nussbaum et al. [1983])

(6,700 ft) in the Sierra San Pedro Mártir, Baja California Norte, México (Loomis 1965). In California, the species occupies foothill and mountain streams in the Klamath, Cascade, Sutter Buttes, Coast, Sierra Nevada, and Transverse ranges from sea level to 1,940 m (6,400 ft), but generally below 1,525 m (5,000 ft) (Hemphill 1952, Nussbaum et al. 1983, Stebbins 2003, Olson et al. 2016). Zweifel (1955) considered Foothill Yellow-legged Frogs to be present and abundant throughout their range where streams possessed suitable habitat.

Taxonomy and Phylogeny

Foothill Yellow-legged Frogs belong to the family Ranidae (true frogs), which inhabits every continent except Antarctica and contains more than 700 species (Stebbins 2003). The species was first described by Baird (1854) as *Rana boylii*. After substantial taxonomic uncertainty with respect to its relationship to other ranids (frogs in the family Ranidae) and several name changes over the next century, the Foothill Yellow-legged Frog (*R. boylii* with no subspecific epithet) was eventually recognized as a distinct species again by Zweifel (1955, 1968). The phylogenetic relationships among the western North American *Rana* spp. have been revised several times and are still not entirely resolved (Thomson et al. 2016). The Foothill Yellow-legged Frog was previously thought to be most closely related to the higher elevation Mountain Yellow-legged Frog (*R. muscosa*) (Zweifel 1955; Green 1986a,b). However, genetic analyses undertaken by Macey et al. (2001) and Hillis and Wilcox (2005) suggest they are more closely related to Oregon Spotted Frogs (*R. pretiosa*) and Columbia Spotted Frogs (*R. luteiventris*), respectively.

Population Structure and Genetic Diversity

Foothill Yellow-legged Frog populations exhibit varying levels of partitioning and genetic diversity at different spatial scales. At the coarse landscape level across the species' extant range, McCartney-Melstad et al. (2018) recovered five deeply divergent, geographically cohesive, genetic clades (Figure 2), while Peek (2018) recovered six (Figure 3). Genetic divergence is the process of speciation; it is a measure of the number of mutations accumulated by populations over time from a shared ancestor that differentiate them from the other populations in a species. When genetic divergence among clades is large enough, it can be used as a tool to define new species or subspecies.

The geographic breaks among the five clades were similar between the studies, but Peek (2018) identified a separate deeply divergent genetic clade in the Feather River watershed that is distinct from the rest of the northern Sierra Nevada clade. The five clades the two studies shared include the following [Note: naming conventions follow McCartney-Melstad et al. (2018) and Peek (2018)]:

(1) Northwest/North Coast: north of San Francisco Bay in the Coast Ranges and east into Tehama County;
(2) Northeast/Northern Sierra: northern El Dorado County (North Fork American River watershed, includes Middle Fork) and north in the Sierra Nevada to southern Plumas County (Upper Yuba River watershed);

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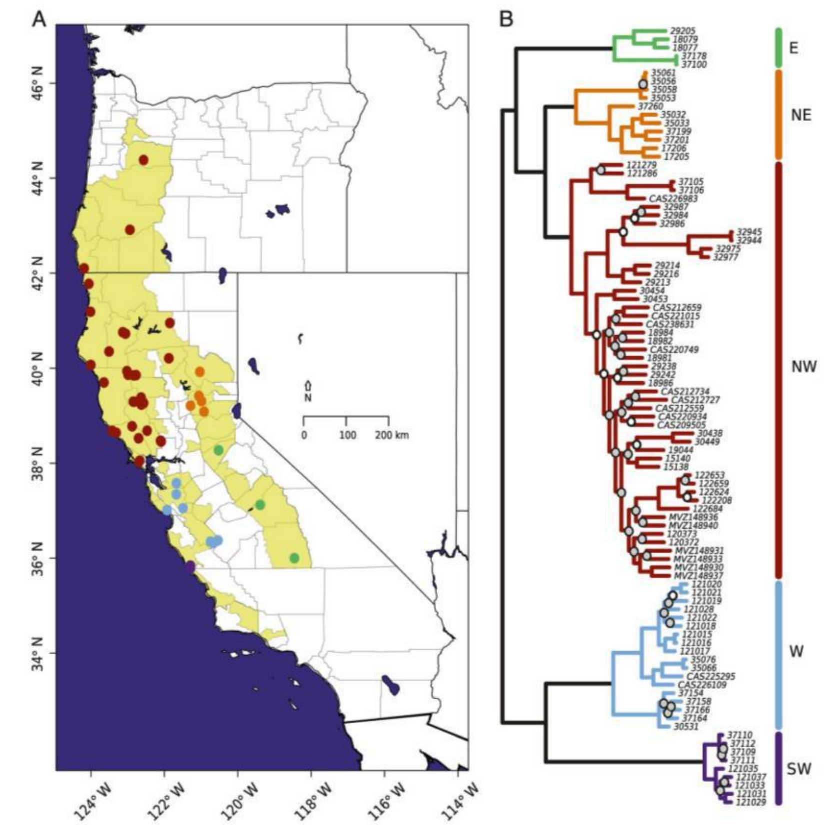

Fig. 1 **a** Map of *Rana boylii* sample localities. County outlines are shown within California and Oregon. Light yellow indicates the IUCN range map of *R. boylii*, excluding a small disjunct population at Sierra San Pedro Martir, Baja California, Mexico. Dots are colored by major grouping as determined in the **b** RAxML phylogeny, with midpoint rooting. Nodes without dots received >95% bootstrap support, those with white dots received <95% but greater than or equal to 75% bootstrap support, while nodes with gray dots received <75% bootstrap support

Figure 2. Foothill Yellow-legged Frog clades by McCartney-Melstad et al. (2018)

(3) East/Southern Sierra: El Dorado County (South Fork American River watershed) and south in the Sierra Nevada [no samples from Amador County were tested, but they would most likely fall within this clade because it is located between two other populations that occur within this clade];

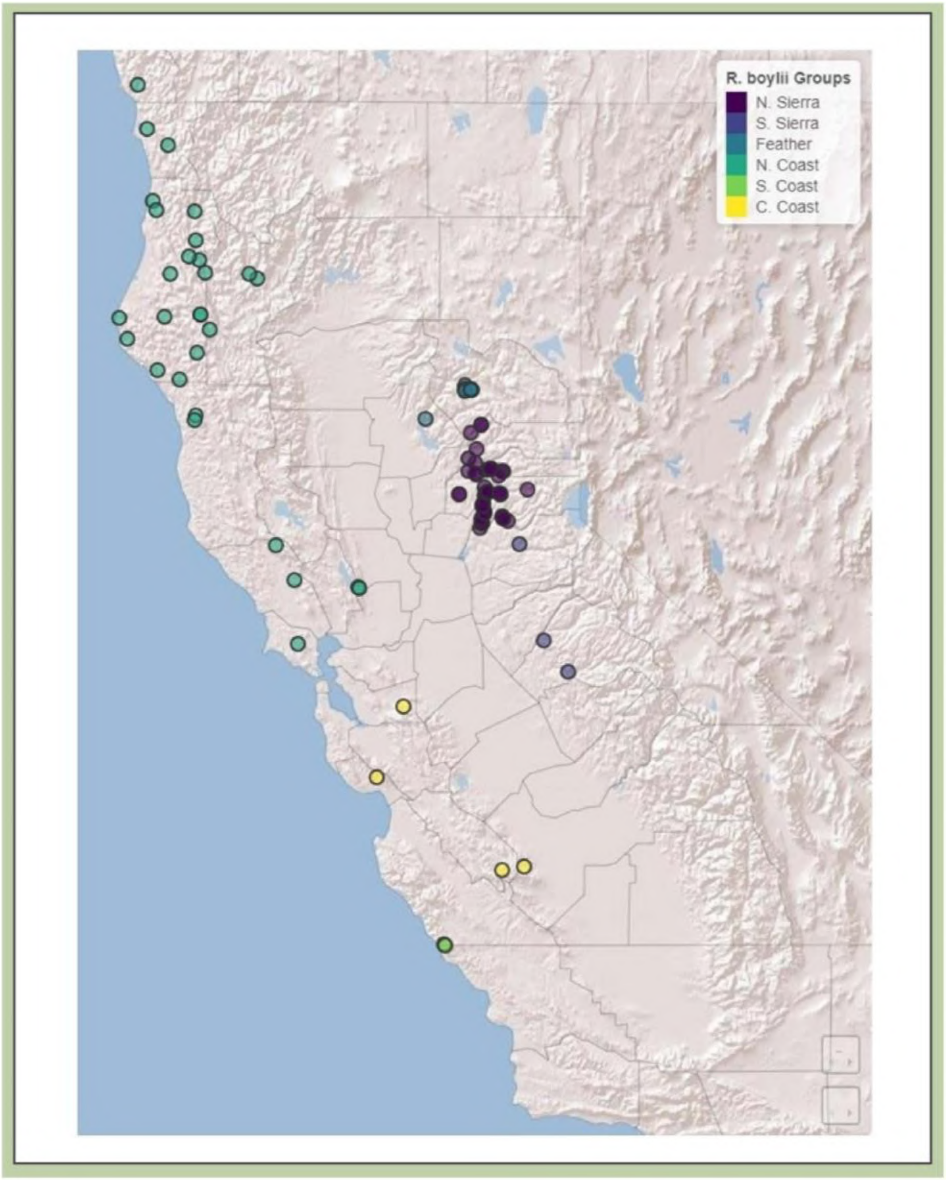

Figure 3. Foothill Yellow-legged Frog clades by Peek (2018)

(4) West/Central Coast: south of San Francisco Bay in the Coast Ranges to San Benito and Monterey counties, presumably east of the San Andreas Fault/Salinas Valley;

(5) Southwest/South Coast presumably west of the San Andreas Fault/Salinas Valley in Monterey County and south in the Coast Ranges.

The Feather River clade is found primarily in Plumas and Butte counties (Peek 2018). Peek's analysis found that this clade is as distinct as the rest of the Sierra Nevada as a cohesive group and all the coastal populations as one group, meaning it was found to be deeply divergent from the rest of the clades. McCartney-Melstad et al. (2018) also recognized the Feather River watershed as distinct from the rest of the northern Sierra but not as deeply divergent from the other clades as Peek. The Feather River watershed is also the only known location where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs (*R. sierrae*) co-occur and where two F1 hybrids (50% ancestry from each species) were found (Peek 2018). In addition, Peek's modeling results only weakly supported dividing the West/Central Coast and Southwest/South Coast groups into separate clades.

Previous work conducted by Lind et al. (2011) found a somewhat similar pattern, that populations on the periphery of the species' range are considerably genetically divergent from the rest of the range. Their results suggested that hydrologic regions and river basins were important landscape features that influenced the genetic structure of Foothill Yellow-legged Frog populations. However, using more modern genomic techniques, McCartney-Melstad et al. (2018) found nearly twice the variation among the five phylogenetic clades than among drainage basins, indicating other factors contributed to current population structure. They report that the depth of genetic divergence among Foothill Yellow-legged Frog clades exceeds that of any anuran (frog or toad) for which similar data are available and recommend using them as management units instead of the previously suggested watershed boundaries.

Levels of genetic diversity within the clades differed significantly. Genetic diversity gives species the ability to adapt to changing conditions (i.e., evolve), and its loss often signals extreme population and range reductions as well as potential inbreeding depression that can reduce survival and reproductive success (Lande and Shannon 1996, Hoffmann and Sgrò 2011, McCartney-Melstad et al. 2018). Loss of genetic diversity in Foothill Yellow-legged Frogs largely follows a north-to-south pattern with the southern clades (Southwest/South Coast and East/Southern Sierra) possessing the least amount (McCartney-Melstad et al. 2018, Peek 2018). In addition, these study results demonstrate that Foothill Yellow-legged Frogs have lost genetic diversity over time across their entire range except for the large Northwest/North Coast clade, which appears to have undergone a relatively recent population expansion (McCartney-Melstad et al. 2018, Peek 2018).

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At a watershed scale, Dever (2007) found that tributaries to rivers and streams are important for preserving genetic diversity, and populations separated by more than 10 km (6.2 mi) show signs of genetic isolation. In other words, even in the absence of anthropogenic barriers to dispersal (e.g., dams and reservoirs), individuals located more than 10 km (6.2 mi) are not typically considered part of a single interbreeding population (Olson and Davis 2009). Peek (2011, 2018) reported that at this finer-scale, population structure and genetic diversity appear to be more strongly influenced by river regulation type (i.e., dammed or undammed) than to geographic distance or watershed boundaries. In general, regulated (dammed) rivers had limited gene flow and higher genetic divergence among subpopulations compared with unregulated (undammed) rivers (Peek 2011, 2018). In addition, differences in water flow regimes within regulated rivers affected connectivity (Peek 2011, 2018). Subpopulations in hydropeaking reaches, in which pulsed flows are used for electricity generation or whitewater boating, exhibited significantly lower gene flow than those in bypass reaches where water is diverted from upstream in the basin down to power generating facilities (Figure 4; Peek 2018). River regulation had a greater influence on genetic differentiation among sites than geographic distance in the Alameda Creek watershed as well (Stillwater Sciences 2012). Reduced connectivity among sites leads to lower gene flow and a loss of genetic diversity through genetic drift, which can diminish adaptability to changing environmental conditions (Palstra and Ruzzante 2008). Peek (2011) posits that given the *R. boylii* species group is estimated to be 8 million years old (Macey et al. 2001), the significant reductions in connectivity and genetic diversity over short evolutionary time periods in regulated rivers (often less than 50 years from the time of dam construction) is cause for concern, particularly when combined with small population sizes.

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Habitat Associations and Use

> *"These frogs are so closely restricted to streams that it is unusual to find one at a greater distance from the water than it could cover in one or two leaps."* – Richard G. Zweifel, 1955

Foothill Yellow-legged Frogs inhabit rivers and streams ranging from primarily rain-fed (coastal populations) to primarily snow-influenced (most Sierra Nevada and Klamath-Cascade populations) from headwater streams to large rivers (Bury and Sisk 1997, Wheeler et al. 2014). Occupied rivers and streams flow through a variety of vegetation types including hardwood, conifer, and valley-foothill riparian forests; mixed chaparral; and wet meadows (Hayes et al. 2016). Because the species is so widespread and can be found in so many types of habitats, the vegetation community is likely less important in determining Foothill Yellow-legged Frog occupancy and abundance than the aquatic biotic and abiotic conditions in the specific river, stream, or reach (Zweifel 1955). The species is an obligate stream-breeder, which sets it apart from other western North American ranids (Wheeler et al. 2014). Foothill Yellow-legged Frog habitat is generally characterized as partly-shaded, shallow, perennial rivers and streams with a low gradient and rocky substrate that is at least cobble-sized (Zweifel 1955, Hayes and Jennings 1988). However, the use of intermittent and ephemeral streams by post-metamorphic Foothill Yellow-legged Frogs may not be all that uncommon in some parts of the species' range in California (R. Bourque pers. comm. 2019). The species has been reported from some atypical habitats as well, including ponds, isolated pools in intermittent streams, and meadows along the edge of streams that lack a rocky substrate (Fitch 1938, Zweifel 1955, J. Alvarez pers. comm. 2017, CDFW 2018a).

As stream-breeding poikilotherms (animals whose internal temperature varies with ambient temperature), appropriate flow velocity, temperature, and water availability are critically important to Foothill Yellow-legged Frogs (Kupferberg 1996a, Van Wagner 1996, Wheeler et al. 2006, Lind et al. 2016). Habitat quality is also influenced by hydrologic regime (regulated vs. unregulated), substrate, presence of non-native predators and competitors, water depth, and availability of high-quality food and basking sites (Lind et al. 1996, Yarnell 2005, Wheeler et al. 2006, Catenazzi and Kupferberg 2017). Habitat suitability and use vary by life stage, sex, geographic location, watershed size, and season and

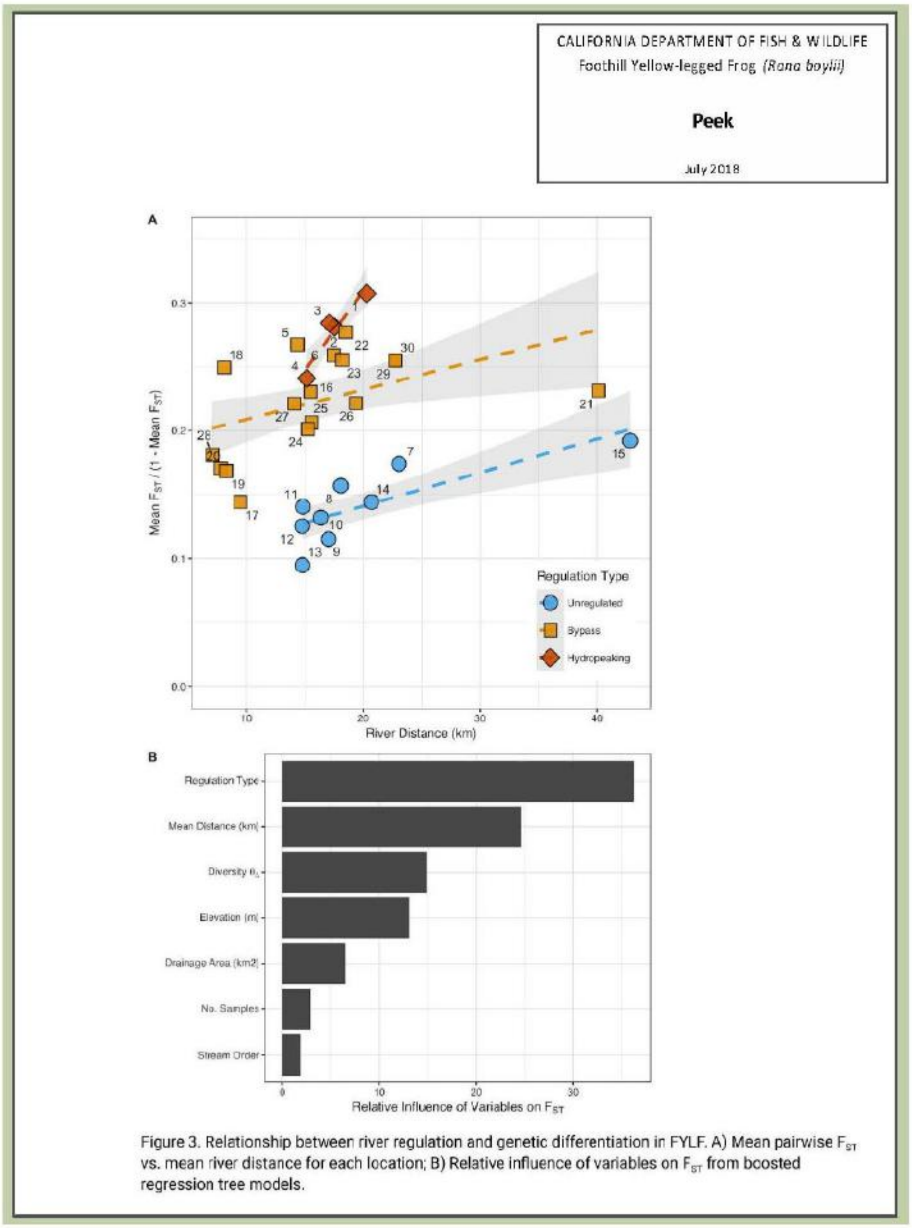

Figure 4. River regulation's relative influence on genetic differentiation from Peek (2018)

can generally be categorized as breeding and rearing habitat, nonbreeding active season habitat, and overwintering habitat (Van Wagner 1996, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011, Hayes et al. 2016, Catenazzi and Kupferberg 2017). Yarnell (2005) located higher densities of Foothill Yellow-legged Frogs in areas with greater habitat heterogeneity and suggested that they were selecting for sites that possessed the diversity of habitats necessary to support each life stage within a relatively short distance.

Breeding and Rearing Habitat

Suitable breeding habitat must be connected to suitable rearing habitat for metamorphosis to be successful. When this connectivity exists, as flows decline through the season, tadpoles can follow the receding shoreline into areas of high productivity and lower predation risk as opposed to becoming trapped in isolated pools with a high risk of overheating, desiccation, and predation (Kupferberg et al. 2009c).

Several studies on Foothill Yellow-legged Frog breeding habitat, carried out across the species' range in California, reported similar findings. Foothill Yellow-legged Frogs select oviposition (egg-laying) sites within a narrow range of depths, velocities, and substrates and exhibit fidelity to breeding sites that consistently possess suitable microhabitat characteristics over time (Kupferberg 1996a, Bondi et al. 2013, Lind et al. 2016). At a coarse-spatial scale, breeding sites in rivers and large streams are often located near the confluence of tributary streams in sunny, wide, shallow reaches (Kupferberg 1996a, Yarnell 2005, GANDA 2008, Peek 2011). These areas are highly productive compared to cooler, deeper, closed-canopy sites (Catenazzi and Kupferberg 2013). At a fine-spatial scale, females prefer to lay eggs in low velocity areas dominated by cobble- and boulder-sized substrates, often associated with sparsely-vegetated point bars (Kupferberg 1996a, Lind et al. 1996, Van Wagner 1996, Bondi et al. 2013, Lind et al. 2016). They tend to select areas with less variable, more stable flows, and in areas with higher flows at the time of oviposition, they place their eggs on the downstream side of large cobblestones and boulders, which protects them from being washed away (Kupferberg 1996a, Wheeler et al. 2006).

Appropriate rearing temperatures are vital for successful metamorphosis. Tadpoles grow faster and larger in warmer water to a point (Zweifel 1955; Catenazzi and Kupferberg 2017, 2018). Zweifel (1955) conducted experiments on embryonic thermal tolerance and determined that the critical low was approximate 6°C (43°F), and the critical high was around 26°C (79°F). Welsh and Hodgson (2011) determined that best the single variable for predicting Foothill Yellow-legged Frog presence was temperature since none were observed below 13°C (55°F), but numbers increased significantly with increasing temperature. Catenazzi and Kupferberg (2013) measured tadpole thermal preference at 16.5-22.2°C (61.7-72.0°F), and the distribution of Foothill Yellow-legged Frog populations across a watershed was consistent within this temperature range. At temperatures below 16°C (61°F), tadpoles were absent under closed canopy and scarce even with an open canopy (Ibid.). Catenazzi and Kupferberg (2017) found regional differences in apparently suitable breeding temperatures. Inland populations from primarily snowmelt-fed systems with relatively cold water were relegated to reaches that are warmer on average during the warmest 30 days of the year than coastal populations in the chiefly rainfall-fed, and thus warmer, systems (17.6-24.2°C [63.7-75.6°F] vs. 15.7-22.0°C [60.3-71.6°F], respectively).

However, experiments on tadpole thermal preference demonstrated that individuals from different source populations selected similar rearing temperatures, which presumably optimized development (Ibid.). In regulated systems, where water released from dams is often colder than normal, suitable rearing temperatures downstream may be limited (Wheeler et al. 2014, Catenazzi and Kupferberg 2017).

Appropriate flow velocities are also critical for survival to metamorphosis. The velocity at which Foothill Yellow-legged Frog egg masses shear away from the substrate they are adhered to varies according to factors such as depth and degree to which the eggs are sheltered (Spring Rivers Ecological Sciences 2003). This critical velocity is expected to decrease as the egg mass ages due to their reduced structural integrity of the protective jelly envelopes (Hayes et al. 2016). Short-duration increases in flow velocity may be tolerated if the egg masses are somewhat sheltered, but sustained high velocities increase the likelihood of detachment (Kupferberg 1996a, Spring Rivers Ecological Sciences 2003). Hatchlings and tadpoles about to undergo metamorphosis are relatively poor swimmers and require especially slow, stable flows during these stages of development (Kupferberg et al. 2011b). Tadpoles respond to increasing flows by swimming against the current to maintain position for a short period of time and eventually swimming to the bottom and seeking refuge in the rocky substrate's interstitial spaces (Ibid.). When tadpoles are exposed to repeated increases in velocities, their growth and development are delayed (Ibid.). Under experimental conditions, the critical velocity at which tadpoles were swept downstream ranged between 20 and 40 cm/s (0.66-1.31 ft/s); however, as they reach metamorphosis it decreases to as low as 10 cm/s (0.33 ft/s) (Ibid.).

Nonbreeding Active Season Habitat

Post-metamorphic Foothill Yellow-legged Frogs utilize a more diverse range of habitats and are much more dispersed during the nonbreeding active season than the breeding season. Microhabitat preferences appear to vary by location and season, but some patterns are common across the species' range. Foothill Yellow-legged Frogs tend to remain close to the water's edge (average < 3 m [10 ft]); select sunny areas with limited canopy cover; and are often associated with riffles and pools (Zweifel 1955, Hayes and Jennings 1988, Van Wagner 1996, Welsh et al. 2005, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011). Adequate water, food resources, cover from predators, ability to thermoregulate (e.g., presence of basking sites and cool refugia), and absence of non-native predators are important components of nonbreeding active season habitat (Hayes and Jennings 1988, Van Wagner 1996, Catenazzi and Kupferberg 2013).

Overwintering Habitat

Overwintering habitat varies depending on local conditions, but as with the rest of the year, Foothill Yellow-legged Frogs are most often found in or near water where they can forage and take cover from predators and high discharge events (Storer 1925, Zweifel 1955). In larger streams and rivers, Foothill Yellow-legged Frogs are often found along tributaries during the winter where the risk of being displaced by heavy flows is reduced (Kupferberg 1996a, Gonsolin 2010). Bourque (2008) found 36.4% of adult females used intermittent and ephemeral tributaries during the overwintering season. Van

Wagner (1996) located most overwintering frogs using pools with cover such as boulders, root wads, and woody debris. During high flow events, they moved to the stream's edge and took cover under vegetation like sedges (*Carex* sp.) or leaf litter (Ibid.). Rombough (2006) found most Foothill Yellow-legged Frogs under woody debris along the high-water line and often using seeps along the stream-edge, which provided them with moisture, a thermally stable environment, and prey.

Exceptions to the pattern of remaining near the stream's edge during winter have been reported. Cook et al. (2012) observed dozens of juvenile Foothill Yellow-legged Frogs traveling over land, as opposed to using riparian corridors. They were found using upland habitats with an average distance of 71.3 m (234 ft) from water (range: 16-331 m [52-1,086 ft]) (Ibid.). In another example, a single subadult that was found adjacent to a large wetland complex 830 m (2,723 ft) straight-line distance from the wetted edge of the Van Duzen River, although it is possible the wetland was connected to the river via a spillway or drainage that may have served as the movement corridor (CDFW 2018a, R. Bourque pers. comm. 2019).

Seasonal Activity and Movements

Because Foothill Yellow-legged Frogs occupy areas with relatively mild winter temperatures, they can be active year-round, although at low temperatures (< 7°C [44 °F], they become lethargic (Storer 1925, Zweifel 1955, Van Wagner 1996, Bourque 2008). They are active both day and night, and during the day adults are often observed basking on warm objects such as sun-heated rocks, although this is also when their detectability is highest (Fellers 2005, Wheeler et al. 2005). By contrast, Gonsolin (2010) tracked radio-telemetered Foothill Yellow-legged Frogs under substrate a third of the time and underwater a quarter of the time, although nearly all his detections of frogs without transmitters were basking.

Adult Foothill Yellow-legged Frogs migrate from their overwintering sites to breeding habitat in the spring, often from a tributary to its confluence with a larger stream or river. In areas where tributaries dry down, juveniles also make this downstream movement (Haggarty 2006). When the tributary itself is perennial and provides suitable breeding habitat, the frogs may not undertake these long-distance movements (Gonsolin 2010). Cues for adults to initiate this migration to breeding sites are somewhat enigmatic and vary by location, elevation, and amount of precipitation (S. Kupferberg and A. Lind pers. comm. 2017). They can also include day length, water temperature, and sex (GANDA 2008, Gonsolin 2010, Yarnell et al. 2010, Wheeler et al. 2018). Males initiate movements to breeding sites where they congregate in leks (areas of aggregation for courtship displays), and females arrive later and over a longer period (Wheeler and Welsh 2008, Gonsolin 2010). Most males utilize breeding sites associated with their overwintering tributaries, but some move substantial distances to other sites and may use more than one breeding site in the same season (Wheeler and Welsh 2006, GANDA 2008).

While the predictable hydrograph in California consists of wet winters with high flows and dry summers with low flows, the timing and quantity of seasonal discharge can vary significantly from year to year. The timing of oviposition can influence offspring growth and survival. Early breeders risk scouring of egg masses from their substrate by late spring storms in wet years or desiccation if waters recede rapidly, but when they successfully hatch, tadpoles benefit from a longer growing season, which can enable them to metamorphose at a larger size and increase their likelihood of survival (Railsback et al. 2016).

Later breeders are less likely to have their eggs scoured away or desiccated because flows are generally more stable, but they have fewer mate choices, and their tadpoles have a shorter growing period before metamorphosis, reducing their chance of survival (Ibid.). Some evidence indicates larger females, who coincidentally lay larger clutches, breed earlier (Kupferberg et al. 2009c, Gonsolin 2010). Consequently, early season scouring or stranding of egg masses or tadpoles can disproportionately impact the population's reproductive output because later breeders produce fewer and smaller eggs per clutch (Kupferberg et al. 2009c, Gonsolin 2010).

Timing of oviposition is often a function of water temperature and flow, but it consistently occurs on the descending limb of the hydrograph which corresponds to high winter discharge gradually receding toward low summer baseflow (Kupferberg 1996a, GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010, Yarnell et al. 2010). Under natural conditions, the timing coincides with intermittent tributaries drying down and increases in algal blooms that provide forage for tadpoles (Haggarty 2006, Power et al. 2008). At lower elevations, breeding can start in late March or early April, and at mid-elevations, breeding typically occurs in mid-May to mid-June (Gonsolin 2010, S. Kupferberg and A. Lind pers. comm. 2017). The time of year a population initiates breeding can vary by a month among water years, occurring later at deeper sites when colder water becomes warmer (Wheeler et al. 2018). In wetter years, delayed breeding into early July can occur in some colder snowmelt systems (S. Kupferberg and A. Lind pers. comm. 2017, GANDA 2018).

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A population's period of oviposition can also vary from two weeks to three months, meaning they could be considered explosive breeders at some sites and prolonged breeders at others (Storer 1925, Zweifel 1955, Van Wagner 1996, Ashton et al. 1997, Wheeler and Welsh 2008). Water temperature typically warms to over 10°C (50°F) before breeding commences (GANDA 2008, Gonsolin 2010, Wheeler et al. 2018). Wheeler and Welsh (2008) observed Foothill Yellow-legged Frogs breeding when flows were below 0.6 m/s (2 ft/s), pausing during increased flows until they receded, and GANDA (2008) reported breeding initiated when flow decreased to less than 55% above baseflow.

Male Foothill Yellow-legged Frogs spend more time at breeding sites during the season than females, many of whom leave immediately after laying their eggs (GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010). Daily movements are usually short (< 0.3 m [1 ft]), but some individuals travel substantial distances: median 70.7 m/d (232 ft/d) in spring and 37.1 m/d (104 ft/day) in fall/winter, nearly always using streams as movement corridors (Van Wagner 1996, Bourque 2008, Gonsolin 2010). The maximum reported movement rate is 1,386 m/d (0.86 mi/d), and the longest seasonal (post-breeding) daily distance reported is 7.04 km (4.37 mi) by a female that traveled up a dry tributary and over a ridge before returning to and moving up the mainstem creek (Bourque 2008). Movements during the non-breeding season are typically in response to drying channels or during rain events (Bourque 2008, Gonsolin 2010, Cook et al. 2012).

Hatchling Foothill Yellow-legged Frogs tend to remain with what is left of the egg mass for several days before dispersing into the interstitial spaces in the substrate (Ashton et al. 1997). They often move downstream in areas of moderate flow and will follow the location of warm water in the channel throughout the day (Brattstrom 1962, Ashton et al. 1997, Kupferberg et al. 2011a). Tadpoles usually

metamorphose in late August or early September (S. Kupferberg and A. Lind pers. comm. 2017). Twitty et al. (1967) reported that newly metamorphosed Foothill Yellow-legged Frogs mostly migrated upstream, which may be an evolutionary mechanism to return to their natal site after being washed downstream (Ashton et al. 1997).

Home Range and Territoriality

Foothill Yellow-legged Frogs exhibit a lek-type mating system in which males aggregate at the breeding site and establish calling territories (Wheeler and Welsh 2008, Bondi et al. 2013). The species has a relatively large calling repertoire for western North American ranids with seven unique vocalizations recorded (Silver 2017). Some of these can be reasonably attributed to territory defense and mate attraction communications (MacTeague and Northen 1993, Silver 2017). Physical aggression among males during the breeding season has been reported (Rombough and Hayes 2007, Wheeler and Welsh 2008). In addition, Wheeler and Welsh (2008) observed a non-random mating pattern in which males engaged in amplexus with females were larger than males never seen in amplexus, suggesting either physical competition or female preference for larger individuals. Very little information has been published on Foothill Yellow-legged Frog home range size. Wheeler and Welsh (2008) studied males during a 17-day period during breeding season and classified some of them "site faithful" based on their movements and calculated their home ranges. Two-thirds of males tracked were site faithful, and their mean home range size was 0.58 m^2 (SE = 0.10 m^2; 6.24 ft^2 [SE = 1.08 ft^2]) (Ibid.). In contrast, perhaps because the study took place over a longer time period, Bourque (2008) reported approximately half of the males he tracked during the spring were mobile, and the other half were sedentary. The median distances traveled along the creek (a proxy for home range size since they rarely leave the riparian corridor) for mobile and sedentary males were 149 m (489 ft) and 5.5 m (18 ft), respectively.

Diet and Predators

Foothill Yellow-legged Frog diet varies by life stage and likely body size. Tadpoles graze on periphyton (algae growing on submerged surfaces) scraped from rocks and vegetation and grow faster, and to a larger size, when it contains a greater proportion of epiphytic diatoms with nitrogen-fixing endosymbionts (*Epithemia* spp.), which are high in protein and fat (Kupferberg 1997b, Fellers 2005, Hayes et al. 2016, Catennazi and Kupferberg 2017). Tadpoles may also forage on necrotic tissue from dead bivalves and other tadpoles, or more likely the algae growing on them (Ashton et al. 1997, Hayes et al. 2016). Post-metamorphic Foothill Yellow-legged Frogs primarily feed on a wide variety of terrestrial arthropods but also some aquatic invertebrates (Fitch 1936, Van Wagner 1996, Haggarty 2006). Most of their diet consists of insects and arachnids (Van Wagner 1996, Haggarty 2006, Hothem et al. 2009). Haggarty (2006) did not identify any preferred taxonomic groups, but she noted larger Foothill Yellow-legged Frogs consumed a greater proportion of large prey items compared to smaller individuals, suggesting the species may be gape-limited generalist predators. Hothem et al. (2009) found mammal hair and bones in a Foothill Yellow-legged Frog. Adult Foothill Yellow-legged Frogs, like many other ranids, also cannibalize conspecifics (Wiseman and Bettaso 2007). In the fall when young-of-year are abundant, they may provide an important source of nutrition for adults prior to overwintering (Ibid.).

Foothill Yellow-legged Frogs are preyed upon by several native and introduced species, including each other as described above. Some predators target specific life stages, while others may consume multiple stages. Several species of gartersnakes (genus *Thamnophis*) are the primary and most widespread group of native predators on Foothill Yellow-legged Frogs tadpoles through adults is (Fitch 1941, Fox 1952, Zweifel 1955, Lind and Welsh 1994, Ashton et al. 1997, Wiseman and Bettaso 2007, Gonsolin 2010). Table 1 lists other known and suspected predators of Foothill Yellow-legged Frogs.

Table 1. Confirmed and potential Foothill Yellow-legged Frog predators in California in addition to gartersnakes (*Thamnophis* spp.)

Common Name	Scientific Name	Classification	Native	Prey Life Stage(s)	Sources
Caddisfly (larva)	*Dicosmoecus gilvipes*	Insect	Yes	Embryos (eggs)	Rombough and Hayes 2005
Dragonfly (nymph)	*Aeshna walker*	Insect	Yes	Larvae	Catenazzi and Kupferberg 2018
Waterscorpion	*Ranatra brevicollis*	Insect	Yes	Larvae	Catenaazi and Kupferberg 2018
Signal Crayfish	*Pacifastacus leniusculus*	Crustacean	No	Embryos (eggs) and Larvae	Rombough and Hayes 2005; Wiseman et al. 2005
Speckled Dace	*Rhinichthys osculus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Reticulate Sculpin	*Cottus perplexus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Sacramento Pike Minnow	*Ptychocheilus grandis*	Fish	Yes*	Embryos (eggs) and Adults	Ashton and Nakamoto 2007
Sunfishes	Family Centrachidae	Fish	No	Larvae	Moyle (1973); Hayes and Jennings 1986
Catfishes	Family Ictaluridae	Fish	No	Larvae	Moyle (1973); Hayes and Jennings 1986
Rough-skinned Newt	*Taricha granulosa*	Amphibian	Yes	Embryos (eggs)	Evenden 1948
California Giant Salamander	*Dicamptodon ensatus*	Amphibian	Yes	Larvae	Fidenci 2006
American Bullfrog	*Rana catesbeiana*	Amphibian	No	Larvae to Adults	Crayon 1998; Hothem et al. 2009
California Red-legged Frog	*Rana draytonii*	Amphibian	Yes	Larvae to Adults	Gonsolin 2010
American Robin	*Turdus migratorius*	Bird	Yes	Larvae	Gonsolin 2010
Common Merganser	*Mergus merganser*	Bird	Yes	Larvae	Gonsolin 2010
American Dipper	*Cinclus mexicanus*	Bird	Yes	Larvae	Ashton et al. 1997
Mallard	*Anas platyrhynchos*	Bird	Yes	Adults	Rombough et al. 2005
Raccoon	*Procyon lotor*	Mammal	Yes	Larvae to Adults	Zweifel 1955; Ashton et al. 1997
River Otter	*Lontra canadensis*	Mammal	Yes	Adults	T. Rose pers. comm. 2014

* Introduced to the Eel River, location of documented predation; Foothill Yellow-legged Frogs are extirpated from most areas of historical range overlap

STATUS AND TRENDS IN CALIFORNIA

Administrative Status

Sensitive Species

The Foothill Yellow-legged Frog is listed as a Sensitive Species by the U.S. Bureau of Land Management (BLM) and ~~U.S.~~ USDA Forest Service (Forest Service). These agencies define Sensitive Species as those species that require special management consideration to promote their conservation and reduce the likelihood and need for future listing under the ESA.

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California Species of Special Concern

The Department's Species of Special Concern (SSC) designation is similar to the federal Sensitive Species designation. It is administrative, rather than regulatory in nature, and intended to focus attention on animals at conservation risk. The designation is used to stimulate needed research on poorly known species and to target the conservation and recovery of these animals before they meet the CESA criteria for listing as threatened or endangered (Thomson et al. 2016). The Foothill Yellow-legged Frog is listed as a Priority 1 (highest risk) SSC (Ibid.).

Trends in Distribution and Abundance

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Range-wide in California

Range is the general geographical area in which an organism occurs. For purposes of CESA and this Status Review, the range is the species' California range (*Cal. Forestry Assn. v. Cal. Fish and Game Com.* (2007) 156 Cal.App.4th 1535, 1551). Systematic, focused, range-wide assessments of Foothill Yellow-legged Frog distribution and abundance are rare, both historically and contemporarily. A detailed account of what has been documented within the National Parks and National Forests in California can be found in Appendix 3 of the *Foothill Yellow-legged Frogs Conservation Assessment in California* (Hayes et al. 2016).

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Most Foothill Yellow-legged Frog records are incidental observations made during stream surveys for ESA-listed salmonids and simply document presence at a particular date and location, although some include counts or estimates of abundance by life stage. This makes assessing trends in distribution and abundance difficult despite a relatively large number of observations compared to many other species tracked by the California Natural Diversity Database (CNDDB). The CNDDB contained 2,366 Foothill Yellow-legged Frog occurrences in its March 2019 edition, 500 of which are documented from the past 5 years.

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A few wide-ranging survey efforts that included Foothill Yellow-legged Frogs exist. Reports from early naturalists suggest Foothill Yellow-legged Frogs were relatively common in the Coast Ranges as far south as central Monterey County, in eastern Tehama County, and in the foothills in and near Yosemite National Park (Grinnell and Storer 1924, Storer 1925, Grinnell et al. 1930, Martin 1940). In addition to

these areas, relatively large numbers of Foothill Yellow-legged Frogs (17-35 individuals) were collected at sites in the central and southern Sierra Nevada and the San Gabriel Mountains between 1911 and 1950 (Hayes et al. 2016). Widespread disappearances of Foothill Yellow-legged Frog populations were documented as early as the 1970s and 80s in southern California, the southern Coast Range, and the central and southern Sierra Nevada foothills (Moyle 1973, Sweet 1983).

Twenty-five years ago, the Department published the first edition of *Amphibians and Reptile Species of Special Concern in California* (Jennings and Hayes 1994). The authors revisited hundreds of localities that had historically been occupied by Foothill Yellow-legged Frogs between 1988 and 1991 and consulted local experts to determine presumed extant or extirpated status. Based on these survey results and stressors observed on the landscape, they considered Foothill Yellow-legged Frogs endangered in central and southern California south of the Salinas River in Monterey County. They considered the species threatened in the west slope drainages of the Cascade Mountains and Sierra Nevada east of the Central Valley, and they considered the remainder of the range to be of special concern (Ibid.).

Fellers (2005) and his field crews conducted surveys for Foothill Yellow-legged Frogs throughout California. They visited 804 sites across 40 counties with suitable habitat within the species' historical range. They detected at least one individual at 213 sites (26.5% of those surveyed) over 28 counties. They located Foothill Yellow-legged Frogs in approximately 40% of streams in the North Coast, 30% in the Cascade Mountains and south of San Francisco in the Coast Range, and 12% in the Sierra Nevada. Fellers estimated population abundance was 20 or more adults at only 14% of the sites where the species was found and noted the largest and most robust populations occurred along the North Coast. In addition, to determine status of Foothill Yellow-legged Frogs across the species' range and potential causes for declines, between 2000-2002, Lind (2005) used previously published status accounts, species expert and local biologist professional opinions, and field visits to historically occupied sites between 2000-2002. She determined that Foothill Yellow-legged Frogs had disappeared from 201 of 394 of the sites, representing just over 50%. The coarse-scale trend in California is one of greater population declines and extirpations in lower elevations and latitudes (Davidson et al. 2002).

Few site-specific population trend data are available from which to evaluate status. However, long-term monitoring efforts have often used egg mass counts as a proxy to estimate adult breeding females. The results of these studies ~~often~~ revealed extreme interannual variability in number of egg masses laid (Ashton et al. 2010, S. Kupferberg and M. Power pers. comm. 2015, Peek and Kupferberg 2016). In a meta-analysis of egg mass count data collected across the species' range in California over the past 25 years, Peek and Kupferberg (2016) reported declines in two unregulated rivers and an increase in another. Their models did not detect any significant trends in abundance across different locations or regulation type (dammed or undammed); however, high interannual variability can render trend detection difficult. Interannual variability was substantially greater in regulated rivers vs. unregulated; the median coefficient of variation was 66.9% and 41.6%, respectively (Ibid.). The greater variability in regulated rivers decreases the probability of detecting significant declines, and coupled with low abundance, it can lead to populations dropping below a density necessary for persistence without detection, resulting in extirpation.

Regional differences in Foothill Yellow-legged Frog persistence across its range have been recognized for nearly 50 years (i.e., more extirpations documented in the south). Because of these differences and the recent availability of new landscape genomic data, more detailed descriptions of trends in Foothill Yellow-legged Frog population distribution and abundance in California are evaluated by clade below. Figure 5 depicts Foothill Yellow-legged Frog localities across all clades in California by the most recent confirmed sighting in the datasets available to the Department within a Public Lands Survey System (PLSS) section. "Transition Zones" are those areas where the exact clade boundaries are unknown due to a lack of samples. In addition, while not depicted as an area of uncertainty, no genetic samples have been ~~tested~~ evaluated from south of the extant population in northern San Luis Obispo County, in the Sutter Buttes in Sutter County, or northeastern Plumas County. It is possible there were historically more clades than is currently understood.

Caution should be exercised in comparing the following observation data across the species' range and across time since survey effort and reporting are not standardized. These data can be useful for making some general inferences about distribution, abundance, and trends. For instance, assuming the observation correctly identifies the species, the date on the record is the last time the species was confirmed to have occurred at that location. However, this only works in the affirmative. For example, at a site where the last time the species was seen was 75 years ago, the species may still persist there if no one has surveyed it since the original observation. CNDDB staff use information on land use conversion, follow-up visits, and biological reports to categorize an occurrence location as "extirpated" or "possibly extirpated".

Northwest/North Coast Clade

This clade extends from north of San Francisco Bay through the Coast Range and Klamath Mountains to the northern limit of the Foothill Yellow-legged Frog's range and east through the Cascade Range. It includes Del Norte, Siskiyou, Humboldt, Trinity, Shasta, Tehama, Mendocino, Glenn, Colusa, Lake, Sonoma, Napa, Yolo, Solano, and Marin counties. This clade covers the largest geographic area and contains the greatest amount of genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). In addition, it is the only clade with an increasing trend in genetic diversity (Peek 2018).

Early records note the comparatively high abundance of Foothill Yellow-legged Frogs in this area. Storer (1925) described Foothill Yellow-legged Frogs as very common in many of Coast Range streams north of San Francisco Bay, and Cope (1879, 1883 as cited in Hayes et al. 2016) noted they were "rather abundant in the mountainous regions of northern California." In addition, relatively large collections occurred over short periods of time in this region in the late 1800s and the first half of the 20th century (Hayes et al. 2016). Nineteen were taken over two weeks in 1893 along Orrs Creek, a tributary to the Russian River, and 40 from near Willits (both in Mendocino County) in 1911; 112 were collected over three days at Skaggs Spring (Sonoma County) in 1911; 57 were taken in one day along Lagunitas Creek (Marin County) in 1928; and 50 were collected in one day near Denny (Trinity County) in 1955 (Ibid.).

A few long-term Foothill Yellow-legged Frog egg mass monitoring efforts undertaken within this clade's boundaries found densities vary significantly, often based on river regulation type, and documented

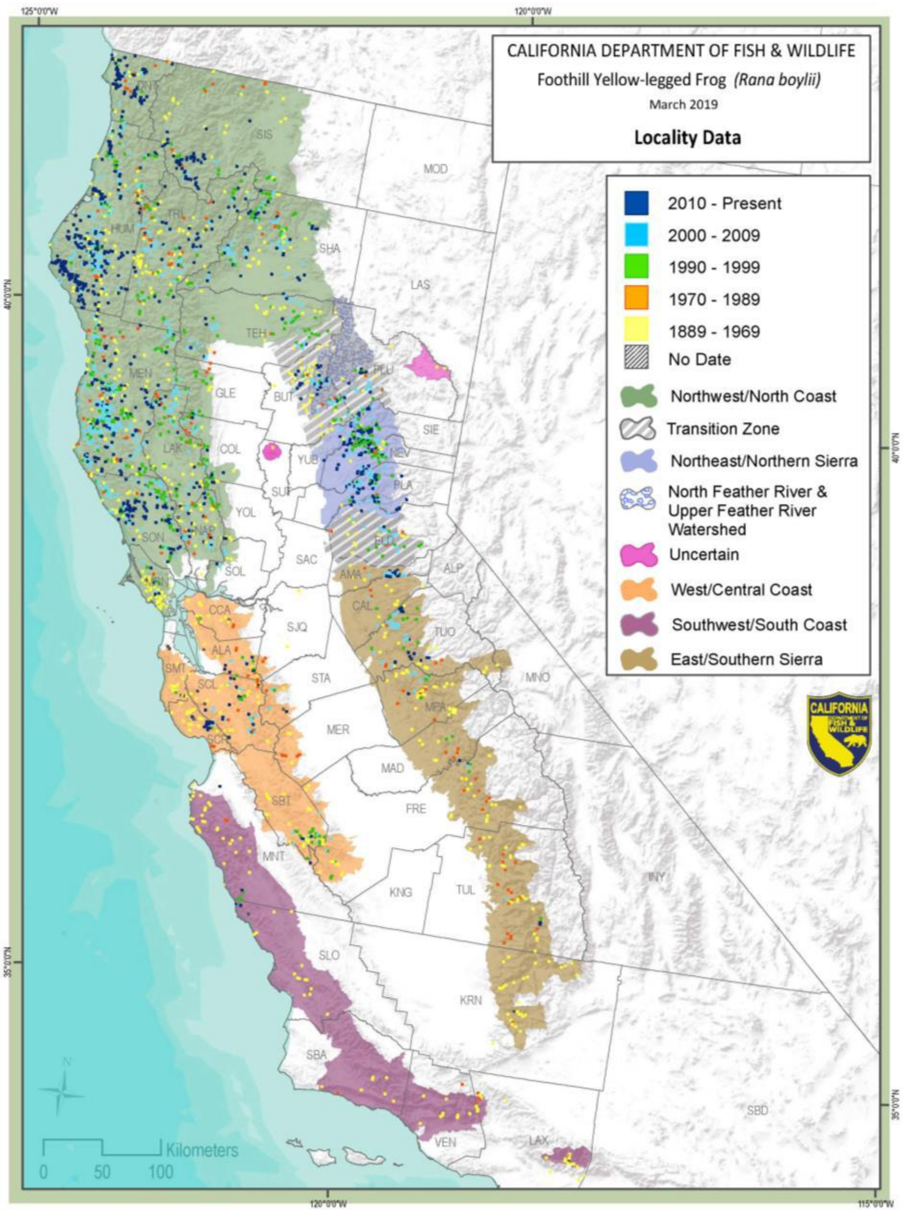

Figure 5. Foothill Yellow-legged Frog occurrence data from 1889-2019 overlaying the six clades by most recent sighting in a Public Lands Survey System section (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

several robust populations. The Green Diamond Resources Company has been monitoring a stretch of the Mad River near Blue Lake (Humboldt County) since 2008 (GDRC 2018). The greatest published density of Foothill Yellow-legged Frog egg masses was documented here in 2009 at 323.6 egg masses/km (520.7/mi) (Bourque and Bettaso 2011). However, in 2017, surveyors counted 625.1 egg masses/km (1,006/mi) along the same reach (GDRC 2018). At its lowest during this period, egg mass density was calculated at 71.54/km (115.1/mi) in 2010, although this count occurred after a flooding even that likely scoured over half of the egg masses laid that season (GDRC 2018, R. Bourque pers. comm. 2019). During a single day survey in 2017 along approximately 2 km (1.3 mi) of Redwood Creek in Redwood National Park (Humboldt County), 2,009 young and 126 adult Foothill Yellow-legged Frogs were found (D. Anderson pers. comm. 2017). Some reaches of the South Fork Eel River (Mendocino County) also support high densities of Foothill Yellow-legged Frogs. Kupferberg (pers. comm. 2018) recorded 206.9 and 106.2 egg masses/km (333 and 171/mi) along two stretches in 2016, and 201.7 and 117.5 egg masses/km (324 and 189/mi) in 2017. However, other reaches yielded counts as low as 6.1 and 8.4 egg masses/km (9.8 and 13.5/mi) (Ibid.). In the Angelo Reserve (an unregulated reach), the 24-year mean density was 109 egg masses/km (175.4/mi) (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015). In contrast, a 10-year mean density of egg masses below Lewiston Dam on the Trinity River (Trinity County) was 0.89/km (1.43/mi) (Ibid.).

Figure 6 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, Biological Information Observation System datasets, and personal communications that are color coded by the most recent date of detection. Within this clade, Foothill Yellow-legged Frogs were observed in at least 343 areas in the past 5 years (CNDDB 2019). The species remains widespread within many watersheds, although most observations only verify presence, or fewer than ten individuals or egg masses are recorded (Ibid.). Documented extirpations are comparatively rare, but also likely undetected or under-reported, and nearly all occurred just north of the high-populated San Francisco Bay area (Figure 7; Ibid.).

West/Central Coast

This clade extends south from the San Francisco Bay through the Diablo Range and down the peninsula through the Santa Cruz and Gabilan Mountains in the Coast Range east of the Salinas Valley. It includes most of Contra Costa, Alameda, San Mateo, Santa Cruz, Santa Clara, and San Benito counties; western San Joaquin, Stanislaus, Merced, and Fresno counties; and a small portion of eastern Monterey County. Records of Foothill Yellow-legged Frogs occurring south of San Francisco Bay did not exist until specimens were collected in 1918 around what is now Pinnacles National Park in San Benito County, and little information exists on historical distribution and abundance within this clade (Storer 1923).

Within this clade, Foothill Yellow-legged Frogs were observed in at least 24 areas in the past five years (Figure 8; CNDDB 2019). Documented and possible extirpations are concentrated around the San Francisco Bay and sites at the southern portion of the clade’s range, although these may not have been resurveyed since their original observations in the 1940s through 1960s, except for a site in Pinnacles National Park that was surveyed in 1994 (Figure 9; Ibid.). In addition, although not depicted,

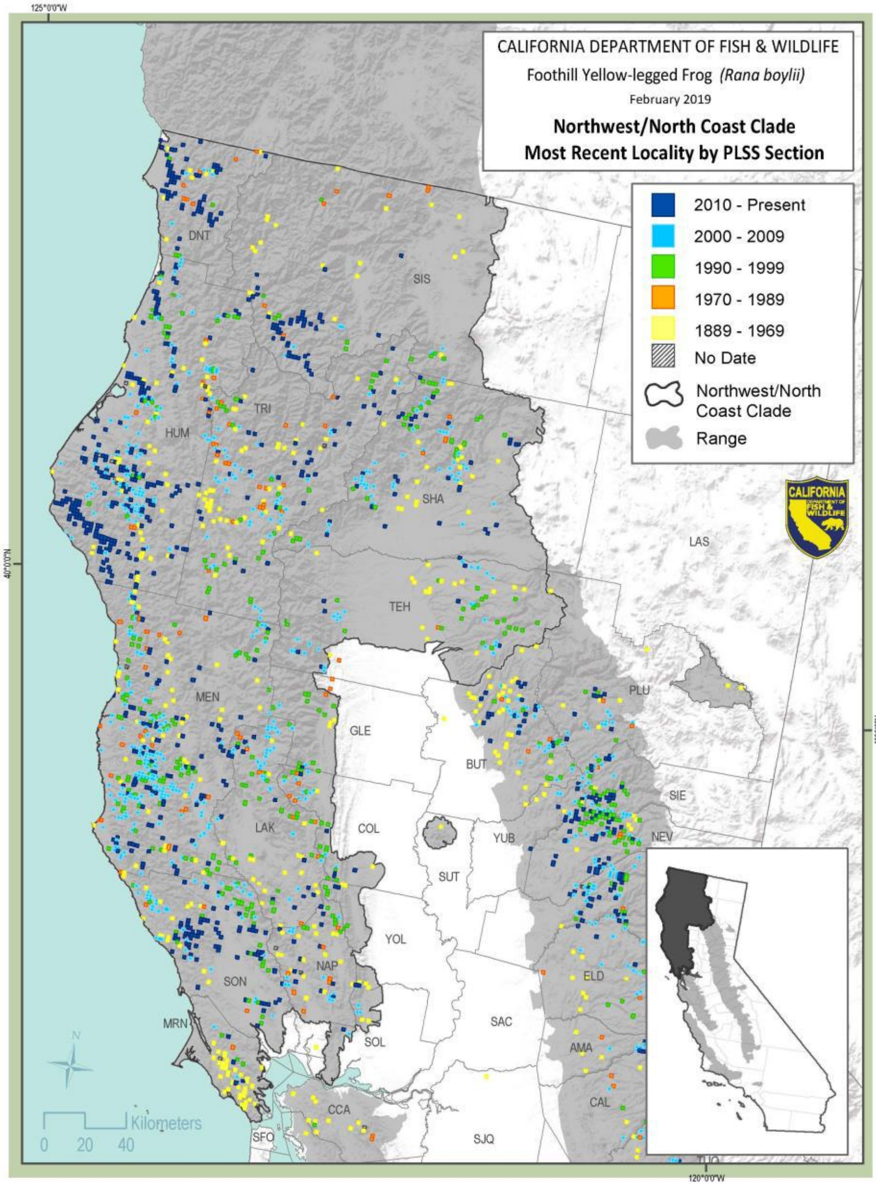

Figure 6. Close-up of Northwest/North Coast Foothill Yellow-legged Frog clade observations from 1889-2019 (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

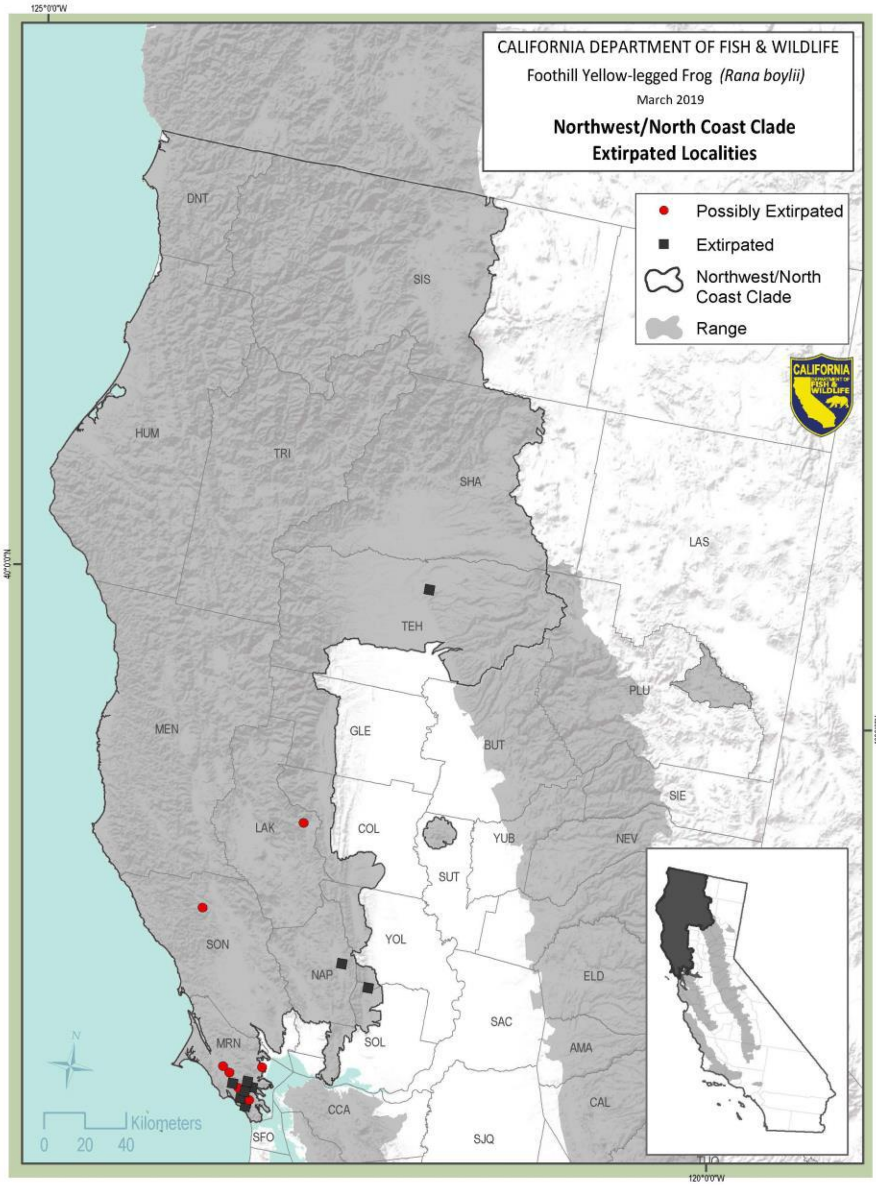

Figure 7. Possibly extirpated and extirpated Northwest/North Coast Foothill Yellow-legged Frog clade sites (CNDDB)

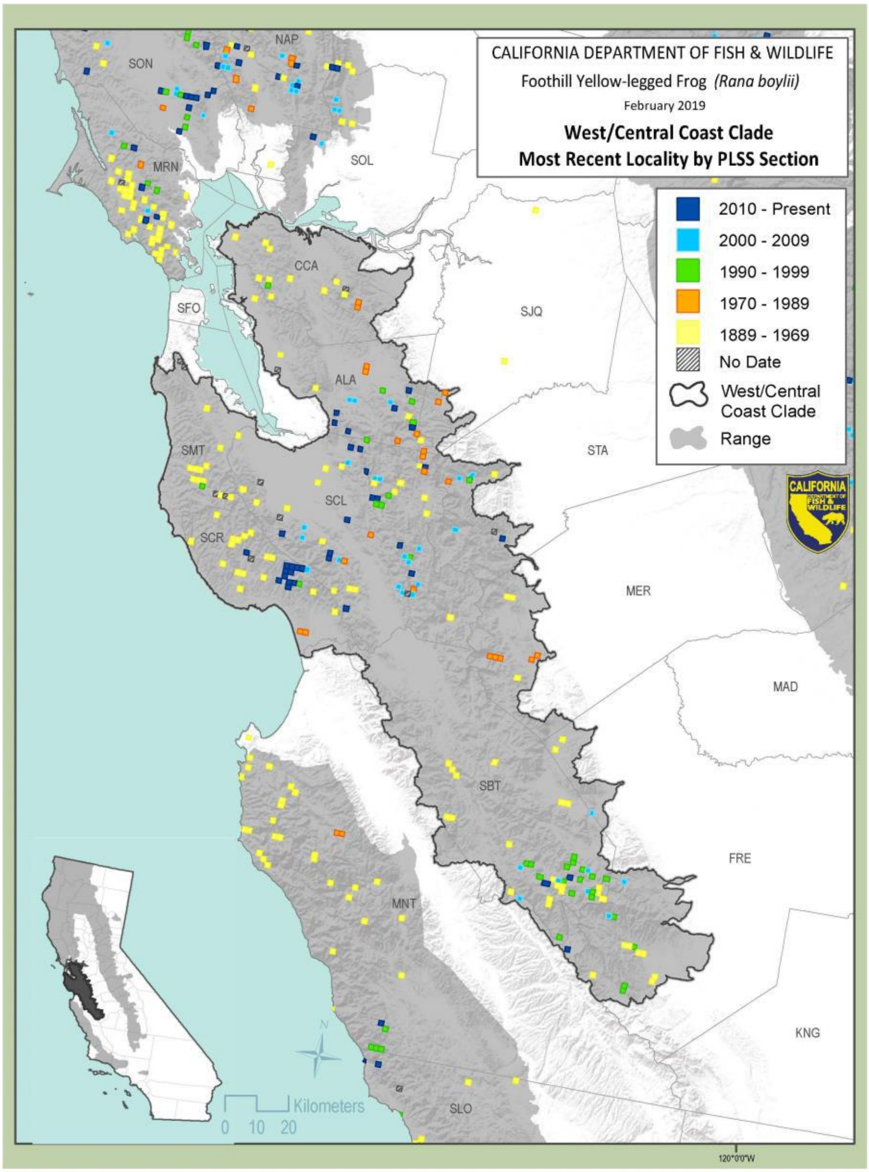

Figure 8. Close-up of West/Central Coast clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

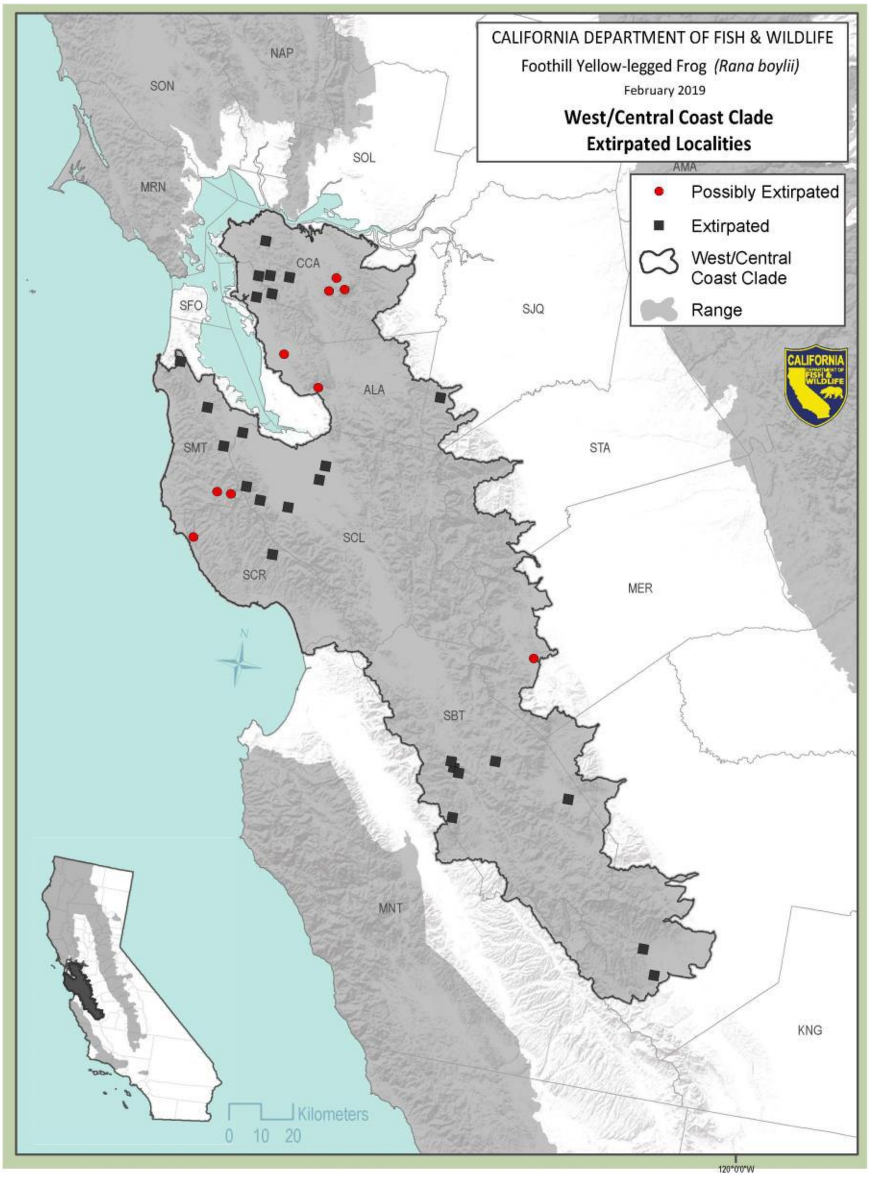

Figure 9. Possibly extirpated and extirpated West/Central Coast Foothill Yellow-legged Frog clade sites (CNDDB)

two populations on Arroyo Mocho and Arroyo Valle south of Livermore (Alameda County) are also likely extirpated (M. Grefsrud pers. comm. 2019).

The San Francisco Bay Area is heavily urbanized. Foothill Yellow-legged Frogs may be gone from Contra Costa County; eight of the nine CNDDB records from the county are museum specimens collected between 1891 and 1953, and the most recent observation was two adults in a plunge pool in an intermittent tributary to Moraga Creek in 1997. No recent (2010 or later) observations exist from San Mateo County (Ibid.). Historically occupied lower-elevation sites surrounding the San Francisco Bay and inland appear to be extirpated, but there are (or were) some moderately abundant breeding populations remaining at higher elevations in Arroyo Hondo (Alameda County), Alameda Creek (Alameda and Santa Clara counties), Coyote and Upper Llagas creeks (Santa Clara County), and Soquel Creek (Santa Cruz County) with some scattered smaller populations also persisting in these counties (J. Smith pers. comm. 2016, 2017; CNDDB 2019). The Alameda Creek and Coyote Creek populations recently underwent large-scale mortality events, so their numbers are likely substantially lower than what is currently reported in the CNDDB (Adams et al. 2017a, Kupferberg and Catenazzi 2019). In addition, the Arroyo Hondo population will lose approximately 1.6 km (1 mi) of prime breeding habitat (i.e., supported the highest density of egg masses on the creek) as the Calaveras Reservoir is refilled following its dam replacement project in 2019 (M. Grefsrud pers. comm. 2019). Foothill Yellow-legged Frogs may be extirpated from Corral Hollow Creek in San Joaquin County, but a single individual was observed five years ago further up the drainage in Alameda County within an Off-Highway Vehicle park (CNDDB 2019). Few recent sightings of Foothill Yellow-legged Frogs in the east-flowing creeks are documented. They may still be extant in the headwaters of Del Puerto Creek (western Stanislaus County), but the records further downstream indicate bullfrogs (known predators and disease reservoirs) are moving up the system (Ibid.). Several locations in southern San Benito, western Fresno, and eastern Monterey counties have relatively recent (2000 and later) detections (Ibid.). However, while many of these sites supported somewhat large populations in the 1990s, the more recent records report fewer than ten individuals (Ibid.). The exception is a Monterey County site where around 25 to 30 were observed in 2012 (Ibid.).

Southwest/South Coast

Widespread extirpations occurred decades ago, primarily in the 1960s and 1970s, in this area (Adams et al. 2017b). As a result, genetic samples were largely unavailable, and the boundaries are speculative. The clade is presumed to include the Coast Range from Monterey Bay south to the Transverse Range across to the San Gabriel Mountains. This clade includes portions of Monterey, San Luis Obispo, Santa Barbara, Ventura, and Los Angeles counties. Storer (1923) reported that Foothill Yellow-legged Frogs were collected for the first time in Monterey County in 1919 and that a specimen collected by Cope in 1889 in Santa Barbara and listed as *Rana temporaria pretiosa* may refer to the Foothill Yellow-legged Frog because as previously mentioned, the taxonomy of this species changed several times over the first century after it was named.

Foothill Yellow-legged Frogs had been widespread and fairly abundant in this area until the late 1960s (Figure 10) but were rapidly extirpated throughout the southern Coast Ranges and western Transverse

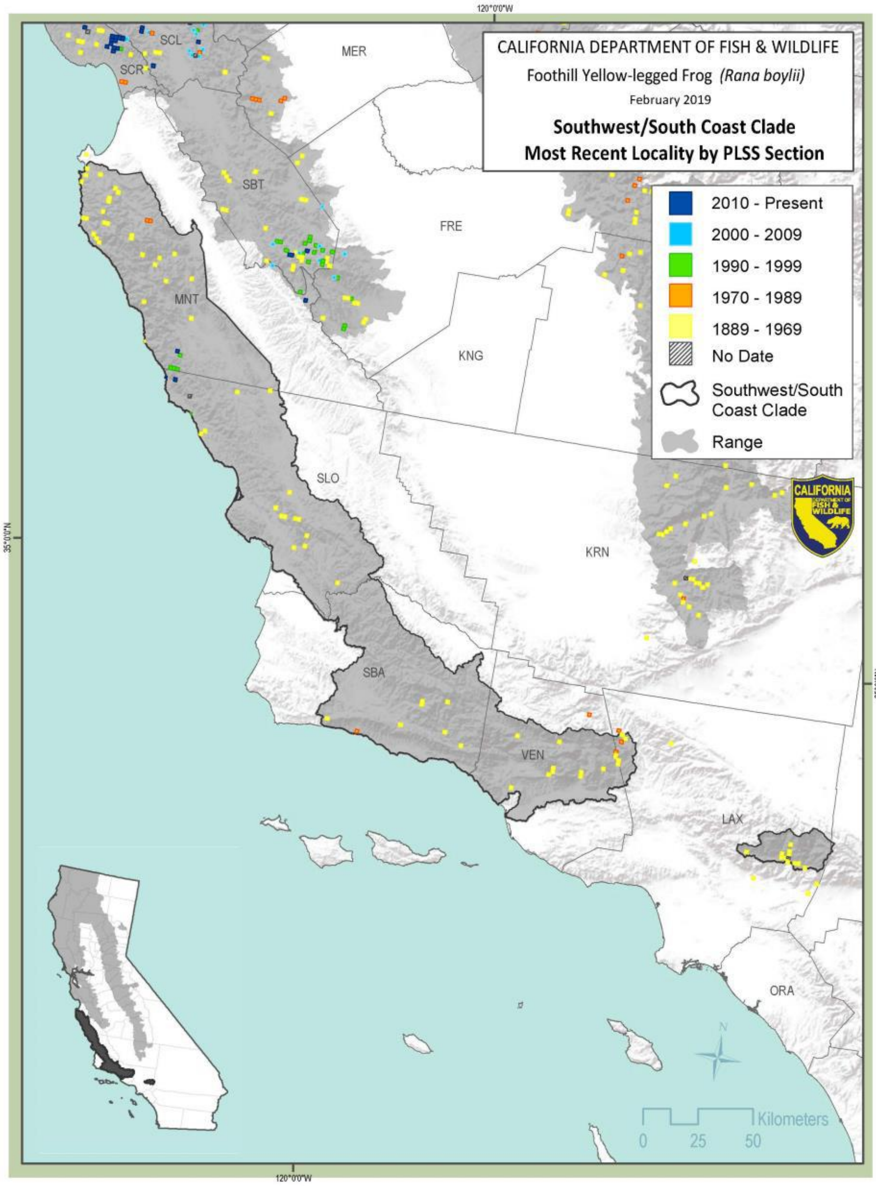

Figure 10. Close-up of Southwest/South Coast clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

Ranges by the mid-1970s (Figure 11; Sweet 1983, Adams et al. 2017b). Only two known extant populations exist from this clade, located near the border of Monterey and San Luis Obispo counties (S. Sweet pers. comm. 2017, McCartney-Melstad et al. 2018, Peek 2018, CNDDB 2019). They appear to be extremely small and rapidly losing genetic diversity, making them at high risk of extirpation (McCartney-Melstad et al. 2018, Peek 2018).

Northeast/Feather River and Northern Sierra

The exact clade boundaries in the Sierra Nevada are unclear and will require additional sampling and testing to define (Figure 12). The Northeast clade presumably encompasses the Feather River and Northern Sierra clades. The Feather River clade is located primarily in Plumas and Butte counties. The Northern Sierra clade roughly extends from the Feather River watershed south to the Middle Fork American River. It includes portions of El Dorado, Placer, Nevada, Sierra, and Plumas counties. It may also include portions of Amador, Butte, and eastern Tehama counties. No genetic samples were available to test in the Sutter Buttes or the disjunct population in northeastern Plumas County to determine which clades they belonged to before they were extirpated (Figure 13; Olson et al. 2016, CNDDB 2019).

In general, there is a paucity of historical Foothill Yellow-legged Frog data for west-slope Sierra Nevada streams, particularly in the lower elevations of the Sacramento Valley, and no quantitative abundance data exist prior to major changes in the landscape (i.e., mining, dams, and diversions) or the introduction of non-native species (Hayes et al. 2016). Foothill Yellow-legged Frogs have been collected frequently from the Plumas National Forest area in small numbers from the turn of the 20th century through the 1970s (Ibid.). Estimates of relative abundance are not clear from the records, but they suggest the species was somewhat widespread in this area.

More recently, Foothill Yellow-legged Frog populations in the Sierra Nevada have been the subject of a substantial number of surveys and focused research associated with recent and ongoing relicensing of hydroelectric power generating dams by the Federal Energy Regulatory Commission (FERC). Consequently, Foothill Yellow-legged Frogs have been observed in at least 30 areas in Plumas and Butte counties (roughly the Feather River clade) over the past five years (CNDDB 2019). As with the rest of the range, most records are observations of only a few individuals; however, many observations occurred over multiple years, and in some cases all life stages were observed over multiple years (Ibid). The populations appear to persist even with the small numbers reported. The only long-term consistent survey effort has been occurring on the North Fork Feather River along the Cresta and Poe reaches (GANDA 2018). The Cresta reach's subpopulation declined significantly in 2006 and never recovered despite modification of the flow regime to reduce egg mass and tadpole scouring and some habitat restoration (Ibid.). A pilot project to augment the Cresta reach's subpopulation through in situ captive rearing was initiated in 2017 (Dillingham et al. 2018). It resulted in the highest number of young-of-year Foothill Yellow-legged Frogs recorded during fall surveys since researchers started keeping count (Ibid.). The number of egg masses laid in the Poe reach varies substantially year-to-year from a low of 26 in 2001 to a high of 154 in 2015 and back down to 36 in 2017 (GANDA 2018).

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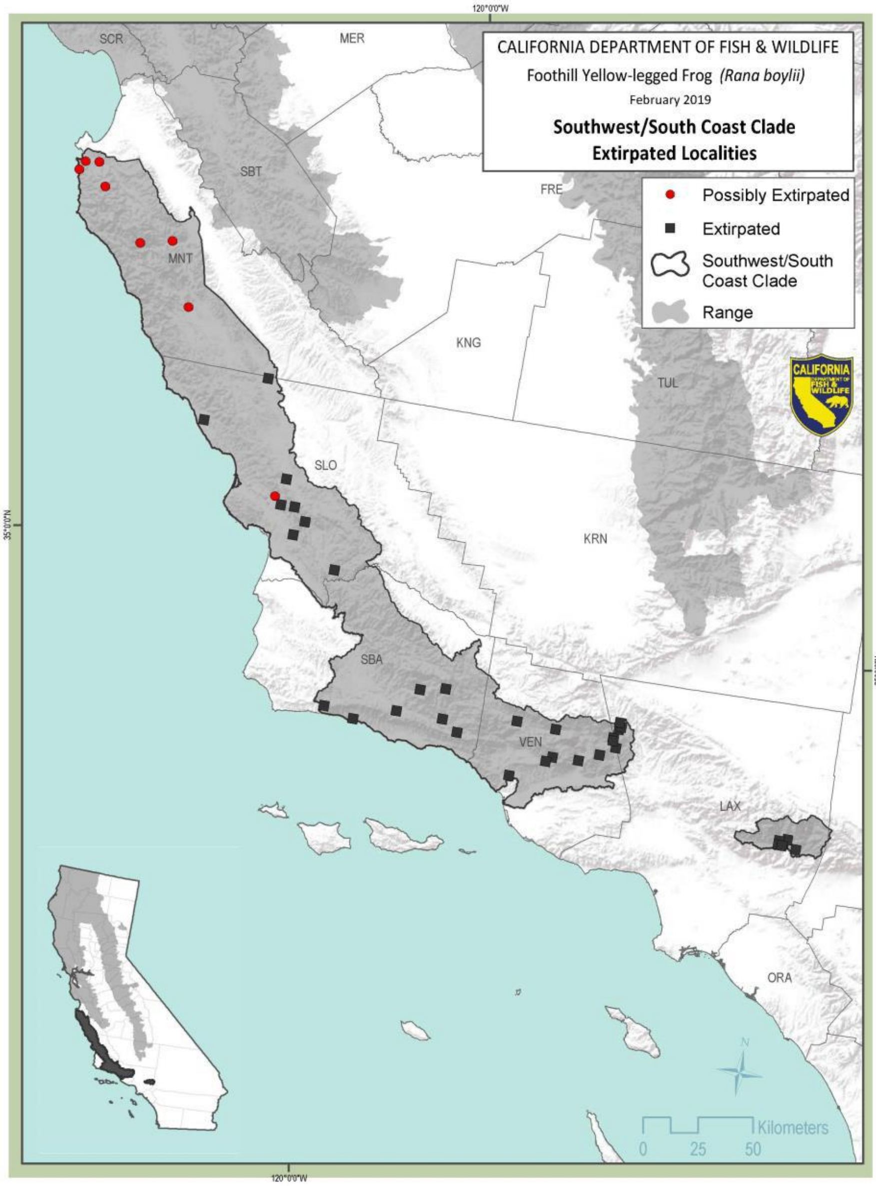

Figure 11. Possibly extirpated and extirpated Southwest/South Coast Foothill Yellow-legged Frog clade sites (CNDDB)

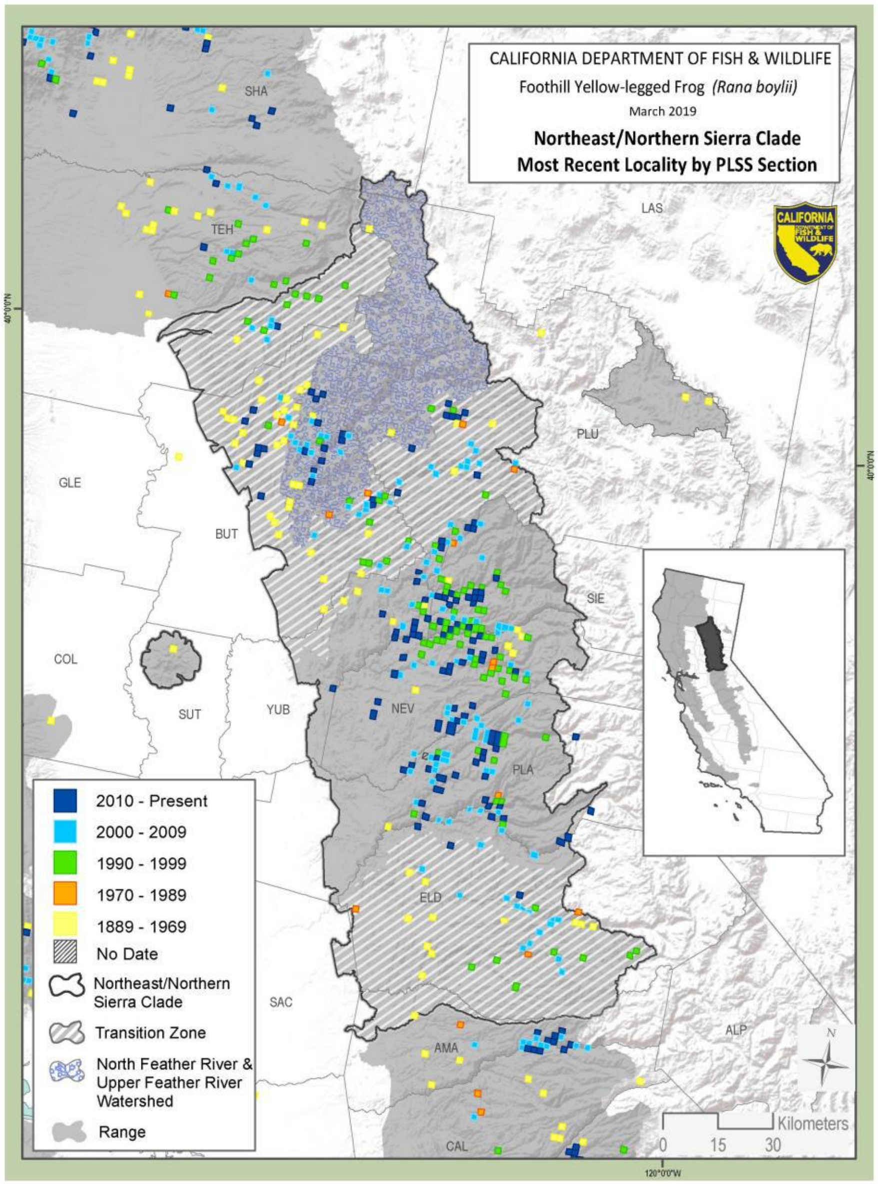

Figure 12. Close-up of Northeast/Feather River and Northern Sierra clades observations from 1889-2019 (ARSSC, BIOS, CNDDB)

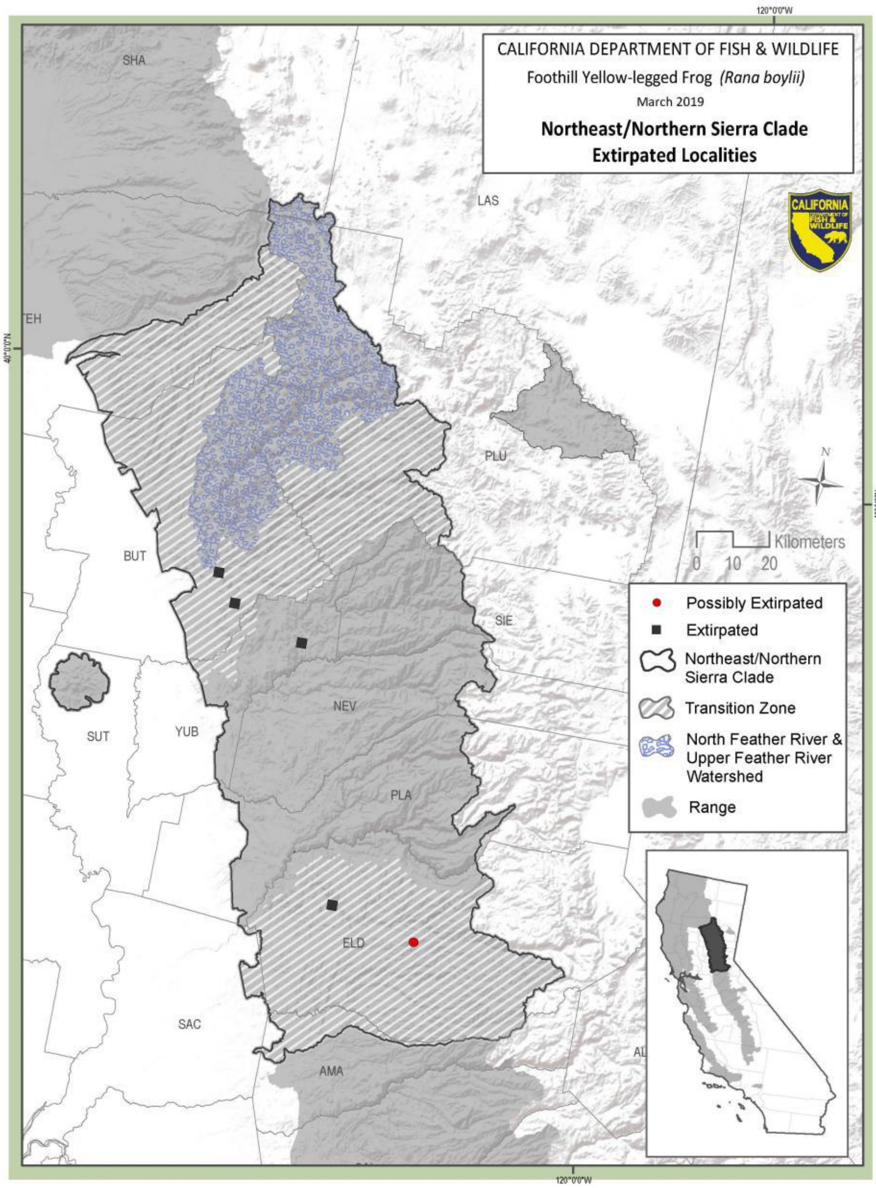

Figure 13. Possibly extirpated and extirpated Northeast/Feather River and Northern Sierra Foothill Yellow-legged Frog clades sites (CNDDB)

Foothill Yellow-legged Frogs have been observed in at least 71 areas in the past 5 years in the presumptive Northeast/Northern Sierra clade. The general pattern in this clade, and across the range for that matter, is that unregulated rivers or reaches have more areas that are occupied more consistently and in larger numbers than regulated rivers or reaches (CNDDB 2019, S. Kupferberg pers. comm. 2019). Foothill Yellow-legged Frogs were rarely observed in the hydropeaking reach of the Middle Fork American River and were observed in low numbers in the bypass reach, but they were present and breeding in small tributary populations (PCWA 2008). Relatively robust populations appear to inhabit the North Fork American River and Lower Rubicon River (Gaos and Bogan 2001, PCWA 2008, Hogan and Zuber 2012, K. Kundargi pers. comm. 2014, S. Kupferberg pers. comm. 2019). Additional apparently sufficiently large and relatively stable populations occur on Clear Creek, South Fork Greenhorn Creek, and Shady Creek (Nevada County) and the North and Middle Yuba River (Sierra County), but the remaining observations are of small numbers in tributaries with minimal connectivity among them (CNDDB 2019, S. Kupferberg pers. comm. 2019).

East/Southern Sierra

The East/Southern Sierra clade is presumed to range from the South Fork American River watershed, the northernmost site where individuals from this clade were collected, south to where the Sierra Nevada meets the Tehachapi Mountains. It likely includes El Dorado, Amador, Calaveras, Tuolumne, Mariposa, Madera, Fresno, Tulare, and Kern counties (Figure 14; Peek 2018). The proportion of extirpated sites in this clade is second only to the Southwest/South Coast and follows the pattern of greater losses in the south (Figure 15). Like the southern coastal clade, the southern Sierra clade has low genetic variability and a trajectory of continued loss of diversity (Ibid.).

Historical collections of small numbers of Foothill Yellow-legged Frogs occurred in every major river system within this clade beginning as early as the turn of the 20th century, indicating widespread distribution but little information on abundance (Hayes et al. 2016). By the early 1970s, declines in Foothill Yellow-legged Frog populations from this area were already apparent; Moyle (1973) found them at 30 of 95 sites surveyed in 1970. Notably bullfrogs inhabited the other 65 sites formerly occupied by Foothill Yellow-legged Frogs, and they co-occurred at only 3 sites (Ibid.). In 1992, Drost and Fellers (1996) revisited the sites around Yosemite National Park (Tuolumne and Mariposa counties) that Grinnell and Storer (1924) surveyed in 1915 and 1919. Foothill Yellow-legged Frogs had disappeared from all seven historically occupied sites and were not found at any new sites surveyed surrounding the park (Ibid.). Resurveys of previously occupied sites on the Stanislaus (Tuolumne County), Sierra (Fresno County), and Sequoia (Tulare County) National Forests were also undertaken (Lind et al. 2003b). Foothill Yellow-legged Frogs were absent from the sites in Sierra and Sequoia National Forests, six at each forest; however, a new population was discovered in the Sierra and two in the Sequoia forests (Ibid.). These populations remain extant but are small and isolated (CNDDB 2019). Two of the six sites on the Stanislaus were still occupied, and 19 new populations were found with evidence of breeding at seven of them (Lind et al. 2003b). Twenty of the 24 populations extant at the time inhabited unregulated waterways (Ibid.). Most of the CNDDB (2019) records of Foothill Yellow-legged Frogs on the Stanislaus are at least a decade old and are represented by low numbers.

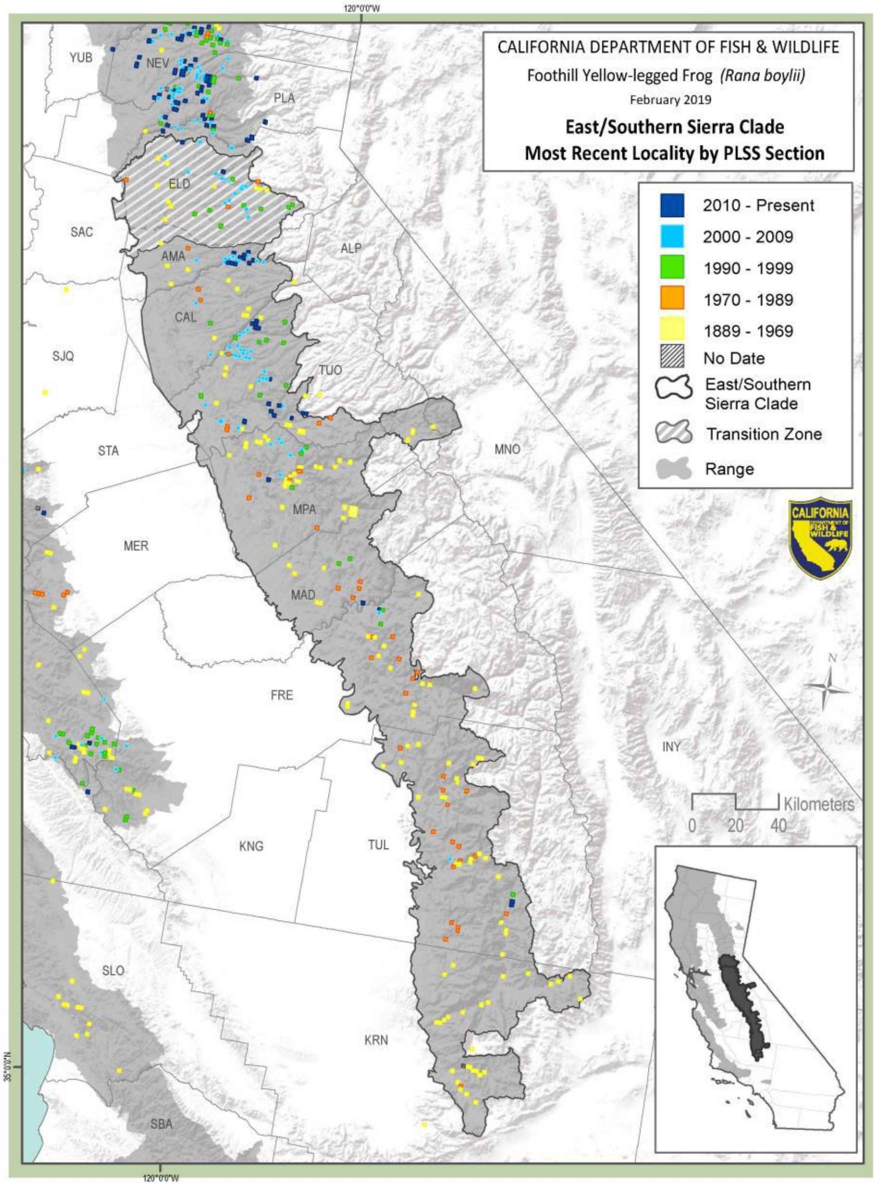

Figure 14. Close-up of East/Southern Sierra clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

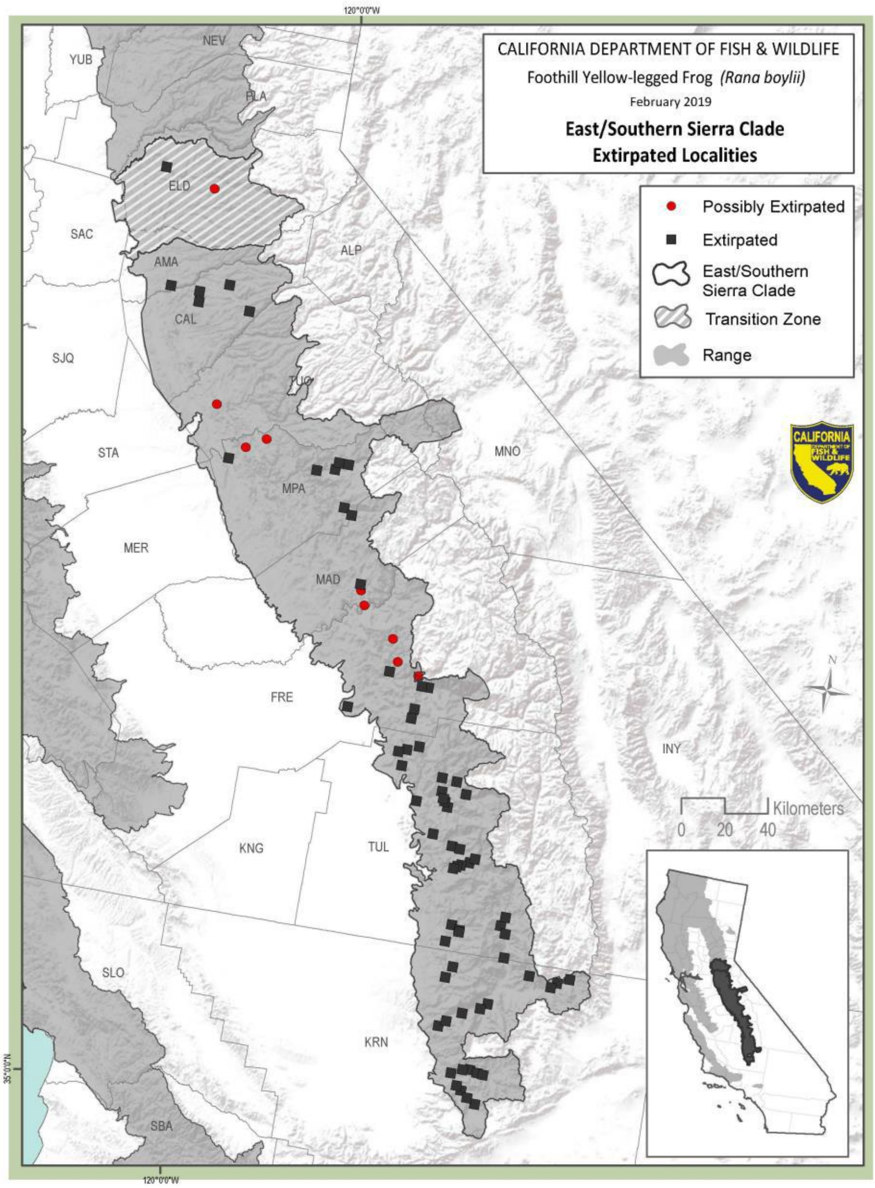

Figure 15. Possibly extirpated and extirpated East/Southern Sierra Foothill Yellow-legged Frog clade sites (CNDDB)

More recently, surveys for Foothill Yellow-legged Frogs were conducted along the South Fork American River as part of the El Dorado Hydroelectric Project's FERC license amphibian monitoring requirements (GANDA 2017). Between 2002 and 2016 counts of different life stages varied significantly by year but the trend for every life stage was a decline over that period (Ibid.). There appears to be a small population persisting along the North Fork Mokelumne River (Amador and Calaveras counties), but it was only productive during the 2012-2014 drought years (Ibid.). Small numbers have also been observed recently in several locations on private timberlands in Tuolumne County (CNDDB 2019).

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FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE

"The fortunes of the boylii *population fluctuate with those of the stream"* - Tracy I. Storer, 1925

Several past and ongoing activities have changed the watersheds upon which Foothill Yellow-legged Frogs depend, and many interact with each other exacerbating their adverse impacts. With such an expansive range in California, the degree and severity of these impacts on the species often vary by location. To the extent feasible based on the best scientific information available, those differences are discussed below.

Dams, Diversions, and Water Operations

Foothill Yellow-legged Frogs evolved in a Mediterranean climate with predictable cool, wet winters and hot, dry summers, with their life cycle is adapted to these conditions. In California and other areas with a Mediterranean climate, human demands for water are at the highest when runoff and precipitation are lowest, and annual water supply varies significantly but always follows the general pattern of peak discharge declining to baseflow in the late spring or summer (Grantham et al. 2010). The Foothill Yellow-legged Frog's life cycle depends on this discharge pattern and the specific habitat conditions it produces (see the Breeding and Rearing Habitat section). Dams are ubiquitous, but not evenly distributed, in California. Figure 16 depicts the locations of dams under the jurisdiction of the Army Corps of Engineers (ACOE) and the California Department of Water Resources (DWR). Figure 17 depicts the number of surface diversions per PLSS section within the Foothill Yellow-legged Frog's range (eWRIMS 2019).

Dam operations frequently change the amount and timing of water availability; its temperature, depth, and velocity; and its sediment transport and channel morphology altering functions, which can result in dramatic consequences on the Foothill Yellow-legged Frog's ability to survive and successfully reproduce. Several studies comparing Foothill Yellow-legged Frog populations in regulated and unregulated reaches within the same watershed investigate potential dam-effects. These studies demonstrated that dams and their operations can result in several factors that contribute to population declines and possible extirpation. These factors include confusing breeding cues, scouring and stranding of egg masses and tadpoles, reduced quality and quantity of breeding and rearing habitat, reduced tadpole growth rate, barriers to gene flow, and establishment and spread of non-native species (Hayes et al. 2016). In addition, as previously discussed in the Population Structure and Genetic Diversity section, subpopulations of Foothill Yellow-legged Frogs on regulated rivers are more isolated, and the

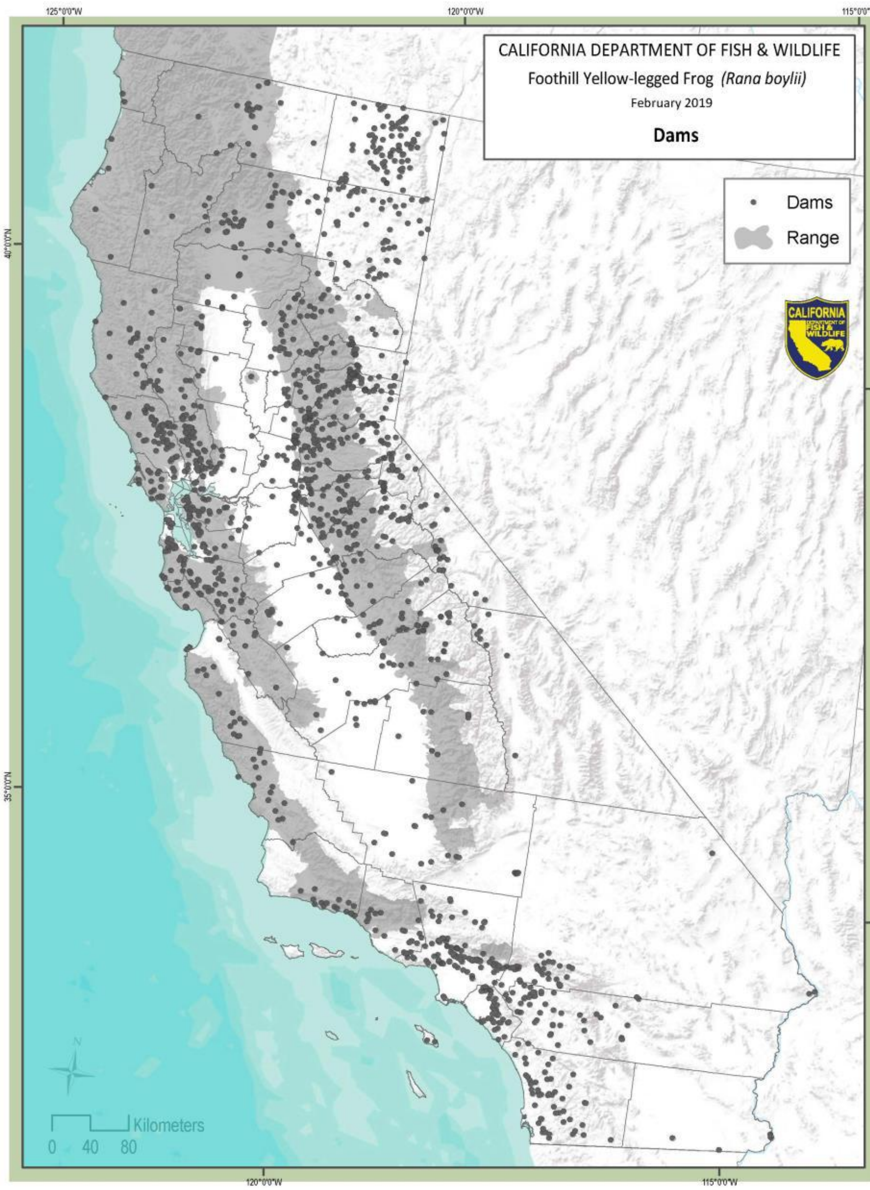


Figure 16. Locations of ACOE and DWR jurisdictional dams (DWR, FRS)

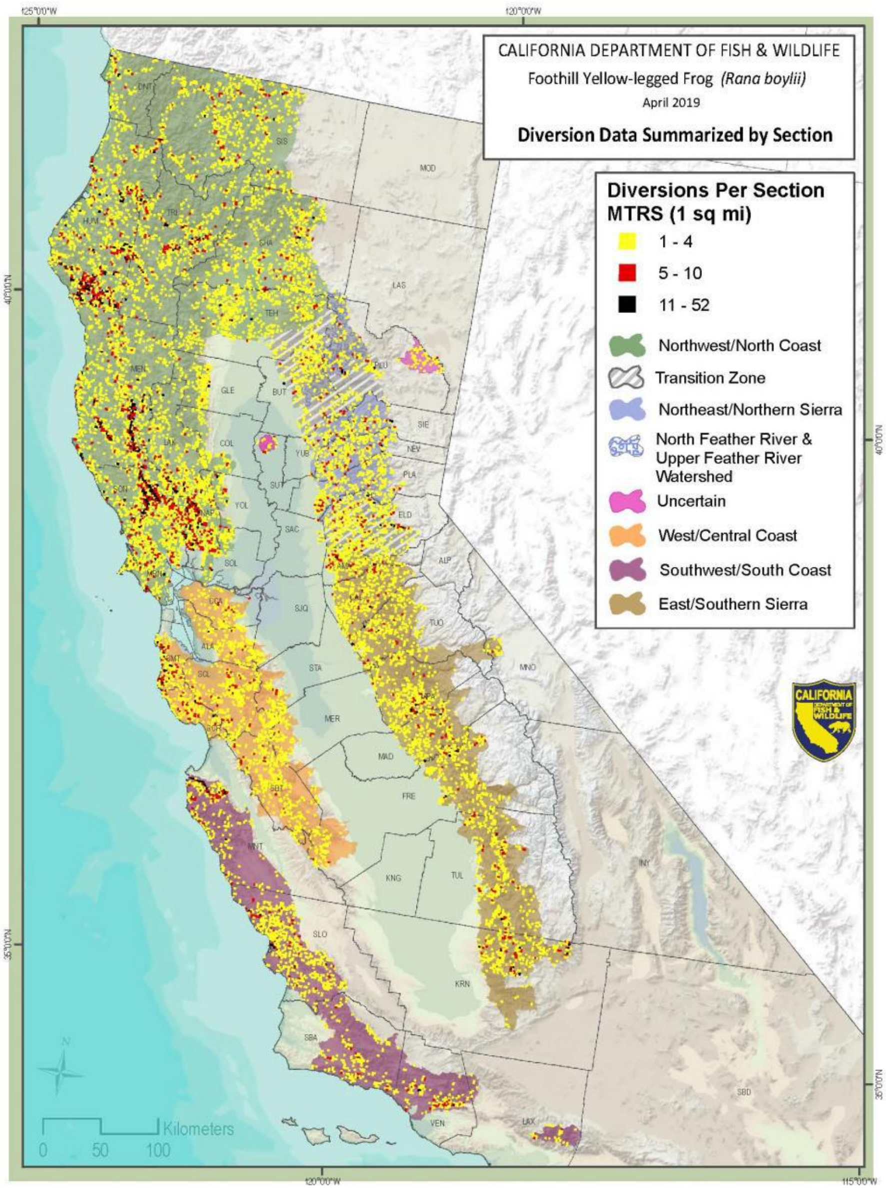


Figure 17. Number of surface water diversions per Public Lands Survey System section within the Foothill Yellow-legged Frog's range in California (eWRIMs)

type of water operations (hydropeaking vs. bypass flows) significantly affects the degree of gene flow loss among them (Peek 2011, 2018). Figure 18 depicts the locations of hydroelectric power plants.

As discussed in the Seasonal Activity and Movements section, cues for Foothill Yellow-legged Frogs to start breeding appear to involve water temperature and velocity, two features altered by dams. Dam operations typically result in reduced flows that are more stable over the course of a year than unimpaired conditions, and dam managers are frequently required to maintain thermally appropriate water temperatures and flows for cold-water-adapted salmonids (USFWS and Hoopa Valley Tribe 1999, Wheeler et al. 2014). For example, late-spring and summer water temperatures on the mainstem Trinity River below Lewiston Dam have been reported to be up to 10°C (20°F) cooler than average pre-dam temperatures, while average winter temperatures are slightly warmer (USFWS and Hoopa Valley Tribe 1999). As a result, Foothill Yellow-legged Frogs breed later on the mainstem Trinity River compared to six nearby tributaries, and some mainstem reaches may never attain the minimum required temperature for breeding (Wheeler et al. 2014, Snover and Adams 2016). In addition, annual discharges past Lewiston Dam have been 10-30% of pre-dam flows and do not mimic the natural hydrograph (Lind et al. 1996).

Aseasonal discharges from dams occur for several reasons including increased flow in late-spring and early summer to facilitate outmigration of salmonids, channel maintenance pulse flows, short-duration releases for recreational whitewater boating, rapid reductions after a spill (uncontrolled flows released down a spillway when reservoir capacity is exceeded) to retain water for power generation or water supply later in the year, peaking flows for hydroelectric power generation, and sustained releases to maintain the seismic integrity of the dam (Lind et al. 1996, Jackman et al. 2004, Kupferberg et al. 2011b, Kupferberg et al. 2012, Snover and Adams 2016). The results of a Foothill Yellow-legged Frog population viability analysis (PVA) suggest that the likelihood a population will persist is very sensitive to early life stage mortality; the 30-year probability of extinction increases significantly with high levels of egg or tadpole scouring or stranding (Kupferberg et al. 2009c). For instance, in 1991 and 1992, all egg masses laid before high flow releases to encourage outmigration of salmonids on the Trinity River were scoured away (Lind et al. 1996). According to the PVA, even a single annual pulse flow such as this or for recreational boating, can result in a three- to five-fold increase in the 30-year extinction risk based on amount of tadpole mortality experienced (Kupferberg et al. 2009c). Management after natural spills can also lead to substantial mortality. For example, in 2006, Foothill Yellow-legged Frogs on the North Fork Feather River bred during a prolonged spill, and the rapid recession below Cresta Dam that followed stranded and desiccated all the eggs laid (Kupferberg et al. 2009b). Rapid flows can also increase predation risk if tadpoles are forced to seek shelter under rocks where crayfish and other invertebrate predators are more common or if they are displaced into the water column where their risk of predation by fish is greater (Ibid.).

The overall reduction of flows and frequency of large winter floods below dams can produce extensive changes to Foothill Yellow-legged Frog habitat quality. They reduce the formation of river bars that are regularly used as breeding habitat, and they create deeper and steeper channels with less complexity and fewer warm, calm, shallow edgewater habitats for tadpole rearing (Lind et al. 1996, Wheeler and Welsh 2008, Kupferberg et al. 2011b, Wheeler et al. 2014). For example, 26 years after construction of

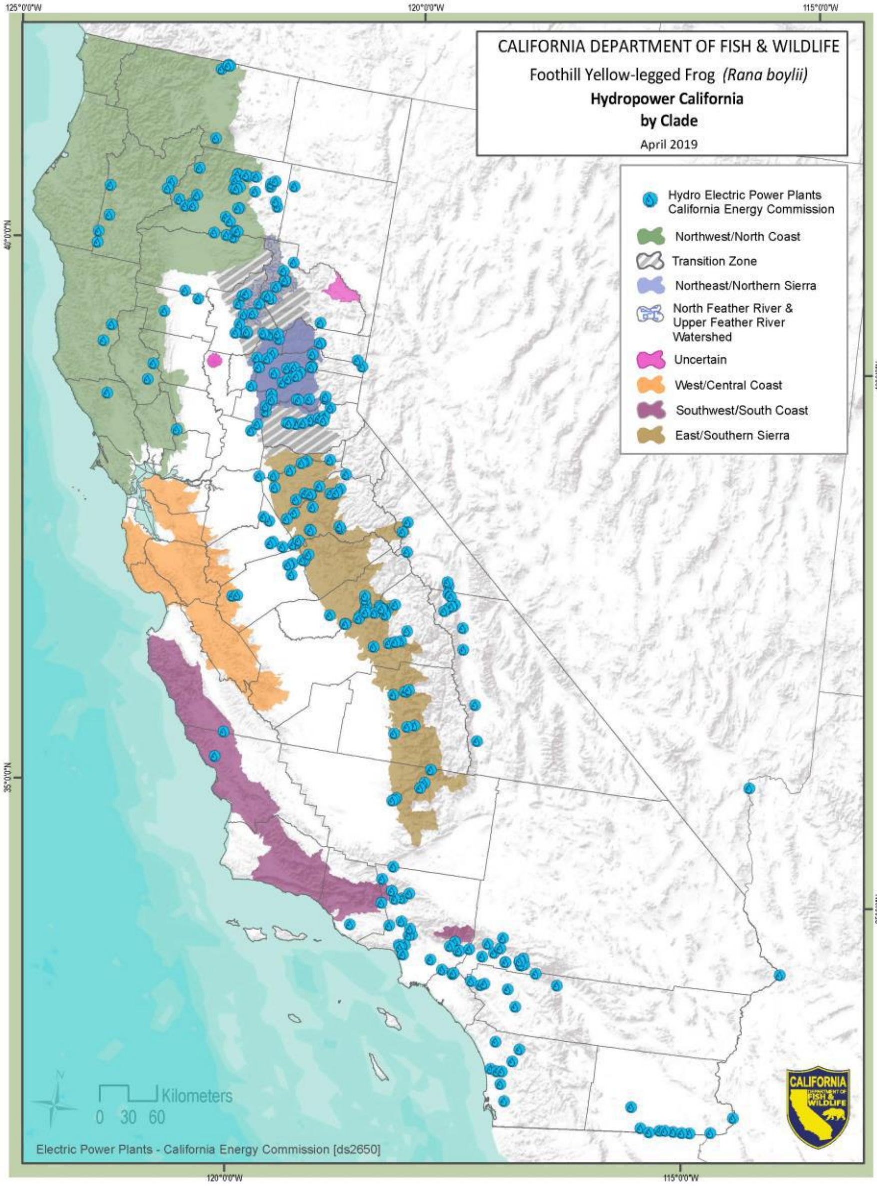


Figure 18. Locations of hydroelectric power generating dams (BIOS)

the Lewiston Dam on the Trinity River, habitat changes in a 63 km (39 mi) stretch from the dam downstream were evaluated (Lind et al. 1996). Riparian vegetation went from covering 30% of the riparian area pre-dam to 95% (Ibid.). Additionally, river bars made up 70% of the pre-dam riparian area compared to 4% post-dam, amounting to a 94% decrease in available Foothill Yellow-legged Frog breeding habitat (Ibid.).

Several features of riverine habitat below dams can decrease tadpole growth rate and other measures of fitness. As ectotherms, Foothill Yellow-legged Frogs require temperatures that support their metabolism, food conversion efficiency, growth, and development, and these temperatures may not be reached until late in the season, or not at all, when the water released is colder than their lower thermal limit (Kupferberg et al. 2011a, Catenazzi and Kupferberg 2013, Wheeler et al. 2014). Colder temperatures and higher flows reduce time spent feeding and efficiency at food assimilation, resulting in slower growth and development (Kupferberg et al. 2011a,b; Catenazzi and Kupferberg 2018). Large bed-scouring winter floods promote greater *Cladophora glomerate* blooms, the filamentous green alga that dominates primary producer biomass during the tadpole rearing season (Power et al. 2008, Kupferberg et al. 2011a). The period of most rapid tadpole growth often coincides with blooms of highly nutritious and more easily assimilated epiphytic diatoms, so reduced flows can have food-web impacts on tadpole growth and survival (Power et al. 2008, Kupferberg et al. 2011a, Catenazzi and Kupferberg 2018). In addition, colder temperatures and fluctuating summer flows, such as those released for hydroelectric power generation, can reduce the amount of algae available for grazing and can change the algal assemblage to one dominated by mucilaginous stalked diatoms like *Didymosphenia geminate* that have low nutritional value (Spring Rivers Ecological Sciences 2003, Kupferberg et al 2011a, Furey et al. 2014). Altered temperatures, flows, and food quality can contribute to slower growth and development, longer time to metamorphosis, smaller size at metamorphosis, and reduced body condition, which adversely impact fitness (Kupferberg et al. 2011b, Catenazzi and Kupferberg 2018).

As discussed in more detail in the Population Structure and Genetic Diversity section, both are strongly affected by river regulation (Peek 2011, 2018; Stillwater Sciences 2012). Foothill Yellow-legged Frogs primarily use watercourses as movement corridors, so the reservoirs created behind dams are often uninhabitable and represent barriers to gene flow (Bourque 2008; Peek 2011, 2018). This decreased connectivity can lead to loss of genetic diversity, inducing a species' ability to adapt to changing conditions (Palstra and Ruzzante 2008).

Decreased winter discharge below dams facilitates establishment and expansion of invasive bullfrogs, whose tadpoles require overwintering and are not well-adapted to flooding events (Lind et al. 1996, Doubledee et al. 2003). Where they occur, bullfrogs tend to dominate areas more altered by dam operations than less impaired areas that support a higher proportion of native species (Moyle 1973, Fuller et al. 2011). In addition to downstream effects, the reservoirs created behind dams directly destroy lotic (flowing) Foothill Yellow-legged Frog habitat, typically do not retain natural riparian communities due to fluctuating water levels, are often managed for human activities not compatible with the species' needs, and act as a source of introduced species upstream and downstream (Brode and Bury 1984, PG&E 2018). Moyle and Randall (1998) identified characteristics of sites with low native biodiversity in the Sierra Nevada foothills; they were often drainages that had been dammed and

diverted in lower- to middle-elevations and dominated by introduced fishes and bullfrogs. Even small-scale operations can have significant effects. Some farming operations divert water during periods of high flows and store it in small impoundments for use during low flow-high need times; these ponds can serve as sources for introduced species like bullfrogs to spread into areas where the habitat would otherwise be unsuitable (Kupferberg 1996b).

The mechanisms described above result in the widespread pattern of greater Foothill Yellow-legged Frog density in unregulated rivers and in reaches far enough downstream of a dam to experience minimal effects from it (Lind et al. 1996, Kupferberg 1996a, Bobzien and DiDonato 2007, Peek 2011). Abundance in unregulated rivers averages five times greater than population abundance downstream of large dams (Kupferberg et al. 2012). Figure 19 depicts a comprehensive collection of egg mass density data where at least four years of surveys have been undertaken, showing much lower abundance in regulated (S. Kupferberg pers. comm. 2019). In California, Foothill Yellow-legged Frog presence is associated with an absence of dams or with only small dams far upstream (Lind 2005, Kupferberg et al. 2012). Hydroelectric power generation from Sierra Nevada rivers accounts for nearly half its statewide production and about 9% of all electrical power used in California (Dettinger et al. 2018). Every major stream below 600 m (1968 ft) in the Sierra Nevada has at least one large reservoir (≥ 0.12 km^3 [100,000 ac-ft]), and many have multiple medium and small ones (Hayes et al. 2016). Because of this, Catenazzi and Kupferberg (2017) posit that the dam-effect on Foothill Yellow-legged Frog populations is likely greater in the Sierra Nevada than the Coast Range because dams are more often constructed in a series along a river in the former and spaced close enough together such that suitable breeding temperatures may never occur in the intervening reaches.

Pathogens and Parasites

Perhaps the most widely recognized amphibian disease is chytridiomycosis, which is caused by the fungal pathogen *Batrachochytrium dendroabatidis* (Bd). Implicated in the decline of over 500 amphibian species, including 90 presumed extinctions, it represents the greatest recorded loss of biodiversity attributable to a disease (Scheele et al. 2019). The global trade in American Bullfrogs (primarily for food) is connected to the disease's spread because the species can persist with low-level Bd infections without developing chytridiomycosis (Yap et al. 2018). Previous studies suggested Foothill Yellow-legged Frogs may not be susceptible to Bd-associated mass mortality; skin peptides strongly inhibited growth of the fungus in the lab, and the only detectable difference between Bd+ and Bd- juvenile Foothill Yellow-legged Frogs was slower growth (Davidson et al. 2007). At Pinnacles National Park in 2006, 18% of post-metamorphic Foothill Yellow-legged Frogs tested positive for Bd; all were asymptomatic and at least one Bd+ Foothill Yellow-legged Frog subsequently tested negative, demonstrating an ability to shed the fungus (Lowe 2009). However, recent studies have found historical evidence of Bd contributing to the extirpation of Foothill Yellow-legged Frogs in southern California, an acute die-off in 2013 in the Alameda Creek watershed, and another in 2018 in Coyote Creek (Adams et al. 2017a,b; Kupferberg and Catenazzi 2019). Evaluation of museum specimens indicates lower Bd prevalence (proportion of individuals infected) in Foothill Yellow-legged Frogs than most other co-occurring amphibians in southern California in the first part of the 20th century, but it spiked in the 1970s just prior to the last observation of an individual in 1977 (Adams et al. 2017b). Two museum specimens collected in 1966,

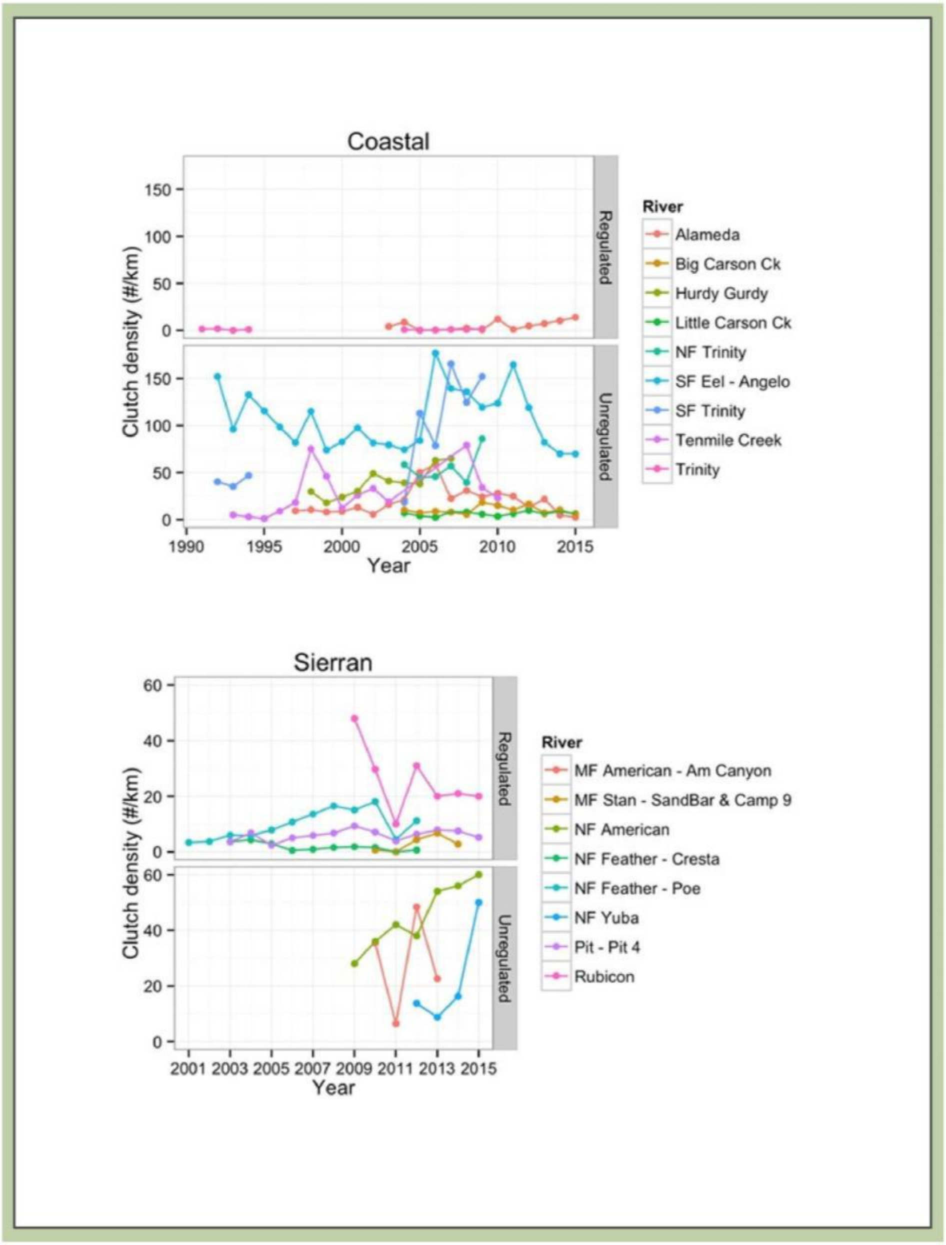


Figure 19. Foothill Yellow-legged Frog Egg mass density estimates along the coast from 1990-2015 and the Sierra Nevada from 2001-2015 from multiple studies compiled by S. Kupferberg (2019)

one from Santa Cruz County and the other from Alameda County, provide the earliest evidence of Bd in Foothill Yellow-legged Frogs in central California (Padgett-Flohr and Hopkins 2009). In contrast to the southern California results, Foothill Yellow-legged Frogs possessed the highest Bd prevalence among all amphibians tested in coastal Humboldt County in 2013 and 2014; however, zoospore (the aquatic dispersal agent) loads were well below the presumed lethal density threshold (Ecoclub Amphibian Group et al. 2016).

In addition to bullfrogs, the native Pacific Treefrog (*Pseudacris regilla*) seems immune to the lethal effects of chytridiomycosis, and owing to its broad ecological tolerances, more terrestrial lifestyle, and relatively large home range size and dispersal ability, the species is ubiquitous across California (Padgett-Flohr and Hopkins 2009). In a laboratory experiment, Bd-infected Pacific Treefrogs shed an average of 68 zoospores per minute, making them the prime candidate for spreading and maintaining Bd in areas where bullfrogs do not occur (Padgett-Flohr and Hopkins 2009, Reeder et al. 2012). In the wild, Pacific Treefrog populations persisted at 100% of sites in the Sierra Nevada (above 1500 m [4920 ft]) where a sympatric ranid species had been extirpated from 72% of its formerly occupied sites due to a Bd outbreak (Reeder et al. 2012). This is consistent with the results of a model that incorporated Bd habitat suitability, host availability, and invasion history in North America, which concluded west coast mountain ranges were at the greatest risk from the disease (Yap et al. 2018).

Several other pathogens and parasites have been encountered with Foothill Yellow-legged Frogs, but none have been ascribed to large-scale mortality events. Another fungus, a water mold (*Saprolegnia* sp.) carried by fish, is an important factor in amphibian embryo mortality in the Pacific Northwest (Blaustein et al. 1994, Kiesecker and Blaustein 1997). Fungal infections of Foothill Yellow-legged Frog egg masses, potentially from *Saprolegnia*, have been observed in the mainstem Trinity River (Ashton et al. 1997). *Saprolegnia* infection is more likely to occur in ponds and lakes, particularly if stocked by hatchery-raised fish into previously fishless areas and when frogs use communal oviposition sites, so it likely does not represent a major source of mortality in Foothill Yellow-legged Frogs (Blaustein et al. 1994, Kiesecker and Blaustein 1997). However, they may be more susceptible to *Saprolegnia* infection when exposed to other environmental stressors that compromise their immune defenses (Blaustein et al. 1994, Kiesecker and Blaustein 1997).

The trematode parasite *Ribeiroia ondatrae* is responsible for limb malformations in ranids (Stopper et al. 2002). *Ribeiroia ondatrae* was detected on a single Foothill Yellow-legged Frog during a study on malformations, but its morphology was normal (Kupferberg et al. 2009a). The results of the study instead linked malformations in Foothill Yellow-legged Frog tadpoles and young-of-year to the Anchor Worm (*Lernae cyprinacea*), a parasitic copepod from Eurasia (Ibid.). Prevalence of malformations was low, under 4% of the population in both years of study, but there was a pattern of infected individuals metamorphosing at a smaller size, which as previously mentioned can have implications on fitness (Ibid.). Three other species of helminths (parasitic worms) were encountered during the study (*Echinostoma* sp., *Manodistomum* sp., and *Gyrodactylus* sp.); their relative impact on their hosts is unknown, but at least one Foothill Yellow-legged Frog had 700 echinstome cysts in its kidney (Ibid.). Bursey et al. (2010) discovered 13 species of helminths in and on Foothill Yellow-legged Frogs from

Humboldt County. Most are common in anurans, and some are generalists with multiple possible hosts, but studies on their impact on Foothill Yellow-legged Frogs are lacking (Ibid.).

Introduced Species

Species not native to an area, but introduced, can alter food webs and ecosystem processes through predation, competition, hybridization, disease transmission, and habitat modification. Native species lack evolutionary history with introduced species, and early life stages of native anurans are particularly susceptible to predation by aquatic non-native species (Kats and Ferrer 2003). Because introduced species often establish in highly modified habitats, it can be difficult to differentiate between impacts from habitat degradation and the introduced species (Fisher and Shaffer 1996). However, native amphibians have been frequently found successfully reproducing in heavily altered habitats when introduced species were absent, suggesting introduced species themselves can impose an appreciable adverse effect (Ibid.). Numerous introduced species have been documented to adversely impact Foothill Yellow-legged Frogs or are suspected of doing so.

American Bullfrogs were introduced to California from the eastern U.S. around the turn of the 20th century, likely in response to overharvest of native ranids by the frog-leg industry that accompanied the Gold Rush (Jennings and Hayes 1985). Nearly 50 years ago, Moyle (1973) reported that distributions of Foothill Yellow-legged Frogs and bullfrogs in the Sierra Nevada foothills were nearly mutually exclusive. He speculated that bullfrog predation and competition may be causal factors in their disparate distributions in addition to the habitat degradation from dams and diversions that facilitated the bullfrog invasion in the first place. In a study along the South Fork Eel River and one of its tributaries, Foothill Yellow-legged Frog abundance was nearly an order of magnitude lower in reaches were bullfrogs were well established (Kupferberg 1997a). At a site in Napa Valley, after bullfrogs were eradicated, Foothill Yellow-legged Frogs, among other native species, recolonized the area (J. Alvarez pers. comm. 2018). In a mesocosm experiment, Foothill Yellow-legged Frog survival in control enclosures measured half that of enclosures containing bullfrog and Foothill Yellow-legged Frog tadpoles, and they weighed approximately one-quarter lighter at metamorphosis (Kupferberg 1997a). The mechanism for these declines appeared to be the reduction of high quality algae by bullfrog tadpole grazing, as opposed to any behavioral or chemical interference (Ibid.). Adult bullfrogs, which can get very large (9.0-15.2 cm [3.5-6.0 in]), also directly consume Foothill Yellow-legged Frogs, including adults (Moyle 1973, Crayon 1998, Powell et al. 2016). Silver (2017) noted that she never heard Foothill Yellow-legged Frogs calling in areas with bullfrogs, which has implications for breeding success; she speculated the lack of vocalizations may have been a predator avoidance strategy.

As discussed briefly in the Pathogens and Parasites section, American Bullfrogs act as reservoirs and vectors of the lethal chytrid fungus. In museum specimens from both southern and central California, Bd was detected in bullfrogs before it was detected in Foothill Yellow-legged Frogs in the same area (Padgett-Flohr and Hopkins 2009, Adams et al. 2017b). During a die-off from chytridiomycosis that commenced in 2013, Bd prevalence and load in Foothill Yellow-legged Frogs was positively predicted by bullfrog presence (Adams et al. 2017a). A similar die-off in 2018 from a nearby county appears to be related to transmission by bullfrogs as well (Kupferberg and Catenazzi 2019). In addition, male Foothill

Yellow-legged Frogs have been observed amplexing female bullfrogs, which may not only constitute wasted reproductive effort but could serve to increase their likelihood of contracting Bd (Lind et al. 2003a). In fact, adult males were more likely to be infected with Bd than females or juveniles during the recent die-off in Alameda Creek (Adams et al. 2017a). African Clawed Frogs (*Xenopus laevis*) have also been implicated in the spread of Bd in California because like bullfrogs, they are asymptomatic carriers (Padgett-Flohr and Hopkins 2009). However, African Clawed-Frog distribution only minimally overlaps with the Foothill Yellow-legged Frog's range unlike the widespread bullfrog (Stebbins and McGuinness 2012).

Hayes and Jennings (1986) observed a negative association between the abundance of introduced fish and Foothill Yellow-legged Frogs. Rainbow trout (*Onchorynchus mykiss*) and green sunfish (*Lepomis cyanellus*) are suspected of destroying egg masses (Van Wagner 1996). Bluegill sunfishes (*L. macrochirus*) are likely predators; in captivity when offered eggs and tadpoles of two ranid species, they consumed both life stages but a significantly greater number of tadpoles (Werschkul and Christensen 1977). Common hatchery-stocked fish like brook (*Salvelinus fontinalis*) and rainbow trout commonly carry of *Saprolegnia* (Blaustein et al. 1994). In addition, presence of non-native fish can facilitate bullfrog invasions by reducing the density of macroinvertebrates that prey on their tadpoles (Adams et al. 2003). Foothill Yellow-legged Frog tadpoles raised from eggs from sites with and without smallmouth bass (*Micropterus dolomieu*) did not differ in their responses to exposure to the non-native, predatory bass and a native, non-predatory fish (Paoletti et al. 2011). This result suggests that Foothill Yellow-legged Frogs have not yet evolved a recognition of bass as a threat, which makes them more vulnerable to predation (Ibid.).

Introduced into several areas within the Coast Range and Sierra Nevada, signal crayfish have been recorded preying on Foothill Yellow-legged Frog egg masses and are suspected of preying on their tadpoles based on observations of tail injuries that looked like scissor snips (Riegel 1959, Wiseman et al. 2005). The introduced red swamp crayfish (*Procambarus clarkii*) likely also preys on Foothill Yellow-legged Frogs. Because Foothill Yellow-legged Frogs evolved with native crayfish in northern California, individuals from those areas may more effectively avoid crayfish predation than in other parts of the state where they are not native (Riegel 1959, USFWS 1998, Kats and Ferrer 2003). The Foothill Yellow-legged Frog's naivety to crayfish was demonstrated in a study that showed they did not change behavior when exposed to signal crayfish chemical cues, but once the crayfish was released and consuming Foothill Yellow-legged Frog tadpoles, the survivors, likely reacting to chemical cues from dead tadpoles, did respond (Kerby and Sih 2015).

Sedimentation

Several anthropogenic activities, some of which are described in greater detail below, can artificially increase sedimentation into waterways occupied by Foothill Yellow-legged Frogs and adversely impact biodiversity (Moyle and Randall 1998). These activities include but are not limited to mining, agriculture, overgrazing, timber harvest, and poorly constructed roads (Ibid.). Increased fine sediments can substantially degrade Foothill Yellow-legged Frog habitat quality. Heightened turbidity decreases light penetration that phytoplankton and other aquatic plants require for photosynthesis (Cordone and Kelley

1961). When silt particles fall out of the water column, they can destroy algae by covering the bottom of the stream (Ibid.). Algae are not only important for Foothill Yellow-legged Frog tadpoles as forage but also oxygen production (Ibid.). Sedimentation may impede attachment of egg masses to substrate (Ashton et al. 1997). The effect of silt accumulation on embryonic development is unknown, but it does make them less visible, which could decrease predation risk (Fellers 2005). Fine sediments can fill interstitial spaces between rocks that tadpoles use for shelter from high velocity flows and cover from predators and that serve as sources for aquatic invertebrate prey for post-metamorphic Foothill Yellow-legged Frogs (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b).

Mining

Current mining practices, as well as legacy effects from historical mining operations, may adversely impact Foothill Yellow-legged Frogs through contaminants, direct mortality, habitat destruction and degradation, and behavioral disruption. While mercury in streams can result from atmospheric deposition, storm-induced runoff of naturally occurring mercury, agricultural runoff, and geothermal springs, runoff from historical mine sites mobilizes a significant amount of mercury (Foe and Croyle 1998, Alpers et al. 2005, Hothem et al. 2010). Beginning in the mid-1800s, extensive mining occurred in the Coast Range to supply mercury for gold mining in the Sierra Nevada, causing widespread contamination of both mountain ranges and the rivers in the Central Valley (Foe and Croyle 1998). Studies on Foothill Yellow-legged Frog tissues collected from the Cache Creek (Coast Ranges) and Greenhorn Creek (Sierra Nevada) watersheds revealed mercury bioaccumulation concentrations as high as 1.7 and 0.3 µg/g (ppm), respectively (Alpers et al. 2005, Hothem et al. 2010). For context, the U.S. Environmental Protection Agency's mercury criterion for issuance of health advisories for fish consumption is 0.3 µg/g; concentrations exceeded this threshold in Foothill Yellow-legged Frog tissues at 62% of sampling sites in the Cache Creek watershed (Hothem et al. 2010). Bioaccumulation of this powerful neurotoxin can cause deleterious impacts on amphibians including inhibited growth, decreased survival to metamorphosis, increased malformations, impaired reproduction, and other sublethal effects (Zillioux et al. 1993, Unrine et al. 2004). In a study measuring Sierra Nevada watershed health, Moyle and Randall (1998) reportedly found very low biodiversity in streams that were heavily polluted by acidic water leaching from historical mines. Acidic drainage measured as low as 3.4 pH from some mined areas in the northern Sierra Nevada (Alpers et al. 2005).

Widespread suction dredging for gold occurred in the Foothill Yellow-legged Frog's California range until enactment of a moratorium on issuing permits in 2009 (Hayes et al. 2016). Suction dredging vacuums up the contents of the streambed, passes them through a sluice box to separate the gold, and then deposits the tailings on the other side of the box (Harvey and Lisle 1998). While most habitat disturbance is localized and minor, it can be especially detrimental if it degrades or destroys breeding and rearing habitat through direct disturbance or sedimentation (Ibid.). In addition, this activity can lead to direct mortality of early life stages through entrainment, and those eggs and tadpoles that do survive passing through the suction dredge may experience greater mortality due to subsequent unfavorable physiochemical conditions and possible increased predation risk (Ibid.). Suction dredging can also reduce the availability of invertebrate prey, although this impact is typically short-lived (Ibid.). Suction dredging alters stream morphology, and relict tailing ponds can serve as breeding habitat for bullfrogs in areas

that would not normally support them (Fuller et al. 2011). However, in some areas these mining holes have reportedly benefited Foothill Yellow-legged Frogs by creating cool persistent pools that adult females appeared to prefer at one Sierra Nevada site (Van Wagner 1996). Senate Bill 637 (2015) directs the Department to work with the State Water Resources Control Board (SWRCB) to develop a statewide water quality permit that would authorize the use of vacuum or suction dredge equipment in California under conditions set forth by the two agencies. SWRCB staff, in coordination with Department staff, are in the process of collecting additional information to inform the next steps that will be taken by the SWRCB (SWRCB 2019).

Instream aggregate (gravel) mining continues today and can have similar impacts to suction dredge mining by removing, processing, and relocating stream substrates (Olson and Davis 2009). This type of mining typically removes bars used as Foothill Yellow-legged Frog breeding habitat and reduces habitat heterogeneity by creating flat wide channels (Kupferberg 1996a). Typically when listed salmonids are present, mining must be conducted above the wetted edge, but this practice can create perennial off-channel bullfrog breeding ponds (M. van Hattem pers. comm. 2018).

Agriculture

Direct loss of Foothill Yellow-legged Frog habitat from wildland conversion to agriculture is rare because the typically rocky riparian areas they inhabit are usually not conducive to farming, but removal of riparian vegetation directly adjacent to streams for agriculture is more common and widespread. The U.S. Department of Agriculture classifies 3.9 million ha (9.6 million ac) in California as cropland, which amounts to less than 10% of the state's land area, and 70% of this occurs in the Central Valley between Redding and Bakersfield (Martin et al. 2018). In addition, several indirect impacts can adversely affect Foothill Yellow-legged Frogs at substantial distances from agricultural operations such as effects from runoff (sediments and agrochemicals), drift and deposition of airborne pollutants, water diversions, and creation of novel habitats like impoundments that facilitate spread of detrimental non-native species. As sedimentation and introduced species impacts were previously discussed, this section instead focuses on the other possible adverse impacts.

Agrochemicals

Many species of amphibians, particularly ranids, have experienced declines throughout California, but the most dramatic declines have occurred in the Sierra Nevada east of the San Joaquin Valley where 60% of the total pesticide usage in the state was sprayed (Sparling et al. 2001). Agrochemicals applied to crops in the Central Valley can volatilize and travel in the atmosphere and deposit in higher elevations (LeNoir et al. 1999). Pesticide concentrations diminish as elevations increase in the lower foothills but change little from 533 to 1,920 m (1,750-6,300 ft), which coincides with the Foothill Yellow-legged Frog's elevational range (Ibid). Foothill Yellow-legged Frog absence at historically occupied sites in California significantly correlated with agricultural land use within 5 km (3 mi), and a positive relationship exists between Foothill Yellow-legged Frog declines and the amount of upwind agriculture, suggesting airborne agrochemicals may be a contributing factor (Figure 20; Davidson et al. 2002). Cholinesterase-inhibitors (most organophosphates and carbamates), which disrupt nerve impulse transmission, were

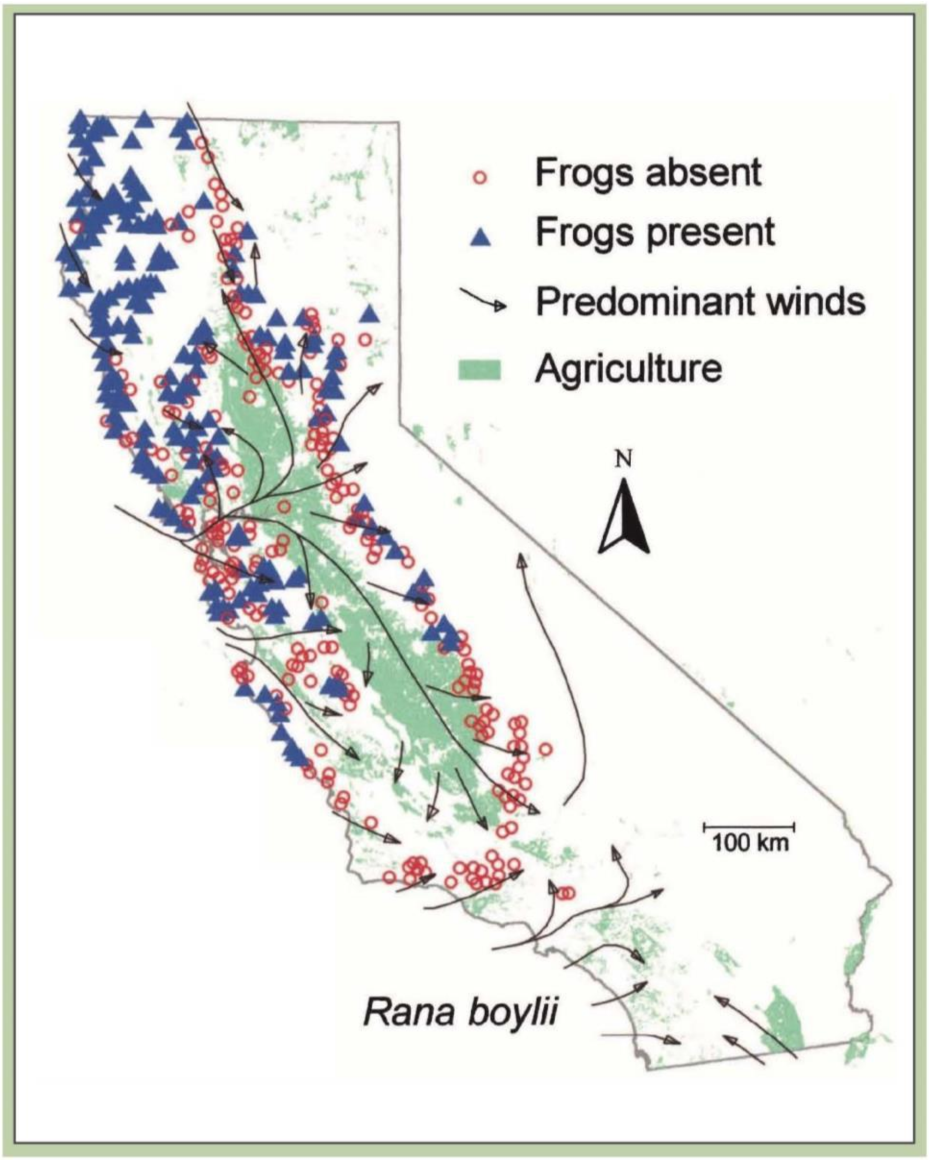


Figure 20. Relationship of Foothill Yellow-legged Frog occupancy to agriculture from Davidson et al. (2002)

more strongly associated with population declines than other pesticide types (Davidson 2004). Olson and Davis (2009) and Lind (2005) also reported a negative correlation between Foothill Yellow-legged Frog presence and proximity and quantity of nearby agriculture in Oregon and across the species' entire range, respectively.

Lethal and sublethal effects of agrochemicals on amphibians can take two general forms: direct toxicity and food-web effects. Sublethal doses of agrochemicals can interact with other environmental stressors to reduce fitness. Foothill Yellow-legged Frog tadpoles showed significantly greater vulnerability to the lethal and sublethal effects of carbaryl than Pacific Treefrogs (Kerby and Sih 2015). An inverse relationship exists between carbaryl concentration and Foothill Yellow-legged Frog activity, and their 72-h LC_{50} (concentration at which 50% die) measured one-fifth that of Pacific Treefrogs (Ibid.). Carbaryl slightly decreased Foothill Yellow-legged Frog development rate, but it significantly increased susceptibility to predation by signal crayfish despite nearly no mortality in the pesticide- and predator-only treatments (Ibid.). Sparling and Fellers (2009) also found Foothill Yellow-legged Frogs were significantly more sensitive to pesticides (chlorpyrifos and endosulfan in this study) than Pacific Treefrogs; their 96-hr LC_{50} was nearly five-times less than for treefrogs. Endosulfan was nearly 121 times more toxic to Foothill Yellow-legged Frogs than chlorpyrifos, and water samples from the Sierra Nevada have contained endosulfan concentrations within their lethal range and sometimes greater than the LC_{50} for the species (Ibid.). Sublethal effects included smaller body size, slower development rate, and increased time to metamorphosis (Ibid.). Sparling and Fellers (2007) determined the organophospates chlorpyrifos, malathion, and diazinon can harm Foothill Yellow-legged Frog populations, and their oxon derivatives (the resultant compounds once they begin breaking down in the body) were 10 to 100 times more toxic than their respective parental forms.

Extrapolating the results of studies on other ranids to Foothill Yellow-legged Frogs should be undertaken with caution; however, those studies can demonstrate additional potential adverse impacts of exposure to agrochemicals. Relyea (2005) discovered that Roundup®, a common herbicide, could cause rapid and widespread mortality in amphibian tadpoles via direct toxicity, and overspray at the manufacturer's recommended application concentrations would be highly lethal. Atrazine, another common herbicide, has been implicated in disrupting reproductive processes in male Northern Leopard Frogs (*Rana pipiens*) by slowing gonadal development, inducing hermaphroditism, and even oocyte (egg) growth (Hayes et al. 2003). However, recent research on sex reversal in wild populations of Green Frogs (*R. clamitans*) suggests it may be a relatively common natural process unrelated to environmental contaminants, requiring more research (Lambert et al. 2019). Malathion, a common organophosphate insecticide, that rapidly breaks down in the environment, applied at low concentrations caused a trophic cascade that resulted in reduced growth and survival of two species of ranid tadpoles (Relyea and Diecks 2008). Malathion caused a reduction in the amount of zooplankton, which resulted in a bloom of phytoplankton and an eventual decline in periphyton, an important food source for tadpoles (Ibid.). In contrast, Relyea (2005) found that some insecticides increased amphibian tadpole survival by reducing their invertebrate predators. Runoff from agricultural areas can contain fertilizers that input nutrients into streams and increase productivity, but they can also result in harmful algal blooms (Cordone and

Kelley 1961). In addition, exposure to pesticides can result in immunosuppression and reduce resistance to the parasites that cause limb malformations (Kiesecker 2002, Hayes et al. 2006).

Cannabis

An estimated 60-70% of the cannabis (*Cannabis indica* and *C. sativa*) used in the U.S. from legal and illegal sources is grown in California, and most comes from the Emerald Triangle, an area comprised of Humboldt, Mendocino, and Trinity counties (Ferguson 2019). Small-scale illegal cannabis farms have operated in this area since at least the 1960s but have expanded rapidly, particularly trespass grows on public land primarily by Mexican cartels, since the passage of the Compassionate Use Act in 1996 (Mallery 2010, Bauer et al. 2015). Like other forms of agriculture, it involves clearing the land, diverting water, and using herbicides and pesticides; however, in addition, many of these illicit operations use large quantities of fertilizers and highly toxic banned pesticides to kill anything that may threaten the crop, and they leave substantial amounts of non-biodegradable trash and human excrement (Mallery 2010, Thompson et al. 2014, Carah et al. 2015).

Measurements of environmental impacts of illegal cannabis grows have been hindered by the difficult and dangerous nature of accessing many of these sites; however, some analyses have been conducted, often using aerial images and geographic information systems (GIS). An evaluation of 54% of watersheds within and bordering Humboldt County revealed that while cannabis grow sites are generally small (< 0.5 ha [1.2 ac]) and comprised a tiny fraction of the study area (122 ha [301 ac]), they were widespread (present in 83% of watersheds) but unevenly distributed, indicating impacts are concentrated in certain watersheds (Butsic and Brenner 2016, Wang et al. 2017). The results also showed that 68% of grows were > 500 m (0.3 mi) from developed roads, 23% were located on slopes steeper than 30%, and 5% were within 100 m (328 ft) of critical habitat for threatened salmonids (Butsic and Brenner 2016). These characteristics suggest wildlands adjacent to cannabis cultivations are at heightened risk of habitat fragmentation, erosion, sedimentation, landslides, and impacts to waterways critical to imperiled species (Ibid.).

A separate analysis in the same general area estimated potentially significant impacts from water diversions alone. Cannabis requires a substantial amount of water during the growing season, so it is often cultivated near sources of perennial surface water for irrigation, commonly diverting from springs and headwater streams (Bauer et al. 2015). In the least impacted of the study watersheds, Bauer et al. (2015) calculated that diversions for cannabis cultivation could reduce the annual seven-day low flow by up to 23%, and in some of the heavily impacted watersheds, water demands for cannabis could exceed surface water availability. If not regulated carefully, cannabis cultivation could have substantial impacts on sensitive aquatic species like Foothill Yellow-legged Frogs in watersheds in which it is concentrated.

For context, cannabis cultivation was responsible for approximately 1.1% of forest cover lost within study watersheds in Humboldt County from 2000 to 2013, while timber harvest accounted for 53.3% (Wang et al. 2017). Cannabis requires approximately two times as much water per day as wine grapes, the other major irrigated crop in the region (Bauer et al. 2015). Impacts from cannabis cultivation have been observed by Foothill Yellow-legged Frog researchers working on the Trinity River and South Fork

Eel River in the form of lower flows in summer, increased egg stranding, and more algae earlier in the season in recent years (S. Kupferberg and M. Power pers. comm. 2015; D. Ashton pers. comm. 2017; S. Kupferberg, M. van Hattem, and W. Stokes pers. comm. 2017). In addition, Gonsolin (2010) reported illegal cannabis cultivations on four headwater streams that drained into his study area along Coyote Creek, three of which were occupied by Foothill Yellow-legged Frogs. The cultivators had removed vegetation adjacent to the creeks, terraced the slopes, diverted water, constructed small water impoundments, poured fertilizers directly into the impoundments, and applied herbicides and pesticides, as evidenced by leftover empty containers littering the site.

Commercial sale of cannabis for recreational use became legal in California on January 1, 2018, through passage of the Control, Regulate and Tax Adult Use of Marijuana Act (2016), and with it an environmental permitting system and habitat restoration fund was established. The number of applications for temporary licenses per watershed is depicted in Figure 21. Two of the expected outcomes of passage of this law were that the profit-margin on growing cannabis would fall to the point that it would discourage illegal trespass grows and move the bulk of the cultivation out of remote forested areas into existing agricultural areas like the Central Valley (CSOS 2016). However, until cannabis is legalized at the federal level, these results may not occur since banks are reluctant to work with growers due to federal prohibitions subjecting them to prosecution for money laundering (ABA 2019). Additional details on cannabis permitting at the state level can be found under the Existing Management section.

Vineyards

Vineyard operators historically built on-stream dams and removed almost all the riparian vegetation to make room for vines and for ease of irrigation (M. van Hattem pers. comm. 2019). They still divert a substantial amount of water for irrigation, and they build on- and off-stream impoundments that support bullfrogs (Ibid.). The acreage of land planted in wine grapes in California began rising dramatically in the 1970s and now accounts for 90% of wine produced in the U.S. (Geisseler and Horwath 2016, Alston et al. 2018). The number of wineries in California rose from approximately 330 to nearly 2,500 between 1975 and 2006; however, expansion slowed and has reversed slightly recently with 24,300 ha (60,000 ac), or 6.5% of total area planted, removed between 2015 and 2017 (Volpe et al. 2010, CDFA 2018). In 2015, 347,000 ha (857,000 ac) were planted in grapes with 70% located in the San Joaquin Valley; 66%, 21%, and 13% were planted in wine, raisin, and table grapes, respectively (Alston et al. 2018).

Expansion of wineries in the coastal counties converted natural areas such as oak woodlands and forests to vineyards (Merenlender 2000, Napa County 2010). The area of Sonoma County covered in grapes increased by 32% from 1990 to 1997, and 42% of these new vineyards were planted above 100 m (328 ft) with 25% on slopes greater than 18% (Merelender 2000). For context, only 18% of vineyards planted before 1990 occurred above 100 m (328 ft) and less than 6% on slopes greater than 18% (Ibid.). This conversion took place on approximately 773 ha (1,909 ac) of conifer and dense hardwood forest, 149 ha (367 ac) of shrubland, and 2,925 ha (7,229 ac) of oak grassland savanna (Ibid.).

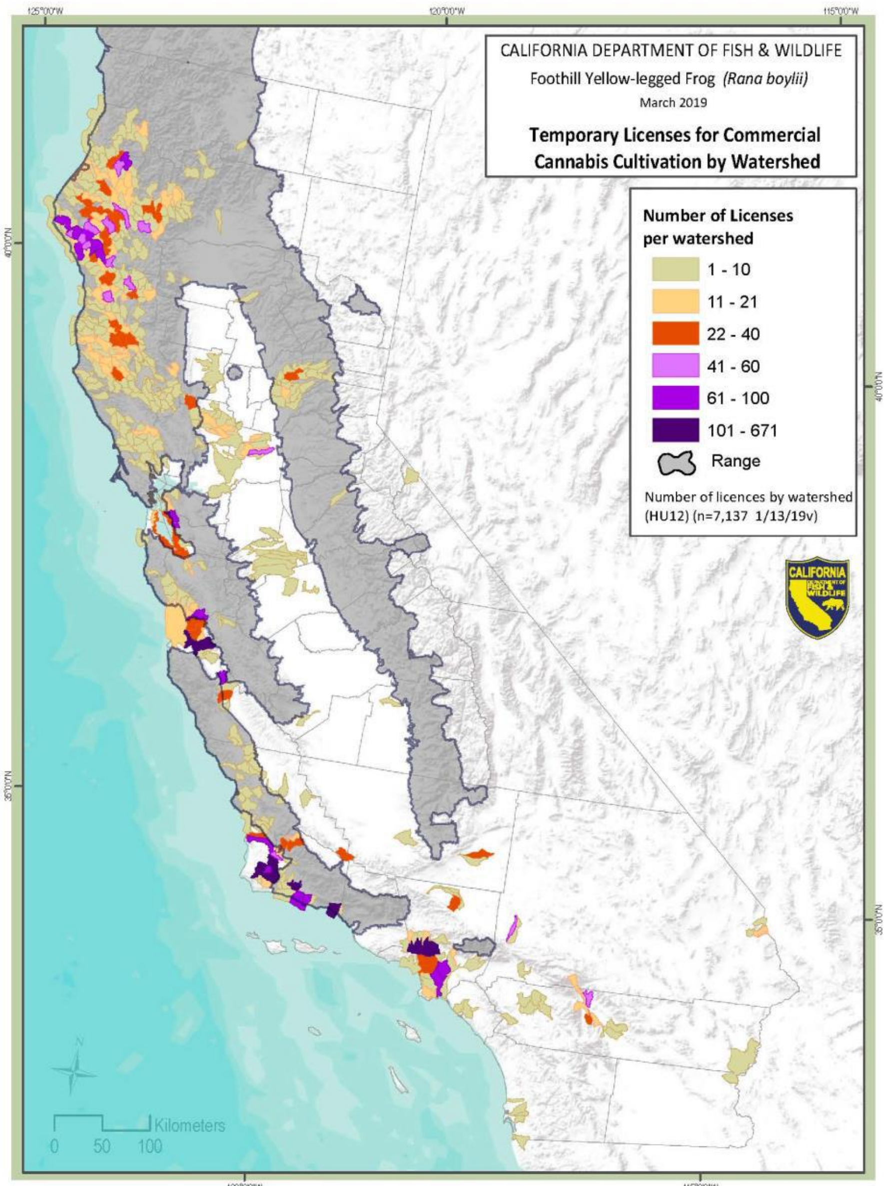


Figure 21. Cannabis cultivation temporary licenses by watershed in California (CDFA, NHD)

Recent expansion of oak woodland conversion to vineyards in Napa County was highest in its eastern hillsides (Napa County 2010). The County estimates that 1,085 and 1,240 ha (2,682-3,065 ac) of woodlands will be converted to vineyards between 2005 and 2030 (Ibid.). For context, 297 ha (733 ac) were converted from 1992 to 2003 (Ibid.). In addition, wine grapes were second only to almonds in terms of overall quantity of pesticides applied in California in 2016, but the quantity per unit area (2.9 kg/ha [2.6 lb/ac]) was 160% greater for the wine grapes (CDPR 2018). Vineyard expansion into hillsides has continued into sensitive headwater areas, and like cannabis cultivation, even small vineyards can have substantial impacts on Foothill Yellow-legged Frog habitat through sedimentation, water diversions, spread of harmful non-native species, and pesticide contamination (Merelender 2000, K. Weiss pers. comm. 2018).

Livestock Grazing

Livestock grazing can be an effective habitat management tool, including control of riparian vegetation encroachment, but overgrazing can significantly degrade the environment (Siekert et al. 1985). Cattle display a strong preference for riparian areas and have been implicated as a major source of habitat damage in the western U.S. where the adverse impacts of overgrazing on riparian vegetation are intensified by arid and semi-arid climates (Behnke and Raleigh 1978, Kauffman and Krueger 1984, Belsky et al. 1999). The severity of grazing impacts on riparian systems can be influenced by the number of animals, duration and time of year, substrate composition, and soil moisture (Benhke and Raleigh 1978, Kauffman et al. 1983, Marlow and Pogacnik 1985, Siekert et al. 1985). In addition to habitat damage, cattle can directly trample any life stage of Foothill Yellow-legged Frog.

Signs of overgrazing include impacts to the streambanks such as increased slough-offs and cave-ins that collapse undercuts used as refuge (Kauffman et al. 1983). Overgrazing reduces riparian cover, increases erosion and sedimentation, which as described above can result in silt degradation of breeding, rearing, and invertebrate food-producing areas (Cordone and Kelley 1961, Behnke and Raleigh 1978, Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). Loss of streamside and instream vegetative cover and changes to channel morphology can increase water temperatures and velocities (Behnke and Raleigh 1978). Water quality can be affected by increased turbidity and nutrient input from excrement, and seasonal water quantity can be impacted through changes to channel morphology (Belsky et al. 1999). In addition, increased nutrients and temperatures can promote blooms of harmful cyanobacteria like *Microcystis aeruginosa*, which releases a toxin when it expires that can cause liver damage to amphibians as well as other animals including humans (Bobzien and DiDonato 2007, Zhang et al. 2013).

While some recent studies indicate livestock grazing continues to damage stream and riparian ecosystems, its impact on Foothill Yellow-legged Frogs in California is unknown (Belsky et al. 1999, Hayes et al. 2016). In Oregon, the species' presence was correlated with significantly less grazing than where they were absent according to Borisenko and Hayes's 1999 report (as cited in Olson and Davis 2009). However, Fellers (2005) reported that apparently some Coast Range foothill populations occupying streams draining east into the San Joaquin Valley were doing well at the time of publication despite being heavily grazed.

Urbanization and Road Effects

Habitat conversion and fragmentation combined with modified environmental disturbance regimes can substantially jeopardize biological diversity (Tracey et al. 2018). This threat is most severe in areas like California with Mediterranean-type ecosystems that are biodiversity hot spots, fire-prone, and heavily altered by human land use (Ibid.). From 1990 to 2010, the fastest-growing land use type in the conterminous U.S. was new housing construction, which rapidly expanded the wildland-urban interface (WUI) where houses and natural vegetation meet or intermix on the landscape (Radeloff et al. 2018).

Of several variables tested, proportion of urban land use within a 5 km (3.1 mi) radius of a site was associated with Foothill Yellow-legged Frog declines (Davidson et al. 2002). Lind (2005) also found significantly less urban development nearby and upwind of sites occupied by Foothill Yellow-legged Frogs, suggesting pollutant drift may be a contributing factor. Changes in wildfires may also contribute to the species' declines; 95% of California's fires are human-caused, and wildfire issues are greatest at the WUI (Syphard et al. 2009, Radeloff et al. 2018). Population density, intermix WUI (where wildland and development intermingle as opposed to an abrupt interface), and distance to WUI explained the most variability in fire frequency (Syphard et al. 2007). In addition to wildfires, habitat loss, and fragmentation, urbanization can impact adjacent ecosystems through non-native species introduction, native predator subsidization, and disease transmission (Bar-Massada et al. 2014).

Projections show growth in California's population to 51 million people by 2060 from approximately 40 million currently (PPIC 2019). This will increase urbanization, the WUI, and habitat fragmentation. The Department of Finance projects the Inland Empire, the San Joaquin Valley, and the Sacramento metropolitan area will be the fastest-growing regions of the state over the next several decades (Ibid.). This puts the greatest pressure in areas outside of the Foothill Yellow-legged Frog's range; however, because the environmental stressors associated with urbanization can span far beyond its physical footprint, they may still adversely affect the species.

Highways are frequently recognized as barriers to dispersal that fragment habitats and populations; however, single-lane roads can pose significant risks to wildlife as well (Cook et al. 2012, Brehme et al. 2018). Foothill Yellow-legged Frogs are at risk of being killed by vehicles when roads are located near their habitat (Cook et al. 2012, Brehme et al. 2018). Fifty-six juvenile Foothill Yellow-legged Frogs were found on a road adjacent to Sulphur Creek (Mendocino County), seven of which had been struck and killed (Cook et al. 2012). When fords (naturally shallow areas) are used as vehicle crossings, they can create sedimentation and poor water quality, and in some cases, the fords are gravel or cobble bars used by Foothill Yellow-legged Frogs for breeding that could result in direct mortality (K. Blanchard pers. comm. 2018, R. Bourque pers. comm. 2018). Construction of culverts under roads to keep vehicles out of the streambed can result in varying impacts. In some cases, they can impede dispersal and create deep scoured pools that support predatory fish and frogs, but when properly constructed, they can facilitate frog movement up and down the channel with reduced road mortality (Van Wagner 1996, GANDA 2008). In areas where non-native species are not a threat, but premature drying is, pools created by culverts can provide habitat in otherwise unsuitable areas (M. Grefsrud pers. comm. 2019). An evaluation of the impact of roads on 166 native California amphibians and reptiles through direct

morality and barriers to movement concluded that Foothill Yellow-legged Frogs, at individual and population levels, were at moderate risk of road impacts in aquatic habitat but very low risk of impacts in terrestrial habitat (Brehme et al. 2018). For context, all chelonids (turtles and tortoises), 72% of snakes, 50% of anurans, 18% of lizards, and 17% of salamander species in California were ranked as having a high or very high risk of negative road impacts in the same evaluation (Ibid.).

Poorly constructed roadways near rivers and streams can result in substantial erosion and sedimentation, leading to reduced amphibian densities (Welsh and Ollivier 1998). Proximity of roads to Foothill Yellow-legged Frog habitat contributes to petrochemical runoff and poses the threat of spills (Ashton et al. 1997). A diesel spill on Hayfork Creek (Trinity County) resulted in mass mortality of Foothill Yellow-legged Frog tadpoles and partial metamorphs (Bury 1972). Roads have also been implicated in the spread of disease and may have aided in the spread of Bd in California (Adams et al. 2017b).

Frogs use auditory and visual cues to defend territories and attract mates, and some studies reveal that realistic levels of traffic noise can impede transmission and reception of these signals (Bee and Swanson 2007). Some male frogs have been observed changing the frequency of their calls to increase the distance they can be heard over traffic noise, but if females have evolved to recognize lower pitched calls as signs of superior fitness, this potential trade-off between audibility and attractiveness could have implications for reproductive success (Parris et al. 2009). In a separate study, traffic noise caused a change in male vocal sac coloration and an increase in stress hormones, which changed sexual selection processes and suppressed immunity (Troïanowski et al. 2017). Because Foothill Yellow-legged Frogs mostly call underwater and are not known to use color displays, communication cues may not be adversely affected by traffic noise, but their stress response is unknown.

Timber Harvest

Because Foothill Yellow-legged Frogs tend to remain close to the water channel (i.e., within the riparian corridor) and current timber harvest practices minimize disturbance in riparian areas for the most part, adverse effects from timber harvest are expected to be relatively low (Hayes et al. 2016, CDFW 2018b). However, some activities have a potential to negatively impact Foothill Yellow-legged Frogs or their habitat, including direct mortality and increased sedimentation during construction and decommissioning of watercourse crossings and infiltration galleries, tree felling, log hauling, and entrainment by water intakes or desiccation of eggs and tadpoles through stranding from dewatering during drafting operations (CDFW 2018b,c). In addition to impacts previously described under the Sedimentation and Road Effects section, when silt runoff into streams is accompanied by organic materials, such as logging debris, impaired water quality can result, including reduced dissolved oxygen, which is important in embryonic and tadpole development (Cordone and Kelley 1961).

Because Foothill Yellow-legged Frogs are heliotherms (i.e, they bask in the sun to raise their body temperature) and sensitive to thermal extremes, some moderate timber harvest may benefit the species (Zweifel 1955, Fellers 2005). Ashton (2002) reported 85% of his Foothill Yellow-legged Frog observations occurred in second-growth forests (37-60 years post-harvest) as opposed to late-seral forests and postulated that the availability of some open canopy areas played a major part in this

disparity. Foothill Yellow-legged Frogs are typically absent in areas with closed canopy (Welsh and Hodgson 2011). Reduced canopy also raises stream temperatures, which could improve tadpole development and promote algal and invertebrate productivity in otherwise cold streams (Olson and Davis 2009; Catenazzi and Kupferberg 2013,2017).

Recreation

Several types of recreation can adversely impact Foothill Yellow-legged Frogs, and some are more severe and widespread than others. One of the main potential factors identified by herpetologists as contributing to disappearance of Foothill Yellow-legged Frogs in southern California was increased and intensified recreation in streams (Adams et al. 2017b). The greater number of people traveling into the backcountry may have facilitated the spread Bd to these areas, and while no evidence shows stress from disturbance or other environmental pressures increases susceptibility to Bd, the stress hormone corticosterone has been implicated in immunosuppression (Hayes et al. 2003, Adams et al. 2017b).

The amount of Foothill Yellow-legged Frog habitat disturbed by off-highway motor vehicles (OHV) throughout its range in California is unknown, but its impacts can be significant, particularly in areas with small isolated populations (Kupferberg et al. 2009c, Kupferberg and Furey 2015). An example is the Carnegie State Vehicular Recreation Area (CVSRA), located in the hills southwest of Tracy in the Corral Hollow Creek watershed (Alameda and San Joaquin counties). The above-described road effects apply: sedimentation, crushing along trail crossings, and potential noise effects (Ibid.). In addition, dust suppression activities employed by CSVRA use magnesium chloride ($MgCl_2$), which has the potential to harm developing embryos and tadpoles (Karraker et al. 2008, Hopkins et al. 2013, OHMVRC 2017). Based on museum records, Foothill Yellow-legged Frogs were apparently abundant in Corral Hollow Creek, but they are extremely rare now and are already extirpated or at risk of extirpation (Kupferberg et al. 2009c, Kupferberg and Furey 2015).

Motorized and non-motorized recreational boating can also impact Foothill Yellow-legged Frogs. The impacts of jet boat traffic were investigated in Oregon; in areas with frequent use and high wakes breaking on shore, Foothill Yellow-legged Frogs were absent (Borisenko and Hayes 1999 as cited in Olson and Davis 2009). This wake action had the potential to dislodge egg masses, strand tadpoles, disrupt adult basking behavior, and erode shorelines (Ibid.). Jet boat tours and races on the Klamath River (Del Norte and Humboldt counties) may have an impact on Foothill Yellow-legged Frog use of the mainstem (M. van Hattem pers. comm. 2019). In addition, using gravel bars as launch and haul out sites for boat trailers, kayaks, or river rafts can result in direct loss of egg masses and tadpoles or damage to breeding and rearing habitat and can disrupt post-metamorphic frog behavior (Ibid.). As described above, pulse flows released for whitewater boating in the late spring and summer can result in scouring and stranding of egg masses and tadpoles (Borisenko and Hayes 1999 as cited in Olson and Davis 2009, Kupferberg et al. 2009b). In addition, the velocities that resulted in stunted growth and increased vulnerability to predation in Foothill Yellow-legged Frog tadpoles were less than the increased velocities experienced in nearshore habitats during intentional release of recreational flows for whitewater boating, as well as hydropeaking for power generation (Kupferberg et al. 2011b).

Hiking, horse-riding, camping, fishing, and swimming, particularly in sensitive breeding and rearing habitat can also adversely impact Foothill Yellow-legged Frog populations (Borisenko and Hayes 1999 in Olson and Davis 2009). Because Foothill Yellow-legged Frog breeding activity was being disturbed and egg masses were being trampled by people and dogs using Carson Falls (Marin County), the land manager established an educational program, including employing docents on weekends that remind people to stay on trails and tread lightly to try to reduce the loss of Foothill Yellow-legged Frog reproductive effort (Prado 2005). In addition, within his study site, Van Wagner (1996) reported that a property owner moved rocks that were being used as breeding habitat to create a swimming hole. The extent to which this is more than a small, local problem is unknown, but as the population of California increases, recreational pressures in Foothill Yellow-legged Frog habitat are likely to increase commensurately.

Drought

Drought is a common phenomenon in California and is characterized by lower than average precipitation. Lower precipitation in general results in less surface water, and water availability is critical for obligate stream-breeding species. Even in the absence of drought, a positive relationship exists between precipitation and latitude within the Foothill Yellow-legged Frog's range in California, and mean annual precipitation has a strong influence on Foothill Yellow-legged Frog presence at historically occupied sites (Davidson et al. 2002, Lind 2005). Figure 22 depicts the recent historical annual average precipitation across the state as well as during the most recent drought and how they differ. Southern California is normally drier than northern California, but the severity of the drought was even greater in the south.

Reduced precipitation can result in deleterious effects to Foothill Yellow-legged Frogs beyond the obvious premature drying of aquatic habitat. When stream flows recede during the summer and fall, sometimes the isolated pools that stay perennially wet are the only remaining habitat. This phenomenon concentrates aquatic species, resulting in several potentially significant adverse impacts. Stream flow volume was negatively correlated with Bd load during a recent chytridiomycosis outbreak in the Alameda Creek watershed (Adams et al. 2017a). The absence of high peak flows in winter coupled with wet years allowed bullfrogs to expand their distribution upstream, and the drought-induced low flows in the fall concentrated them with Foothill Yellow-legged Frogs in the remaining drying pools (Ibid.). This mass mortality event appeared to have been the result of a combination of drought, disease, and dam effects (Ibid.). This die-off occurred in a regulated reach that experiences heavy recreational use and presence of crayfish and bass (Ibid.). Despite these threats, the density of breeding females in this reach was greater in 2014 and 2015 than the in the unregulated reach upstream because the latter dried completely before tadpoles could metamorphose during the preceding drought years (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015).

In addition to increasing the spread of pathogens, drought-induced stream drying can increase predation and competition by introduced fish and frogs in the pools they are forced to share (Moyle 1973, Hayes and Jennings 1988, Drost and Fellers 1996). This concentration in isolated pools can also result in increased native predation as well as facilitate spread of Bd. An aggregation of six adult Foothill

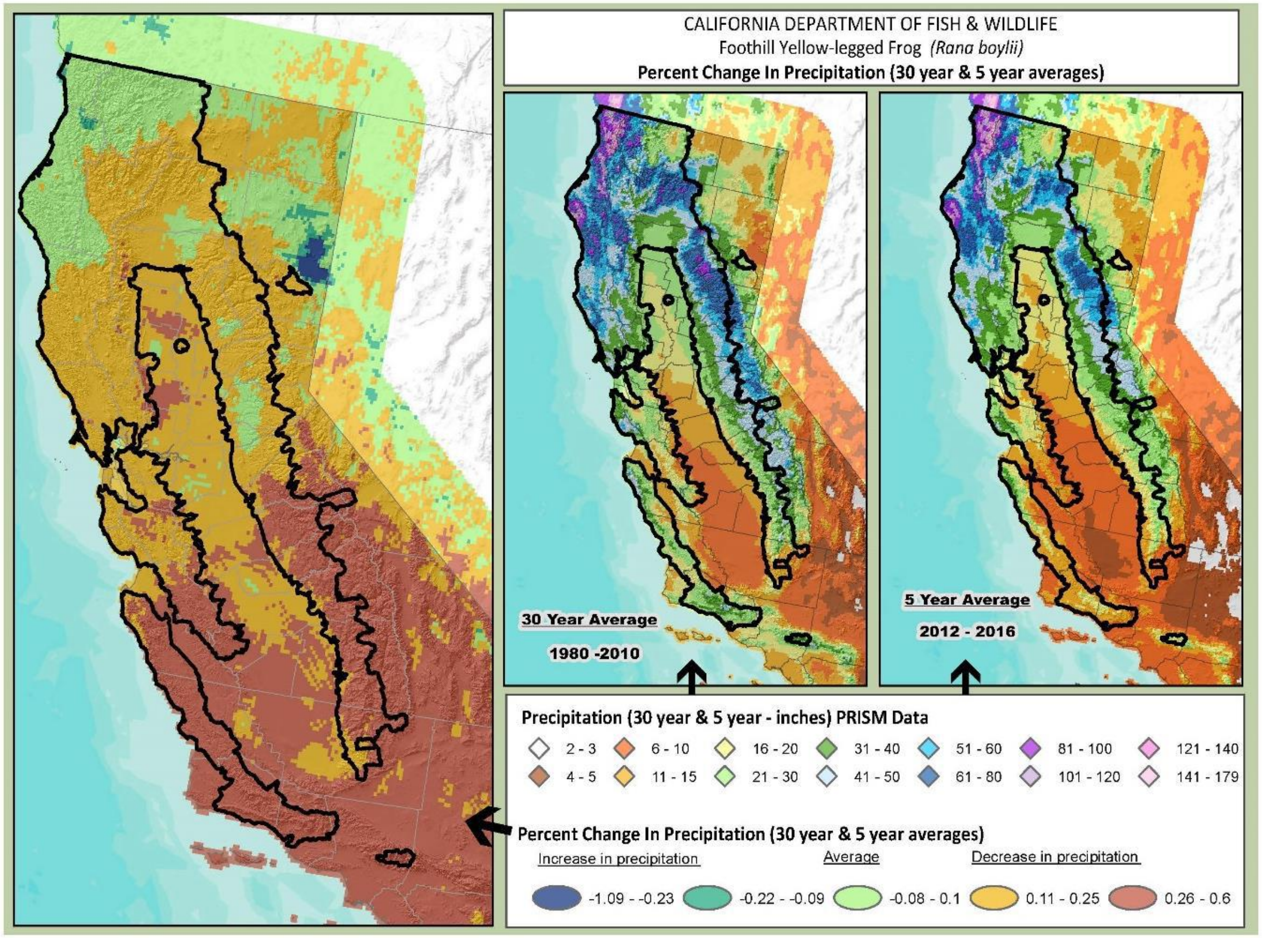


Figure 22. Change in precipitation from 30-year average and during the recent drought (PRISM)

Yellow-legged Frogs was observed perched on a rock above an isolated pool where a gartersnake was foraging on tadpoles during the summer; this close contact may reduce evaporative water loss when they are forced out of the water during high temperatures, but it can also increase disease transmission risk (Leidy et al. 2009.). Gonsolin (2010) also documented a late summer aggregation of juvenile Foothill Yellow-legged Frogs out of water during extremely high temperatures. In addition, drought-induced low flow, high water temperatures, and high densities of tadpoles were associated with outbreaks of malformation-inducing parasitic copepods (Kupferberg et al. 2009a).

Rapidly receding spring flows can result in stranding egg masses and tadpoles. However, this risk is likely less significant when it is drought-induced on an unregulated stream vs. a result of dam operations since Foothill Yellow-legged Frogs have evolved to initiate breeding earlier and shorten the breeding period in drought years (Kupferberg 1996a). If pools stay wet long enough to support metamorphosis, complete drying at the end of the season may benefit Foothill Yellow-legged Frogs if it eliminates introduced species like warm water fish and bullfrogs. Moyle (1973) noted that the only intermittent streams occupied by Foothill Yellow-legged Frogs in the Sierra Nevada foothills had no bullfrogs. At a long-term study site in upper Coyote Creek in 2015, Foothill Yellow-legged Frogs had persisted in reaches that had at least some summer water through the three preceding years of the most severe drought in over a millennium, albeit at much lower abundance than a decade before (Gonsolin 2010, Griffin and Anchokaitis 2014, J. Smith pers. comm. 2015). The population's abundance appeared to have never recovered from the 2007-2009 drought before the 2012-2016 drought began (J. Smith pers. comm. 2015). In 2016, after a relatively wet winter, Foothill Yellow-legged Frogs bred en masse, and only a single adult bullfrog was detected, an unusually low number for that area (CDWR 2016, J. Smith pers. comm. 2016). It appeared the population may rebound; however, in 2018, it experienced lethal chytridiomycosis outbreak, and like the Alameda Creek die-off probably resulted from crowding during drought, presence of bullfrogs as Bd-reservoirs and predators and competitors, and the stress associated with the combination of the two (Kupferberg and Catenazzi 2019).

Drought effects can also exacerbate other environmental stressors. During the most recent severe drought, tree mortality increased dramatically from 2014 to 2017 and reached approximately 129 million dead trees (OEHHA 2018). Multiple years of high temperatures and low precipitation left them weakened and more susceptible to pathogens and parasites (Ibid.). Vast areas of dead and dying trees are more prone to severe wildfires, and they lose their carbon sequestration function while also emitting methane, which is an extremely damaging greenhouse gas (CNRA 2016). Post-wildfire storms can result in erosion of fine sediments from denuded hillsides into the stream channel (Florsheim et al. 2017). If the storms are short duration and low precipitation, as happens during droughts, their magnitude may not be sufficient to transport the material downstream, resulting in a longer temporal loss or degradation of stream habitat (Ibid.). Reduced rainfall may also infiltrate the debris leading to subsurface flows rather than the surface water Foothill Yellow-legged Frogs require (Ibid.). Extended droughts increase risk of the stream being uninhabitable or inadequate for breeding for multiple years, which would result in population-level impacts and possible extirpation (Ibid.).

Wildland Fire and Fire Management

Fire is an important element for shaping and maintaining the species composition and integrity of many California ecosystems (Syphard et al. 2007, SBFFP 2018). Prior to European settlement, an estimated 1.8 to 4.9 million ha (4.5-12 million ac) burned annually (4-11% of total area of the state), ignited both deliberately by Native Americans and through lightning strikes (Keeley 2005, SBFFP 2018). The impacts of wildland fires on Foothill Yellow-legged Frogs are poorly understood and likely vary significantly across the species' range with differences in climate, vegetation, soils, stream-order, slope, frequency, and severity (Olson and Davis 2009). Mortality from direct scorching is unlikely because Foothill Yellow-legged Frogs are highly aquatic, and most wildfires occur during the dry period of the year when the frogs are most likely to be in or near the water (Pilliod et al. 2003, Bourque 2008). Field observations support this presumption; sightings of post-metamorphic Foothill Yellow-legged Frogs immediately after fires in the northern Sierra Nevada and North Coast indicate they are not very vulnerable to the direct effects of fire (S. Kupferberg and R. Peek pers. comm. 2018). Similarly, Foothill Yellow-legged Frogs were observed two months, and again one year, after a low- to moderate-intensity fire burned an area in the southern Sierra Nevada in 2002, and the populations were extant and breeding as recently as 2017 (Lind et al. 2003b, CNDDB 2019). While water may provide a refuge during the fire, it is also possible for temperatures during a fire, or afterward due to increased solar exposure, to near or exceed a threshold resulting lethal or sublethal harm; this would likely impact embryos and tadpoles with limited dispersal abilities (Pilliod et al. 2003).

Intense fires remove overstory canopy, which provides insulation from extreme heat and cold, and woody debris that increases habitat heterogeneity (Pilliod et al. 2003, Olson and Davis 2009). If this happens frequently enough, it can permanently change the landscape. For example, frequent high-severity burning of crown fire-adapted ecosystems can prevent forest regeneration since seeds require sufficient time between fires to mature, and repeated fires can deplete the seed bank (Stephens et al. 2014). Smoke and ash change water chemistry through increased nutrient and heavy metal inputs that can reach concentrations harmful to aquatic species during the fire and for days, weeks, or years after (Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Erosion rates on granitic soils, which make up a large portion of the Foothill Yellow-legged Frog's range, can be over 60 times greater in burned vs. unburned areas and can increase sedimentation for over 10 years (Megahan et al. 1995, Hayes et al. 2016). Post-fire nutrient inputs into streams could benefit Foothill Yellow-legged Frogs through increased productivity and more rapid growth and development (Pilliod et al. 2003). While the loss of leaf litter that accompanies fire alters the food web, insects are expected to recolonize rapidly, and the lack of cover could increase their vulnerability to predation by Foothill Yellow-legged Frogs (Ibid.).

Low-intensity fires likely have no adverse effect on Foothill Yellow-legged Frogs (Olson and Davis 2009). If they occur in areas with dense canopy, wildfires can improve habitat quality for Foothill Yellow-legged Frogs by reducing riparian cover, providing areas to bask, and increasing habitat heterogeneity, which is likely to outweigh any adverse effects from some fire-induced mortality (Russell et al. 1999, Olson and Davis 2009). In a preliminary analysis of threats to Foothill Yellow-legged Frogs in Oregon, proximity to stand-replacing fires was not associated with absence (Olson and Davis 2009).

Euro-American colonization of California significantly altered the pattern of periodic fires with which California's native flora and fauna evolved through fire exclusion, land use practices, and development (OEHHA 2018). Fire suppression can lead to canopy closure, which reduces habitat quality by limiting thermoregulatory opportunities (Olson and Davis 2009). In addition, fire suppression and its subsequent increase in fuel loads combined with expanding urbanization and rising temperatures have resulted in a greater likelihood of catastrophic stand-replacing fires that can significantly alter riparian systems for decades (Pilliod et al. 2003). Firebreaks, in which vegetation is cleared from a swath of land, can result in similar impacts to roads and road construction (Ibid.). Fire suppression can also include bulldozing within streams to create temporary reservoirs for pumping water, which can cause more damage than the fire itself to Foothill Yellow-legged Frogs in some cases (S. Kupferberg and R. Peek pers. comm. 2018). In addition, fire suppression practices can involve applying hundreds of tons of ammonia-based fire retardants and surfactant-based fire suppressant foams from air tankers and fire engines (Pilliod et al. 2003). Some of these chemicals are highly toxic to some anurans (Little and Calfee 2000).

Fire suppression has evolved into fire management with a greater understanding of its importance in ecosystem health (Keeley and Syphard 2016). Several strategies are employed including prescribed burns, mechanical fuels reduction, and allowing some fires to burn instead of necessarily extinguishing them (Pilliod et al. 2003). Like wildfires themselves, fire management strategies have the potential to benefit or harm Foothill Yellow-legged Frogs. Prescribed fires and mechanical fuels removal lessen the likelihood of catastrophic wildfires, but they can also result in loss of riparian vegetation, excessive sedimentation, and increased water temperatures (Ibid.). Salvage logging after a fire may result in similar impacts to timber harvest but with higher rates of erosion and sedimentation (Ibid.). A balanced approach to wildland fires is likely to have the greatest beneficial impact on species and ecosystem health (Stephens et al. 2012).

Floods and Landslides

As previously described, Foothill Yellow-legged Frog persistence is highly sensitive to early life stage mortality (Kupferberg et al. 2009c). While aseasonal dam releases are a major source of egg mass and tadpole scouring, storm-driven floods are also capable of it (Ashton et al. 1997). Van Wagner (1996) concluded that the high discharge associated with heavy rainfall could account for a significant source of mortality in post-metamorphic Foothill Yellow-legged Frogs as well as eggs and tadpoles; he observed two adult females and several juveniles swept downstream with fatal injuries post-flooding. Severe flooding, specifically two 500-year flood events in early 1969 in Evey Canyon (Los Angeles County), resulted in massive riparian habitat destruction (Sweet 1983). Prior to the floods, Foothill Yellow-legged Frogs were widespread and common, but only four subsequent sightings were documented between 1970 and 1974 and none since (Sweet 1983, Adams 2017b). Sweet (1983) speculates that because Foothill Yellow-legged Frogs overwinter in the streambed in that area, the floods may have reduced the population's abundance below an extinction threshold. Four other herpetologists interviewed about Foothill Yellow-legged Frog extirpations in southern California listed severe flooding as a likely cause (Adams et al. 2017b).

As mentioned above, landslides are a frequent consequence of post-fire rainstorms and can result in lasting impacts to stream morphology, water quality, and Foothill Yellow-legged Frog populations. On the other hand, Olson and Davis (2009) suggest that periodic landslides can have beneficial effects by transporting woody debris into the stream that can increase habitat complexity and by replacing sediments that are typically washed downstream over time. Whether a landslide is detrimental or beneficial is likely heavily influenced by amount of precipitation and the underlying system. As previously described, too little precipitation could lead to prolonged loss of habitat through failure to transport material downstream, and too much precipitation can result in large-scale habitat destruction and direct mortality.

Climate Change

Global climate change threatens biodiversity and may lead to increased frequency and severity of drought, wildfires, flooding, and landslides (Williams et al. 2008, Keely and Syphard 2016). Data show a consistent trend of warming temperatures in California and globally; 2014 was the warmest year on record, followed by 2015, 2017, and 2016 (OEHHA 2018). Climate model projections for annual temperature in California in the 21st century range from 1.5 to 4.5°C (2.7-8.1°F) greater than the 1961-1990 mean (Cayan et al. 2008). Precipitation change projections are less consistent than those for temperature, but recent studies indicate increasing variability in precipitation, and increasingly dry conditions in California resulting from increased evaporative water loss primarily due to rising temperatures (Cayan et al. 2005, Williams et al. 2015, OEHHA 2018). Precipitation variability and proportion of dry years were negatively associated with Foothill Yellow-legged Frog presence in a range-wide analysis (Lind 2005). In addition, low precipitation intensified the adverse effects of dams on the species (Ibid.).

California recently experienced the longest drought since the U.S. Drought Monitor began reporting in 2000 (NIDIS 2019). Until March 5, 2019, California experienced drought effects in at least a portion of the state for 376 consecutive weeks; the most intense period occurred during the week of October 28, 2014 when D4 (the most severe drought category) affected 58.4% of California's land area (Figure 23; NIDIS 2019). A recent modeling effort using data on historical droughts, including the Medieval megadrought between 1100 and 1300 CE, indicates the mean state of drought from 2050 to 2099 in California will likely exceed the Medieval-era drought, under both high and moderate greenhouse gas emissions models (Cook et al. 2015). The probability of a multidecadal (35 yr) drought occurring during the late 21st century is greater than 80% in all models used by Cook et al. (2015). If correct, this would represent a climatic shift that not only falls outside of contemporary variability in aridity but would also be unprecedented in the past millennium (Ibid.).

As a result of increasing temperatures, a decreasing proportion of precipitation falls as snow, resulting in more runoff from rainfall during the winter and a shallower snowpack that melts more rapidly (Stewart 2009). A combination of reduced seasonal snow accumulation and earlier streamflow timing significantly reduces surface water storage capacity and increases the risk for winter and spring floods, which may require additional and taller dams and result in alterations to hydroelectric power generation flow regimes (Cayan et al. 2005, Knowles et al. 2006, Stewart 2009). The reduction in snowmelt volume

is expected to impact the northern Sierra (Feather, Yuba, and American River watersheds) to a greater extent than the southern portion (Young et al. 2009). The earlier shift in peak snowmelt timing is predicted to exceed four to six weeks across the entire Sierra Nevada depending on the amount of warming that occurs this century (Ibid.). In addition, the snow water equivalent is predicted to significantly decline by 2070-2099 over the 1961-1990 average in the Trinity, Sacramento, and San Joaquin drainages from -32% to -79%, and effectively no snow is expected to fall below 1000 m (3280 ft) in the high emissions/sensitive model (Cayan et al. 2008).

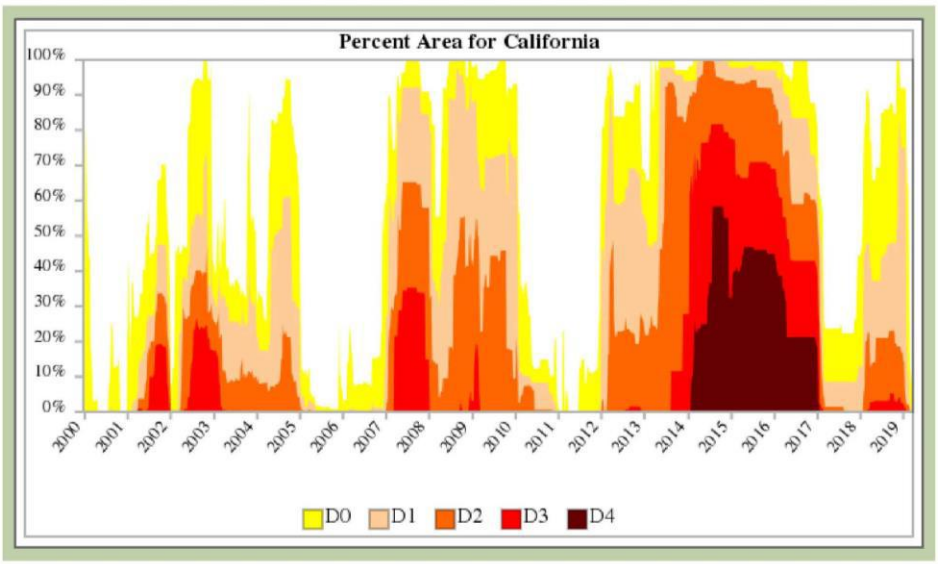


Figure 23. Palmer Hydrological Drought Indices 2000-present (NIDIS)

The earlier shift of snowmelt and lower water content will result in lower summer flows, which will intensify the competition for water among residential, agricultural, industrial, and environmental needs (Field et al. 1999, Cook et al. 2015). In unregulated systems, as long as water is present through late summer, an earlier hydrograph recession that triggers Foothill Yellow-legged Frog breeding could result in a longer time to grow larger prior to metamorphosis, which improves probability of survival (Yarnell et al. 2010, Kupferberg 2011b). However, if duration from peak to base flow shortens, it can result in increased sedimentation and reduced habitat complexity in addition to stranding (Yarnell et al. 2010).

Fire frequency relates to temperature, fuel loads, and fuel moisture (CCSP 2008). Therefore, increasing periods of drought combined with extreme heat and low humidity that stress or kill trees and other vegetation create ideal conditions for wildland fires (Ibid). Not surprisingly, the area burned by wildland fires over the western U.S. increased since 1950 but rose rapidly in the mid-1980s (Westerling et al. 2006, OEHHA 2018). As temperatures warmed and snow melted earlier, large-wildfire frequency and duration increased, and wildfire seasons lengthened (Westerling et al. 2006, OEHHA 2018).

In California, latitude inversely correlates with temperature and annual area burned, but the climate-fire relationship is substantially different across the state, and future wildfire regimes are difficult to predict (Keeley and Syphard 2016). For example, the relationship between spring and summer temperature and area burned in the Sierra Nevada is highly significant but not in southern California (Ibid.). Climate has a greater influence on fire regimes in mesic than arid environments, and the most influential climatological factor (e.g., precipitation, temperature, season, or their interactions) shifts over time (Ibid.). Nine of the 10 largest fires in California since 1932 have occurred in the past 20 years, 4 within the past 2 years (Figure 24; CAL FIRE 2019). However, it is possible this trend will not continue; climate- and wildfire-induced changes in vegetation could reduce wildfire severity in the future (Parks et al. 2016).

Wildfires themselves can accelerate the effects of climate change. Wildfires emit short-lived climate pollutants like black carbon (soot) and methane that are tens to thousands of times greater than carbon dioxide (the main focus of greenhouse gas reduction) in terms of warming effect and are responsible for 40% or more of global warming to date (CNRA 2016). Healthy forests can sequester large amounts of carbon from the atmosphere, but recently carbon emissions from wildfires have exceeded their uptake by vegetation in California (Ackerly et al. 2018).

With increased variability and changes in precipitation type, magnitude, and timing comes more variable and extreme stream flows (Mallakpour et al. 2018). Models for stream flow in California project higher high flows, lower low flows, wetter rainy seasons, and drier dry seasons (Ibid.). The projected water cycle extremes are related to strengthening El Niño and La Niña events, and both severe flooding and intense drought are predicted to increase by at least 50% by the end of the century (Yoon et al. 2015). These changes increase the likelihood of Foothill Yellow-legged Frog egg mass and tadpole scouring and stranding, even in unregulated rivers.

A species' vulnerability to climate change is a function of its sensitivity to climate change effects, its exposure to them, and its ability to adapt its behaviors to survive with them (Dawson et al. 2011). Myriad examples exist of species shifting their geographical distribution toward the poles and to higher elevations and changing their growth and reproduction with increases in temperature over time (Parmesan and Yohe 2003). However, in many places, fragmentation of suitable habitat by anthropogenic barriers (e.g., urbanization, agriculture, and reservoirs) limits a species' ability to shift its range (Pounds et al. 2007). The proportion of sites historically occupied by Foothill Yellow-legged Frogs that are now extirpated increases significantly on a north-to-south latitudinal gradient and at drier sites within California, suggesting climate change may contribute to the spatial pattern of the species' declines (Davidson et al. 2002).

An analysis of the climate change sensitivity of 195 species of plants and animals in northwestern North America revealed that, as a group, amphibians and reptiles were estimated to be the most sensitive (Case et al. 2015). Nevertheless, examples exist of amphibians adjusting their breeding behaviors (e.g., calling and migrating to breeding sites) to occur earlier in the year as global warming increases (Beebee 1995, Gibbs and Breisch 2001). Because of the rapid change in temperature, Beebee (1995) posits these are examples of behavioral and physiological plasticity rather than natural selection. However, for

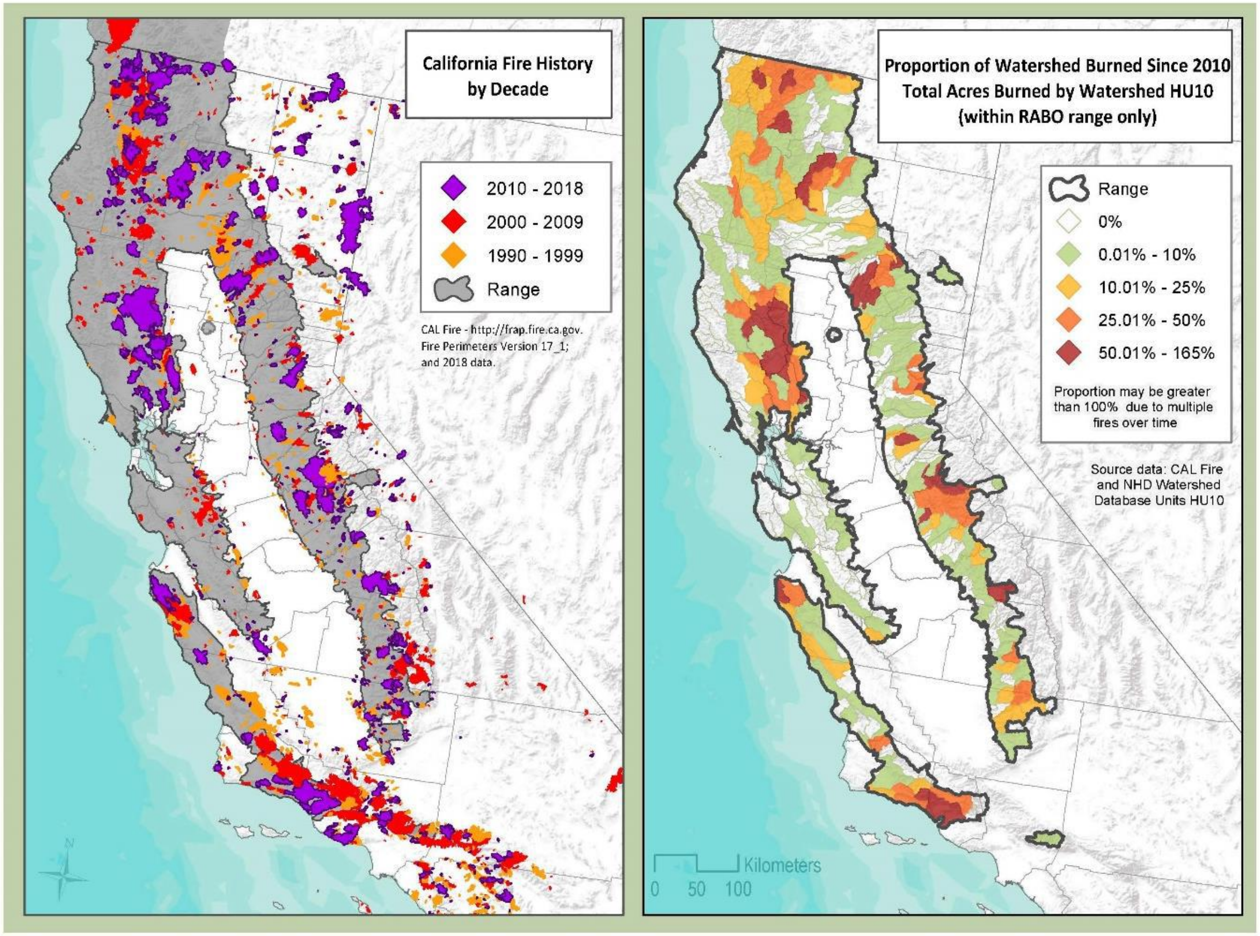


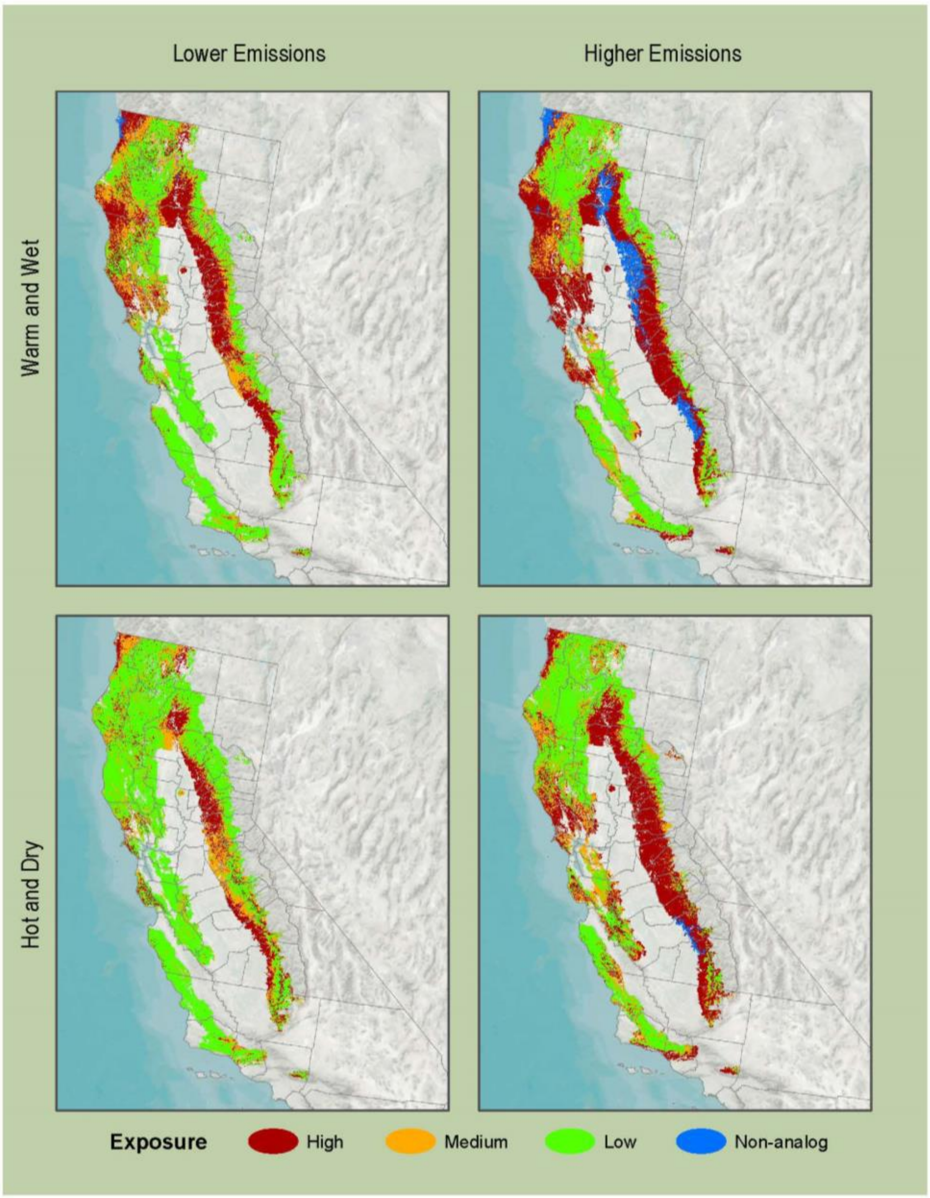
Figure 24. Fire history (1990-2018) and proportion of watershed burned (2010-2018) in California (CAL FIRE, NHD)

species with short generation times or in areas less affected by climate change, populations may be able to undergo evolutionary adaptation to the changing local environmental conditions (Hoffman and Sgrò 2011).

As previously described in the Seasonal Activity and Movements section, Foothill Yellow-legged Frog breeding is closely tied to water temperature, flow, and stage, and the species already adjusts its timing of oviposition by as much as a month in the same location during different water years, so the species may have enough inherent flexibility to reduce their vulnerability. The species appears fairly resilient to drought, fire, and flooding, at least in some circumstances. For example, after the 2012-2016 drought, the Loma Fire in late 2016, and severe winter flooding and landslides in 2016 and 2017, Foothill Yellow-legged Frog adults and metamorphs, as well as aquatic insects and rainbow trout, were abundant throughout Upper Llagas Creek in fall of 2017, and the substrate consisted of generally clean gravels and cobbles with only a slight silt coating in some pools (J. Smith pers. comm. 2017). The frogs and fish likely took refuge in a spring-fed pool, and the heavy rains scoured the fine sediments that eroded downstream (Ibid.). These refugia from the effects of climate change reduce the species' exposure, thereby reducing their vulnerability (Case et al. 2015).

Climate change models that evaluate the Foothill Yellow-legged Frog's susceptibility from a species and habitat perspective yield mixed results. An investigation into the possible effects of climate on California's native amphibians and reptiles used ecological niche models, future climate scenarios, and general circulation models to predict species-specific climatic suitability in 2050 (Wright et al. 2013). The results suggested approximately 90-100% of localities currently occupied by Foothill Yellow-legged Frogs are expected to remain climatically suitable in that time, and the proportion of currently suitable localities predicted to change ranges from -20% to 20% (Ibid.). However, a second study using a subset of these models found that 66.4% of currently occupied cells will experience reduced environmental suitability in 2050 (Warren et al. 2014). This analysis included 90 species of native California mammals, birds, reptiles, and amphibians. For context, over half of the taxa were predicted to experience > 80% reductions, a consistent pattern reflected across taxonomic groups (Ibid.).

A third analysis investigated the long-term risk of climate change by modeling the relative environmental stress a vegetative community would undergo in 2099 given different climate and greenhouse gas emission scenarios (Thorne et al. 2016). This model does not incorporate any Foothill Yellow-legged Frog-specific data; it strictly projects climatic stress levels vegetative communities will experience within the species' range boundaries (Ibid.). Unsurprisingly, higher emissions scenarios resulted in a greater proportion of habitat undergoing climatic stress (Figure 25). Perhaps counterintuitively, the warm and wet scenario resulted in a greater amount of stress than the hot and dry scenario. When high emissions and warm and wet changes are combined, a much greater proportion of the vegetation communities will experience "non-analog" conditions, those outside of the range of conditions currently known in California (Ibid.).



Source - model extracts from -Thorne, J.H. et al. (2016) A climate change vulnerability assessment of California's terrestrial vegetation. CDFW.

Figure 25. Vegetative community exposure to climate change in 2099 based on Thorne et al. (2016).

Habitat Restoration and Species Surveys

Potential conflicts between managing riverine habitat below dams for both cold-water adapted salmonids and Foothill Yellow-legged Frogs was discussed previously. In addition to problems with temperatures and pulse flows, some stream restoration projects aimed at physically creating or improving salmonid habitat can also adversely affect the species. For example, boulder deflectors were placed in Hurdygurdy Creek (Del Norte County) to create juvenile steelhead rearing habitat; deflectors change broad, shallow, low-velocity reaches into narrower, deeper, faster reaches preferred by the fish (Fuller and Lind 1992). Foothill Yellow-legged Frogs were documented using the restoration reach as breeding habitat annually prior to placement of the boulders, but no breeding was detected in the following three years, suggesting this project eliminated the conditions the frogs require (Ibid.). In addition, a fish ladder to facilitate salmonid migration above the Alameda Creek Diversion Dam was recently constructed on a Foothill Yellow-legged Frog lek site, and the frogs may become trapped in the ladder (M. Grefsrud pers. comm. 2019). Use of rotenone to eradicate non-native fish as part of a habitat restoration project is rare, but if it is applied in streams occupied by Foothill Yellow-legged Frogs, it can kill tadpoles but is unlikely to impact post-metamorphic frogs (Fontenot et al. 1994). Metamorphosing tadpoles may be able to stay close enough to the surface to breathe air and survive but may display lethargy and experience increased susceptibility to predation (Ibid.).

Commonly when riparian vegetation is removed, regulatory agencies require a greater amount to be planted as mitigation to offset the temporal loss of habitat. This practice can have adverse impacts on Foothill Yellow-legged Frogs by reducing habitat suitability. Foothill Yellow-legged Frogs have been observed moving into areas where trees were recently removed, and they are known to avoid heavily shaded areas (Welsh and Hodgson 2011, M. Grefsrud pers. comm. 2019).

Biologists conducting surveys in Foothill Yellow-legged Frog habitat can trample egg masses or larvae if they are not careful. One method for sampling fish is electroshocking, which runs a current through the water that stuns the fish temporarily allowing them to be captured. Post-metamorphic frogs are unlikely to be killed by electroshocking; however, at high frequencies (60 Hz), they may experience some difficulty with muscle coordination for a few days (Allen and Riley 2012). This could increase their risk of predation. At 30 Hz, there were no differences between frogs that were shocked and controls (Ibid.). Tadpoles are more similar to fish in tail muscle and spinal structure and are at higher risk of injuries; however, researchers who reported observing stunned tadpoles noted they appeared to recover completely within several seconds (Ibid.). Adverse effects to Foothill Yellow-legged Frogs from electrofishing may only happen at frequencies higher than those typically used for fish sampling (Ibid.)

Small Population Sizes

Small populations are at greater risk of extirpation, primarily through the disproportionately greater impact of demographic, environmental, and genetic stochasticity on them compared to large populations, so any of the threats previously discussed will likely have an even greater adverse impact on small populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). This risk of extinction from genetic stochasticity is amplified when connectivity between the small populations, and thus gene flow,

is impeded (Fahrig and Merriam 1985, Taylor et al. 1993, Lande and Shannon 1996, Palstra and Ruzzante 2008). Genetic diversity provides capacity to evolve in response to environmental changes, and the "rescue effect" of gene flow is important in minimizing probability of local extinction (Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). However, the rescue effect is diminished in conditions of high local environmental stochasticity of recruitment or survival (Eriksson et al. 2014). In addition, populations living near their physiological limits and lacking adaptive capacity may not be able to evolve in response to rapid changes (Hoffmann and Sgrò 2011). Furthermore, while pathogens or parasites rarely result in host extinction, they can increase its likelihood in small populations by driving the host populations below a critically low threshold beneath which demographic stochasticity can lead to extinction, even if they possess the requisite genetic diversity to adapt to a changed environment (Gomulkiewicz and Holt 1995, Adams et al. 2017b).

A Foothill Yellow-legged Frog PVA revealed that, even with no dam effects considered (e.g., slower growth and increased egg and tadpole mortality), populations with the starting average density of adult females in regulated rivers (4.6/km [2.9/mi]) were four times more likely to go extinct within 30 years than those with the starting average density of adult females from unregulated rivers (32/km [120/mi]) (Kupferberg et al. 2009c). When the density of females in sparse populations was used (2.1/km [1.3/mi], the 30-year risk of extinction increased 13-fold (Ibid.). With dam effects, a number of the risk factors above contribute to the additional probability of local extinction such as living near their lower thermal tolerance and reduced recruitment and survival from scouring and stranding flows, poor food quality, and increased predation and competition (Kupferberg 1997a; Hoffmann and Sgrò 2011; Kupferberg et al. 2011a,b; Kupferberg et al. 2012; Eriksson et al. 2014). These factors act synergistically, contributing in part to the small size, high divergence, and low genetic diversity exhibited by many Foothill Yellow-legged Frog populations located in highly regulated watersheds (Kupferberg et al. 2012, Peek 2018).

EXISTING MANAGEMENT

Land Ownership within the California Range

Using the Department's Foothill Yellow-legged Frog range boundary and the California Protected Areas Database (CPAD), a GIS dataset of lands that are owned in fee title and protected for open space purposes by over 1,000 public agencies or non-profit organizations, the total area of the species' range in California comprises 13,620,447 ha (33,656,857 ac) (CPAD 2019, CWHR 2019). Approximately 37% is owned by federal agencies, 80% of which (4,071,178 ha [10,060,100 ac]) is managed by the Forest Service (Figure 26). Department of Fish and Wildlife-managed lands, State Parks, and other State agency-managed lands constitute around 2.6% of the range. The remainder of the range includes < 1% Tribal lands, 2.3% other conserved lands (e.g., local and regional parks), and 57% private and government-managed lands that are not protected for open space purposes. It is important to note that even if included in the CPAD, a property's management does not necessarily benefit Foothill Yellow-legged Frogs, but in some cases changes in management to conserve the species may be easier to undertake than on private lands or public lands not classified as conserved.

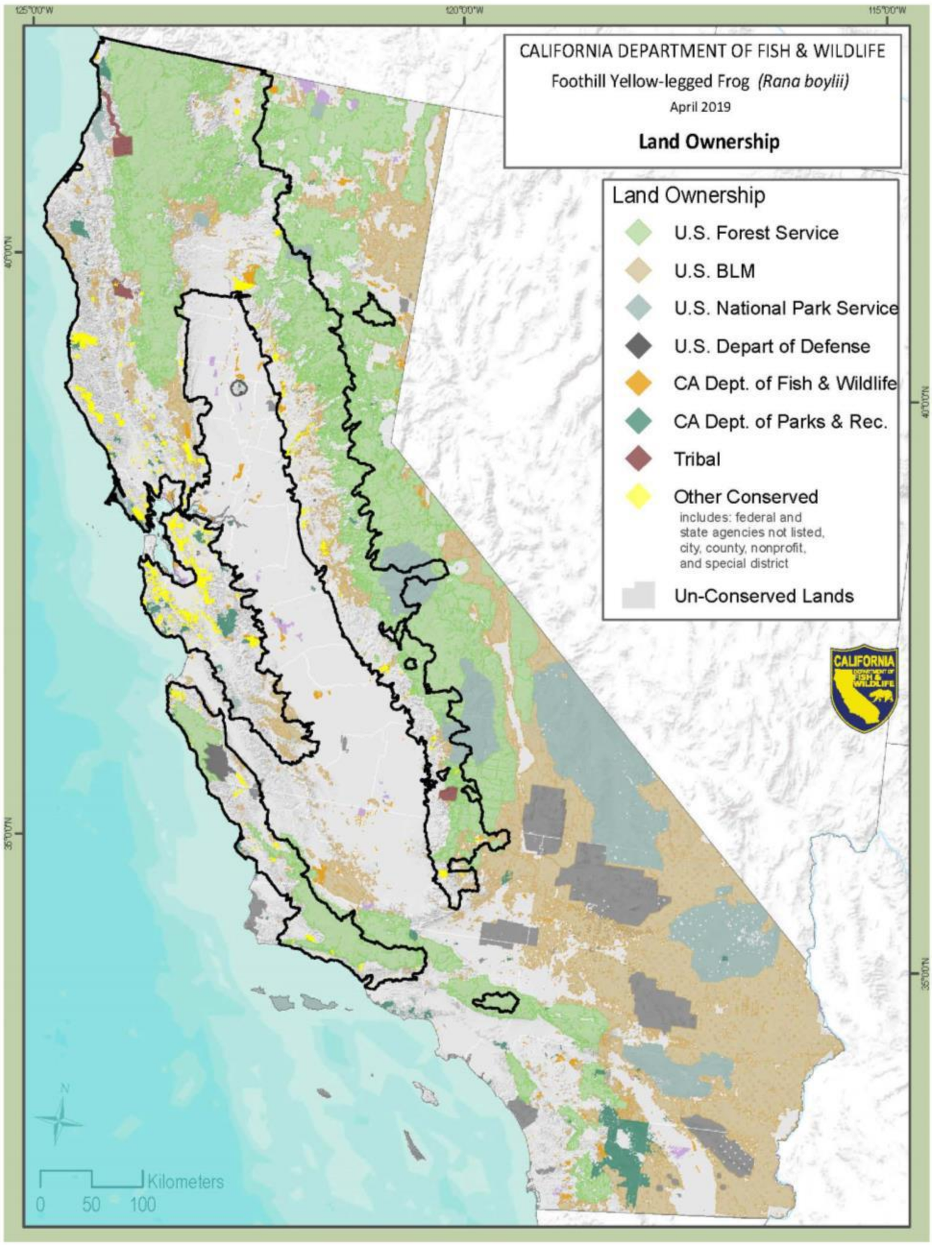


Figure 26. Conserved, Tribal, and other lands (BLM, CMD, CPAD, CWHR, DOD)

Statewide Laws

The laws and regulations governing land management within the Foothill Yellow-legged Frog's range vary by ownership. Several state and federal environmental laws apply to activities undertaken in California that may provide some level of protection for Foothill Yellow-legged Frogs and their habitat. The following is not an exhaustive list.

National Environmental Policy Act and California Environmental Quality Act

Most federal land management actions must undergo National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. § 4321, et seq.) analysis. NEPA requires federal agencies to document, consider alternatives, and disclose to the public the impacts of major federal actions and decisions that may significantly impact the environment. As a BLM and Forest Service Sensitive Species, impacts to Foothill Yellow-legged Legged Frogs are considered during NEPA analysis; however, the law has no requirement to minimize or mitigate adverse effects.

The California Environmental Quality Act (CEQA) is similar to NEPA; it requires state and local agencies to identify, analyze, and consider alternatives, and to publicly disclose environmental impacts from projects over which they have discretionary authority (Pub. Resources Code § 21000 et seq.). CEQA differs substantially from NEPA in requiring mitigation for significant adverse effects to a less than significant level unless overriding considerations are documented. CEQA requires an agency find projects may have a significant effect on the environment if they have the potential to substantially reduce the habitat, decrease the number, or restrict the range of any rare, threatened, or endangered species (Cal. Code Regs., tit. 14, §§ 15065(a)(1), 15380.). CEQA establishes a duty for public agencies to avoid or minimize such significant effects where feasible (Cal. Code regs., tit. 14, § 15021). Impacts to Foothill Yellow-legged Frogs, as an SSC, should be identified, evaluated, disclosed, and mitigated or justified under the Biological Resources section of an environmental document prepared pursuant to CEQA. However, a lead agency is not required to make a mandatory finding of significance conclusion unless it determines on a project-specific basis that the species meets the CEQA criteria for rare, threatened, or endangered.

Clean Water Act and Porter-Cologne Water Quality Control Act

The Clean Water Act originated in 1948 as the Federal Water Pollution Control Act of 1948. It was heavily amended in 1972 and became known as the Clean Water Act (CWA). The purpose of the CWA was to establish regulations for the discharge of pollutants into waters of the United States and establish quality standards for surface waters. Section 404 of the CWA forbids the discharge of dredged or fill material into waters and wetlands without a permit from the ACOE. The CWA also requires an alternatives analysis, and the ACOE is directed to issue their permit for the least environmentally damaging practicable alternative. The definition of waters of the United States has changed substantially over time based on Supreme Court decisions and agency rule changes.

The Porter-Cologne Water Quality Act was established by the State in 1969 and is similar to the CWA in that it establishes water quality standards and regulates discharge of pollutants into state waters, but it

also administers water rights which regulate water diversions and extractions. The SWRCB and nine Regional Water Boards share responsibility for implementation and enforcement of Porter-Cologne as well as the CWA's National Pollutant Discharge Elimination System permitting.

Federal and California Wild and Scenic Rivers Acts

In 1968, the U.S. Congress passed the federal Wild and Scenic Rivers Act (WSRA) (16 U.S.C. § 1271, et seq.) which created the National Wild and Scenic River System. The WSRA requires the federal government to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The WSRA prohibits the federal government from building, licensing, funding or otherwise aiding in the building of dams or other project works on rivers or segments of designated rivers. The WSRA does not give the federal government control of private property including development along protected rivers.

California's Wild and Scenic Rivers Act was enacted in 1972 so rivers that "possess extraordinary scenic, recreational, fishery, or wildlife values shall be preserved in their free-flowing state, together with their immediate environments, for the benefit and enjoyment of the people of the state." (Pub. Res. Code, § 5093.50). Designated waterways are codified in Public Resources Code sections 5093.50-5093.70. In 1981, most of California's designated Wild and Scenic Rivers were adopted into the federal system. Currently in California, 3,218 km (1,999.6 mi) of 23 rivers are protected by the WSRA, most of which are located in the northwest. Foothill Yellow-legged Frogs have been observed in 11 of the 17 designated rivers within their range (CNDDB 2019).

Lake and Streambed Alteration Agreements

Fish and Game Code Section 1602 requires entities to notify the Department of activities that "divert or obstruct the natural flow of, or substantially change or use any material from the bed, channel, or bank of any river, stream, or lake, or deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake." If the activity may substantially adversely affect an existing fish and wildlife resource, the Department may enter into a lake or streambed alteration agreement with the entity that includes reasonable measures necessary to protect the fish or wildlife resource (Fish & G. Code, §1602, subd. (a)(4)(B)). A lake or stream alteration agreement does not authorize take of species listed as candidates, threatened, or endangered under CESA (see Protection Afforded by Listing for CESA compliance requirements).

Medicinal and Adult-Use Cannabis Regulation and Safety Act

The commercial cannabis cultivation industry is unique in that any entity applying for an annual cannabis cultivation license from California Department of Food and Agriculture (CDFA) must include "a copy of any final lake or streambed alteration agreement…or written verification from the California Department of Fish and Wildlife that a lake or streambed alteration agreement is not required" with their license application (Cal. Code Regs., tit. 3, § 8102, subd. (v)). The SWRCB also enforces the laws related to waste discharge and water diversions associated with cannabis cultivation (Cal. Code Regs., tit. 3, § 8102, subd. (p)).

Forest Practice Act

The Forest Practice Act was originally enacted in 1973 to ensure that logging in California is undertaken in a manner that will also preserve and protect the State's fish, wildlife, forests, and streams. This law and the regulations adopted by the California Board of Forestry and Fire Protection (BOF) pursuant to it are collectively referred to as the Forest Practice Rules. The Forest Practice Rules implement the provisions of the Forest Practice Act in a manner consistent with other laws, including CEQA, Porter-Cologne, CESA, and the Timberland Productivity Act of 1982. The California Department of Forestry and Fire Protection (CAL FIRE) enforces these laws and regulations governing logging on private land.

Federal Power Act

The Federal Power Act and its major amendments are implemented and enforced by FERC and require licenses for dams operated to generate hydroelectric power. One of the major amendments required that these licenses "shall include conditions for the protection, mitigation and enhancement of fish and wildlife including related spawning grounds and habitat" (ECPA 1986). Hydropower licenses granted by FERC are usually valid for 30-50 years. If a licensee wants to renew their license, it must file a Notice of Intent and a pre-application document five years before the license expires to provide time for public scoping, any potentially new studies necessary to analyze project impacts and alternatives, and preparation of environmental documents. The applicant must officially apply for the new license at least two years before the current license expires.

As a federal agency, FERC must comply with federal environmental laws prior to issuing a new license or relicensing an existing hydropower project, which includes NEPA and ESA. As a result of environmental compliance or settlement agreements formed during the relicensing process, some operations have been modified and habitat restored to protect fish and wildlife. For example, the Lewiston Dam relicensing resulted in establishment of the Trinity River Restoration Program, which takes an ecosystem-approach to studying dam effects and protecting and restoring fish and wildlife populations downstream of the dam (Snover and Adams 2016). Similarly, relicensing of the Rock Creek-Cresta Project on the North Fork Feather River resulted in establishment of a multi-stakeholder Ecological Resources Committee (ERC). As a result of the ERC's studies and recommendations, pulse flows for whitewater boating were suspended for several years following declines of Foothill Yellow-legged Frogs, and the ERC is currently working toward augmenting the population in an attempt to increase abundance to a viable level.

Administrative and Regional Plans

Forest Plans

NORTHWEST FOREST PLAN

In 1994, BLM and the Forest Service adopted the Northwest Forest Plan to guide the management of over 97,000 km^2 (37,500 mi^2) of federal lands in portions of northwestern California, Oregon, and Washington. The Northwest Forest Plan created an extensive network of forest reserves including

Riparian Reserves. Riparian Reserves apply to all land designations to protect riparian dependent resources. With the exception of silvicultural activities consistent with Aquatic Conservation Strategy objectives, timber harvest is not permitted within Riparian Reserves, which can vary in width from 30 to 91 m (100-300 ft) on either side of streams, depending on the classification of the stream or waterbody (USFS and BLM 1994). Fuel treatment and fire suppression strategies and practices implemented within these areas are designed to minimize disturbance.

SIERRA NEVADA FOREST PLAN

Land and Resource Management Plans for forests in the Sierra Nevada were changed in 2001 by the Sierra Nevada Forest Plan Amendment and subsequently adjusted via a supplemental Environmental Impact Statement and Record of Decision in 2004, referred to as the Sierra Nevada Framework (USFS 2004). This established an Aquatic Management Strategy with Goals including maintenance and restoration of habitat to support viable populations of riparian-dependent species; spatial and temporal connectivity for aquatic and riparian species within and between watersheds to provide physically, chemically, and biologically unobstructed movement for their survival, migration, and reproduction; instream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats; the physical structure and condition of streambanks and shorelines to minimize erosion and sustain desired habitat diversity; and prevention of new introductions of invasive species and reduction of invasive species impacts that adversely affect the viability of native species. The Sierra Nevada Framework also includes Riparian Conservation Objectives and associated standards and guidelines specific to aquatic-dependent species, including the Foothill Yellow-legged Frog.

Resource Management Plans

Sequoia, Kings Canyon, and Yosemite National Parks fall within the historical range of the Foothill Yellow-legged Frog, but the species has been extirpated from these areas. The guiding principles for managing biological resources on National Park Service lands include maintenance of animal populations native to park ecosystems (Hayes et al. 2016). They also commit the agency to work with other land managers on regional scientific and planning efforts and maintenance or reintroduction of native species to the parks including conserving Foothill Yellow-legged Frogs in the Sierra Nevada (USDI NPS 1999 as cited in Hayes et al. 2016). A Sequoia and Kings Canyon National Parks Resource Management Plan does not include specific management goals for Foothill Yellow-legged Frogs, but it does include a discussion of the factors leading to the species' decline and measures to restore the integrity of aquatic ecosystems (Ibid.). The Yosemite National Park Resource Management Plan includes a goal of restoring Foothill Yellow-legged Frogs to the Upper Tuolumne River below Hetch Hetchy Reservoir (USDI NPS 2003 as cited in Hayes et al. 2016).

FERC Licenses

Dozens of hydropower dams have been relicensed in California since 1999, and several are in the process of relicensing (FERC 2019). In addition to following the Federal Power Act and other applicable federal laws, Porter-Cologne Water Quality Act requires non-federal dam operators to obtain a Water Quality Certification (WQC) from the SWRCB. Before it can issue the WQC, the SWRCB must consult with

the Department regarding the needs of fish and wildlife. Consequently, SWRCB includes conditions in the WQC that seek to minimize adverse effects to native species, and Foothill Yellow-legged Frogs have received some special considerations due to their sensitivity to dam operations during these licensing processes. As discussed above, the typical outcome is formation of an ERC-type group to implement the environmental compliance requirements and recommend changes to flow management to reduce impacts. Foothill Yellow-legged Frog-specific requirements fall into three general categories: data collection, modified flow regimes, and standard best management practices.

Data Collection

When little is known about the impacts of different flows and temperatures on Foothill Yellow-legged Frog occupancy and breeding success, data are collected and analyzed to inform recommendations for future modifications to operations such as temperature trigger thresholds. These surveys include locating egg masses and tadpoles, monitoring temperatures and flows, and recording their fate (e.g., successful development and metamorphosis, displacement, desiccation) during different flow operations and different water years. Examples of licenses with these conditions include the Lassen Lodge Project (FERC 2018), Rock Creek-Cresta Project (FERC 2009a), and El Dorado Project (EID 2007).

Modified Flow Regimes

When enough data exist to understand the effect of different operations on Foothill Yellow-legged Frog occupancy and success, license conditions may include required minimum seasonal instream flows, specific thermal regimes, gradual ramping rates to reduce the likelihood of early life stage scour or stranding, or freshet releases (winter/spring flooding simulation) to maintain riparian processes, and cancellation or prohibition of recreational pulse flows during the breeding season. Examples of licenses with these conditions include the Poe Hydroelectric Project (SWRCB 2017), Upper American Project (FERC 2014), and Pit 3, 4, 5 Project (FERC 2007b).

Best Management Practices

Efforts to reduce the impacts from maintenance activities and indirect operations include selective herbicide and pesticide application, aquatic invasive species monitoring and control, erosion control, and riparian buffers. Examples of licenses with these conditions include the South Feather Project (SWRCB 2018), Spring Gap-Stanislaus Project (FERC 2009b), and Chili Bar Project (FERC 2007a).

Habitat Conservation Plans and Natural Community Conservation Plans

Non-federal entities can obtain authorization for take of federally threatened and endangered species incidental to otherwise lawful activities through development and implementation of a Habitat Conservation Plan (HCP) pursuant to Section 10 of the ESA. The take authorization can extend to species not currently listed under ESA but which may become listed as threatened or endangered over the term of the HCP, which is often 25-75 years. California's companion law, the Natural Community Conservation Planning Act of 1991, takes a broader approach than either CESA or ESA. A Natural Community Conservation Plan (NCCP) identifies and provides for the protection of plants, animals, and their

habitats, while allowing compatible and appropriate economic activity. There are currently four HCPs that include Foothill Yellow-legged Frogs as a covered species, two of which are also NCCPs.

Humboldt Redwood (formerly Pacific Lumber) Company

The Humboldt Redwood Company (HRC) HCP covers 85,672 ha (211,700 ac) of private Coast Redwood and Douglas-fir forest in Humboldt County (HRC 2015). It is a 50-year HCP/incidental take permit (ITP) that was executed in 1999, revised in 2015 as part of its adaptive management strategy, and expires on March 1, 2049. The HCP includes an Amphibian and Reptile Conservation Plan and an Aquatics Conservation Plan with measures designed to sustain viable populations of Foothill Yellow-legged Frogs and other covered aquatic herpetofauna. These conservation measures include prohibiting or limiting tree harvest within Riparian Management Zones (RMZ), controlling sediment by maintaining roads and hillsides, restricting controlled burns to spring and fall in areas outside of the RMZ, conducting effectiveness monitoring throughout the life of the HCP, and use the data collected to adapt monitoring and management plans accordingly.

Watershed assessment surveys include observations of Foothill Yellow-legged Frogs and have documented their widespread distribution on HRC lands with a pattern of fewer near the coast in the fog belt and more inland (S. Chinnici pers. comm. 2017). The watersheds within the property are largely unaffected by dam-altered flow regimes or non-native species, so aside from the operations described under Timber Harvest above that are minimized to the extent feasible, the focus on suitable temperatures and denser canopy cover for salmonids may reduce habitat suitability for Foothill Yellow-legged Frogs over time (Ibid.).

San Joaquin County Multi-Species Habitat Conservation and Open Space Plan

The San Joaquin County Multi-Species Habitat Conservation and Open Space Plan (SJMSCP) is a 50-year HCP/ITP that was signed by the USFWS on November 14, 2000 (San Joaquin County 2000). The SJMSCP covers almost all of San Joaquin County except federal lands, a few select projects, and some properties with certain land uses, roughly 364,000 ha (900,000 ac). At the time of execution, approximately 70 ha (172 ac) of habitat within the SJMSCP area in the southwest portion of the county were considered occupied by Foothill Yellow-legged Frogs with another 1,815 ha (4,484 ac) classified as potential habitat, but it appears the species had been considered extirpated before then (Jennings and Hayes 1994, San Joaquin County 2000, Lind 2005). The HCP estimates around 8% of the combined modeled habitat would be converted to other uses over the permit term, but the establishment of riparian preserves with buffers around Corral Hollow Creek, where the species occurred historically, was expected to offset those impacts (San Joaquin County 2000, SJCOG 2018). However, the HCP did not require surveys to determine if Foothill Yellow-legged Frogs are benefiting (M. Grefsrud pers. comm. 2019).

East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan

The East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan (ECCC HCP/NCCP) is a multi-jurisdictional 30-year plan adopted in 2007 that covers over 70,423 ha (174,018 ac) in eastern Contra Costa County (Jones & Stokes 2006). The Foothill Yellow-legged Frog appears to be

extirpated from the ECCC HCP/NCCP area (CNDDB 2019). Nevertheless, suitable habitat was mapped, and impacts were estimated at well under 1% of both breeding and migratory habitat (Jones & Stokes 2006). One of the HCP/NCCP's objectives is acquiring high-quality Foothill Yellow-legged Frog habitat that has been identified along Marsh Creek (Ibid.). In 2017, the Viera North Peak 65 ha (160 ac) property was acquired that possesses suitable habitat for Foothill Yellow-legged Frogs (ECCCHC 2018).

SANTA CLARA VALLEY HABITAT PLAN

The Santa Clara Valley Habitat Plan (SCVHP) is a 50-year HCP/NCCP covering over 210,237 ha (519,506 ac) in Santa Clara County (ICF 2012). As previously mentioned, Foothill Yellow-legged Frogs appear to have been extirpated from lower elevation sites, particularly below reservoirs in this area. Approximately 17% of modeled Foothill Yellow-legged Frog habitat, measured linearly along streams, was already permanently preserved, and the SCVHP seeks to increase that to 32%. The maximum allowable habitat loss is 11 km (7 mi) permanent loss and 3 km (2 mi) temporary loss, while 167 km (104 mi) of modeled habitat is slated for protection. By mid-2018, 8% of impact area had been accrued and 3% of habitat protected (SCVHA 2019).

GREEN DIAMOND AQUATIC HABITAT CONSERVATION PLAN

Green Diamond Resources Company has an Aquatic Habitat Conservation Plan (AHCP) covering 161,875 ha (400,000 ac) of their land that is focused on cold-water adapted species, but many of the conservation measures are expected to benefit Foothill Yellow-legged Frogs as well (K. Hamm pers. comm. 2017). Examples include slope stability and road management measures to reduce stream sedimentation from erosion and landslides, and limiting water drafting during low flow periods with screens over the pumps to avoid entraining animals (Ibid.). Although creating more open canopy areas and warmer water temperatures is not the goal of the AHCP, the areas that are suitable for Foothill Yellow-legged Frog breeding are likely to remain that way because they are wide channels that receive sufficient sunlight (Ibid.).

SUMMARY OF LISTING FACTORS

CESA's implementing regulations identify key factors relevant to the Department's analyses and the Fish and Game Commission's decision on whether to list a species as threatened or endangered. A species will be listed as endangered or threatened if the Commission determines that the species' continued existence is in serious danger or is threatened by any one or any combination of the following factors: (1) present or threatened modification or destruction of its habitat; (2) overexploitation; (3) predation; (4) competition; (5) disease; or (6) other natural occurrences or human-related activities (Cal. Code Regs., tit. 14, § 670.1, subd. (i).

This section provides summaries of information from the foregoing sections of this status review, arranged under each of the factors to be considered by the Commission in determining whether listing is warranted.

Present or Threatened Modification or Destruction of Habitat

Most of the factors affecting ability to survive and reproduce listed above involve destruction or degradation of Foothill Yellow-legged Frog habitat. The most widespread, and potentially most significant, threats are associated with dams and their flow regimes, particularly in areas where they are concentrated and occur in a series along a river. Dams and the way they are operated can have up- and downstream impacts to Foothill Yellow-legged Frogs. They can result in confusing natural breeding cues, scouring and stranding of egg masses and tadpoles, reducing quality and quantity of breeding and rearing habitat, reducing tadpole growth rate, impeding gene flow among populations, and establishing and spreading non-native species (Hayes et al. 2016). These impacts appear to be most severe when the dam is operated for the generation of hydropower utilizing hydropeaking and pulse flows (Kupferberg et al. 2009c, Peek 2018). Foothill Yellow-legged Frog abundance below dams is an average of five times lower than in unregulated rivers (Kupferberg et al. 2012). The number, height, and distance upstream of dams in a watershed influenced whether Foothill Yellow-legged Frogs still occurred at sites where they had been present in 1975 in California (Ibid.). Water diversions for agricultural, industrial, and municipal uses also reduce the availability and quality of Foothill Yellow-legged Frog habitat. Dams are concentrated in the Bay Area, Sierra Nevada, and southern California (Figure 17), while hydropower plants are densest in the northern and central Sierra Nevada (Figure 18).

With predicted increases in the human population, ambitious renewable energy targets, higher temperatures, and more extreme and variable precipitation falling increasingly more as rain rather than snow, the need for more and taller dams and water diversions for hydroelectric power generation, flood control, and water storage and delivery is not expected to abate in the future. California voters approved Proposition 1, the Water Quality, Supply and Infrastructure Improvement Act of 2014, which dedicated $2.7 billion to water storage projects (PPIC 2018). In 2018, the California Water Commission approved funding for four new dams in California: expansion of Pacheco Reservoir (Santa Clara County), expansion of Los Vaqueros Reservoir (Contra Costa County), Temperance Flat Dam (new construction) on the San Joaquin River (Fresno County), and the off-stream Sites Reservoir (new construction) diverting the Sacramento River (Colusa County) (CWC 2019). No historical records of Foothill Yellow-legged Frogs from the Los Vaqueros or Sites Reservoir areas exist in the CNDDB, and one historical (1950) collection is documented from the Pacheco Reservoir area (CNDDB 2019). However, the proposed Temperance Flat Dam site is downstream of one of the only known extant populations of Foothill Yellow-legged Frogs in the East/Southern Sierra clade (Ibid.).

The other widespread threat to Foothill Yellow-legged Frog habitat is climate change, although the severity of its impacts is somewhat uncertain. While drought, wildland fires, floods, and landslides are natural and ostensibly necessary disturbance events for preservation of native biodiversity, climate change is expected to result in increased frequency and severity of these events in ways that may exceed species' abilities to adapt (Williams et al. 2008, Hoffmann and Sgrò 2011, Keely and Syphard 2016). These changes can lead to increased competition, predation, and disease transmission as species become concentrated in areas that remain wet into the late summer (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Loss of riparian vegetation from wildland fires can result in increased stream temperatures or concentrations of nutrients and trace heavy metals that inhibit growth and survival

(Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Stream sedimentation from landslides following fire or excessive precipitation can destroy or degrade breeding and rearing habitat (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). At least some models predict unprecedented dryness in the latter half of the century (Cook et al. 2015). The effects of climate change will be realized across the Foothill Yellow-legged Frog's range, and their severity will likely differ in ways that are difficult to predict. However, the impacts from extended droughts will likely be greatest in the areas that are naturally more arid, the lower elevations and latitudes of southern California and the foothills surrounding the Central Valley (Figure 21).

While most future urbanization is predicted to occur in areas outside of the Foothill Yellow-legged Frog's range, it has already contributed to the loss and fragmentation of Foothill Yellow-legged Frog habitat in California. In addition, the increased predation, wildland fires, introduced species, road mortality, disease transmission, air and water pollution, and disturbance from recreation that can accompany urbanization expand its impact far beyond its physical footprint (Davidson et al. 2002, Syphard et al. 2007, Cook et al. 2012, Bar-Massada et al. 2014). Within the Foothill Yellow-legged Frog's historical range, these effects appear most significant and extensive in terms of population extirpations in southern California and the San Francisco Bay Area.

Several other activities have the potential to destroy or degrade Foothill Yellow-legged Frog habitat, but they are less common across the range. They also tend to have relatively small areas of impact, although they can be significant in those areas, particularly if populations are already small and declining. These include impacts from mining, cannabis cultivation, vineyard expansion, overgrazing, timber harvest, recreation, and some stream habitat restoration projects (Harvey and Lisle 1998, Belsky et al. 1999, Merelender 2000, Pilliod et al. 2003, Bauer et al. 2015, Kupferberg and Furey 2015).

Overexploitation

Foothill Yellow-legged Frogs are not threatened by overexploitation. There is no known pet trade for Foothill Yellow-legged Frogs (Lind 2005). During the massive frog harvest that accompanied the Gold Rush, some Foothill Yellow-legged Frogs were collected, but because they are relatively small and have irritating skin secretions, there was much less of a market for them (Jennings and Hayes 1985). Within these secretions is a peptide with antimicrobial activity that is particularly potent against *Candida albicans*, a human pathogen that has been developing resistance to traditional antifungal agents (Conlon et al. 2003). However, the peptide's therapeutic potential is limited by its strong hemolytic activity, so further studies will focus on synthesizing analogs that can be used as antifungals, and collection of Foothill Yellow-legged Frogs for lab cultures is unlikely (Ibid.).

Like all native California amphibians, collection of Foothill Yellow-legged Frogs is unlawful without a permit from the Department. They may only be collected for scientific, educational, or propagation reasons through a Scientific Collecting Permit (Fish & G. Code § 1002 et seq.). The Department has the discretion to limit or condition the number of individuals collected or handled to ensure no significant adverse effects. Incidental harm from authorized activities on other aquatic species can be avoided or minimized by the inclusion of special terms and conditions in permits.

Predation

Predation is a likely contributor to Foothill Yellow-legged Frog population declines where the habitat is degraded by one or many other risk factors (Hayes and Jennings 1986). Predation by native gartersnakes can be locally substantial; however, it may only have an appreciable population-level impact if the availability of escape refugia is diminished. For example, when streams dry and only pools remain, Foothill Yellow-legged Frogs are more vulnerable to predation by native and non-native species because they are concentrated in a small area with little cover.

Several studies have demonstrated the synergistic impacts of predators and other stressors. Foothill Yellow-legged Frogs, primarily as demonstrated through studies on tadpoles, are more susceptible to predation when exposed to some agrochemicals, cold water, high velocities, excess sedimentation, and even the presence of other species of predators (Harvey and Lisle 1998, Adams et al. 2003, Olson and Davis 2009, Kupferberg et al. 2011b, Kerby and Sih 2015, Catenazzi and Kupferberg 2018). Foothill Yellow-legged Frog tadpoles appear to be naïve to chemical cues from some non-native predators; they have not evolved those species-specific predator avoidance behaviors (Paoletti et al. 2011). Furthermore, early life stages are often more sensitive to environmental stressors, making them more vulnerable to predation, and Foothill Yellow-legged Frog population dynamics are highly sensitive to egg and tadpole mortality (Kats and Ferrer, 2003, Kupferberg et al. 2009c). Predation pressure is likely positively associated with proximity to anthropogenic changes in the environment, so in more remote or pristine places, it probably does not have a serious population-level impact.

Competition

Intra- and interspecific competition in Foothill Yellow-legged Frogs has been documented. Intraspecific male-to-male competition for females has been reported (Rombough and Hayes 2007). Observations include physical aggression and a non-random mating pattern in which larger males were more often engaged in breeding (Rombough and Hayes 2007, Wheeler and Welsh 2008). A behavior resembling clutch-piracy, where a satellite male attempts to fertilize already laid eggs, has also been documented (Rombough and Hayes 2007). These acts of competition play a role in population genetics, but they likely do not result in serious physical injury or mortality. Intraspecific competition among Foothill Yellow-legged Frog tadpoles was negligible (Kupferberg 1997a).

Interspecific competition appears to have a greater possibility of resulting in adverse impacts. Kupferberg (1997a) did not observe a significant change in tadpole mortality for Foothill Yellow-legged Frogs raised with Pacific Treefrogs compared to single-species controls. However, when reared together, Foothill Yellow-legged Frog tadpoles lost mass, while Pacific Treefrog tadpoles increased mass (Kerby and Sih 2015). As described previously under Introduced Species, Foothill Yellow-legged Frog tadpoles experienced significantly higher mortality and smaller size at metamorphosis when raised with bullfrog tadpoles (Kupferberg 1997a). The mechanism of these declines appeared to be exploitative competition, as opposed to interference, through the reduction of available algal resources from bullfrog tadpole grazing in the shared enclosures (Ibid.).

The degree to which competition threatens Foothill Yellow-legged Frogs likely depends on the number and density of non-native species in the area rather than intraspecific competition, and co-occurrence of Foothill Yellow-legged Frog and bullfrog tadpoles may be somewhat rare since the latter tends to breed in lentic (still water) environments (M. van Hattem pers. comm. 2019). Interspecific competition with other native species may have some minor adverse consequences on fitness.

Disease

Currently, the only disease known to pose a serious risk to Foothill Yellow-legged Frogs is Bd. Until 2017, the only published studies on the impact of Bd on Foothill Yellow-legged Frog suggested it could reduce growth and body condition but was not lethal (Davidson et al. 2007, Lowe 2009, Adams et al. 2017b). However, two recent mass mortality events caused by chytridiomycosis proved they are susceptible to lethal effects, at least under certain conditions like drought-related concentration and presence of bullfrogs (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Some evidence indicates disease may have played a principal role in the disappearance of the species from southern California (Adams et al. 2017b). Bd is likely present in the environmental throughout the Foothill Yellow-legged Frog's range, and with bullfrogs and treefrogs acting as carriers, it will remain a threat to the species; however, given the dynamics of the two recent die-offs in the San Francisco Bay area, the probability of future outbreaks may be greater in areas where the species is under additional stressors like drought and introduced species (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Therefore, as with predation, Foothill Yellow-legged Frogs are less likely to experience the adverse impacts of diseases in more remote areas with fewer anthropogenic changes to the environment.

Other Natural Events or Human-Related Activities

Agrochemicals, particularly organophosphates that act as endocrine disruptors, can travel substantial distances from the area of application through atmospheric drift and have been implicated in the disappearance and declines of many species of amphibians in California including Foothill Yellow-legged Frogs (LeNoir et al. 1999, Davidson 2004, Lind 2005, Olson and Davis 2009). Foothill Yellow-legged Frogs appear to be significantly more sensitive to the adverse impacts of some pesticides than other native species (Sparling and Fellers 2009, Kerby and Sih 2015). These include smaller body size, slower development rate, increased time to metamorphosis, immunosuppression, and greater vulnerability to predation and malformations (Kiesecker 2002, Hayes et al. 2006, Sparling and Fellers 2009, Kerby and Sih 2015). Some of the most dramatic declines experienced by ranids in California occurred in the Sierra Nevada east of the San Joaquin Valley where over half of the state's total pesticide usage occurs (Sparling et al. 2001).

Many Foothill Yellow-legged Frog populations are small, isolated from other populations, and possess low genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). Genetic diversity is important in providing a population the capacity to evolve in response to environmental changes, and connectivity among populations is important for gene exchange and in minimizing probability of local extinction (Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). Small populations are at much greater risk of extirpation primarily through the disproportionate impact of demographic, environmental, and genetic stochasticity than robust populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). Based on a Foothill Yellow-legged Frog PVA, populations in regulated rivers face a 4- to 13-fold greater extinction risk in 30 years than populations in unregulated rivers due to smaller population sizes (Kupferberg et al. 2009c). The threat posed by small population sizes is significant and the general pattern shows increases in severity from north to south; however, many sites, primarily in the northern Sierra Nevada, in watersheds with large hydropower projects are also at high risk.

PROTECTION AFFORDED BY LISTING

It is the policy of the State to conserve, protect, restore and enhance any endangered or threatened species and its habitat (Fish & G. Code, § 2052). The conservation, protection, and enhancement of listed species and their habitat is of statewide concern (Fish & G. Code, § 2051(c)). CESA defines "take" as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill (Fish & G. Code, § 86). The Fish and Game Code provides the Department with related authority to authorize "take" of species listed as threatened or endangered under certain circumstances (see, e.g., Fish & G. Code, §§ 2081, 2081.1, 2086, & 2835).

If the Foothill Yellow-legged Frog is listed under CESA, impacts of take caused by activities authorized through incidental take permits must be minimized and fully mitigated according to state standards (Fish & G. Code, § 2081, subd. (b)). These standards typically include protection of land in perpetuity with an easement, development and implementation of a species-specific adaptive management plan, and funding through an endowment to pay for long-term monitoring and maintenance to ensure the mitigation land meets performance criteria. Obtaining an incidental take permit is voluntary. The Department cannot force compliance; however, any person violating the take prohibition may be criminally and civilly liable under state law.

Additional protection of Foothill Yellow-legged Frogs following listing would be expected to occur through state and local agency environmental review under CEQA. CEQA requires affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on rare, threatened, and endangered species. In common practice, potential impacts to listed species are examined more closely in CEQA documents than potential impacts to unlisted species. Where significant impacts are identified under CEQA, the Department expects project-specific avoidance, minimization, and mitigation measures to benefit the species. State listing, in this respect, and consultation with the Department during state and local agency environmental review under CEQA, would be expected to benefit the Foothill Yellow-legged Frog in terms of reducing impacts from individual projects, which might otherwise occur absent listing.

For some species, CESA listing may prompt increased interagency coordination and the likelihood that state and federal land and resource management agencies will allocate funds toward protection and recovery actions. In the case of the Foothill Yellow-legged Frog, some multi-agency efforts exist, often associated with FERC license requirements, to improve habitat conditions and augment declining populations. The USFWS is leading an effort to develop regional Foothill Yellow-legged Frog conservation strategies, and CESA listing may result in increased priority for limited conservation funds.

LISTING RECOMMENDATION

CESA directs the Department to prepare this report regarding the status of the Foothill Yellow-legged Frog in California based upon the best scientific information available (Fish & G. Code, § 2074.6). CESA also directs the Department based on its analysis to indicate in the status report whether the petitioned action (i.e., listing as threatened) is warranted (Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

Under CESA, an endangered species is defined as "a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease" (Fish & G. Code, § 2062). A threatened species is defined as "a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA]" (Fish and G. Code, § 2067).

The Department includes and makes its recommendation in its status report as submitted to the Commission in an advisory capacity based on the best available science. In consideration of the scientific information contained herein, the Department has determined that listing the Foothill Yellow-legged Frog under CESA by genetic clade is the prudent approach due to the disparate degrees of imperilment among them. In areas of uncertainty, the Department recommends the higher protection status until clade boundaries can be better defined.

NORTHWEST/NORTH COAST: Not warranted at this time.

Clade-level Summary: This is the largest clade with the most robust populations (highest densities) and the greatest genetic diversity. This area is the least densely populated by humans; contains relatively few hydroelectric dams, particularly further north; and has the highest precipitation in the species' California range. The species is still known to occur in most, if not all, historically occupied watersheds; presumed extirpations are mainly concentrated in the southern portion of the clade around the heavily urbanized San Francisco Bay area. The proliferation of cannabis cultivation, particularly illicit grows in and around the Emerald Triangle, the apparent increase in severe wildland fires in the area, and potential climate change effects are cause for concern, so the species should remain a Priority 1 SSC here with continued monitoring for any change in its status.

WEST/CENTRAL COAST: Endangered.

Clade-level Summary: Foothill Yellow-legged Frogs appear to be extirpated from a relatively large proportion of historically occupied sites within this clade, particularly in the heavily urbanized northern portion around the San Francisco Bay. In the northern portion of the clade, nearly all the remaining populations (which may be fewer than a dozen) are located above dams, which line the mountains surrounding the Bay Area, and two are known to have undergone recent disease-associated die-offs. These higher elevation sites are more often intermittent or ephemeral streams than the lower in the watersheds. As a result, the more frequent and extreme droughts that have dried up large areas seem to have contributed to recent declines. Illegal cannabis cultivation, historical mining effects, overgrazing, and recreation likely contributed to declines and may continue to threaten remaining populations.

SOUTHWEST/SOUTH COAST: Endangered.

Clade-level Summary: The most extensive extirpations have occurred in this clade, and only two known extant populations remain. Both are small with apparently low genetic diversity, making them especially vulnerable to extirpation. This is also an area with a large human population, many dams, and naturally arid, fire-prone environments, particularly in the southern portion of the clade. Introduced species are widespread, and cannabis cultivation is rivaling the Emerald Triangle in some areas (e.g., Santa Barbara County). Introduced species, expanded recreation, disease, and flooding appear to have contributed to the widespread extirpations in southern California over 40 years ago.

FEATHER RIVER: Threatened.

Clade-level Summary: This is the smallest clade and has a high density of hydroelectric dams. It also recently experienced one of the largest, most catastrophic wildfires in California history. Despite these threats, Foothill Yellow-legged Frogs appear to continue to be relatively broadly distributed within the clade, although with all the dams in the area, most populations are likely disconnected. The area is more mesic and experienced less of a change in precipitation in the most recent drought than the clades south of it. The clade is remarkable genetically and morphologically as it is the only area where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs overlap and can hybridize. The genetic variation within the clade is greater than the other clades except for the Northwest/North Coast. Most of the area within the clade's boundaries is Forest Service-managed, and little urbanization pressure or known extirpations exist in this area. Recent FERC licenses in this area require Foothill Yellow-legged Frog specific conservation, which to date has included cancelling pulse flows, removing encroaching vegetation, and translocating egg masses and in situ head-starting to augment a population that had recently declined.

NORTHEAST/NORTHERN SIERRA: Threatened.

Clade-level Summary: The Northeast/Northern Sierra clade shares many of the same threats as the Feather River clade (e.g., relatively small area with many hydroelectric dams). The area is also more mesic and experienced less of a change in precipitation during the recent drought than more southern clades. However, this pattern may not continue as some models suggest loss of snowmelt will be greater in the northern Sierra Nevada, and one of the climate change exposure models suggests a comparatively large proportion of the lower elevations will experience climatic conditions not currently known from the area (i.e., non-analog) by the end of the century. Recent surveys suggest the area continues to support several populations of the species, some of which seem to remain robust, with a fairly widespread distribution. However, genetic analyses from several watersheds suggest many of these populations are isolated and diverging, particularly in regulated reaches with hydropeaking flows.

EAST/SOUTHERN SIERRA: Endangered.

Clade-level Summary: Like the Southwest/South Coast clade, widespread extirpations in this area were observed as early as the 1970s. Dams and introduced species were credited as causal factors in these declines in distribution and abundance, and mining and disease may also have contributed. This area is relatively arid, and drought effects appear greater here than in northern areas that exhibit both more precipitation and a smaller difference between drought years and the historical average. There is a relatively high number of hydroelectric power generating dams in series along the major rivers in this clade and at least one new proposed dam near one of the remaining populations. This area is also the most heavily impacted by agrochemicals from the San Joaquin Valley.

MANAGEMENT RECOMMENDATIONS

The Department has evaluated existing management recommendations and available literature applicable to the management and conservation of the Foothill Yellow-legged Frog to arrive at the following recommendations. These recommendations, which represent the best available scientific information, are largely derived the from the Foothill Yellow-legged Frog Conservation Assessment, the California Energy Commission's Public Interest Energy Research Reports, the Recovery Plans of West Coast Salmon and Steelhead, and the California Amphibian and Reptile Species of Special Concern (Kupferberg et al. 2009b,c; 2011a; NMFS 2012, 2013, 2014, 2016; Hayes et al. 2016, Thomson et al. 2016).

Conservation Strategies

Maintain current distribution and genetic diversity by protecting existing Foothill Yellow-legged Frog populations and their habitats and providing opportunities for genetic exchange. Increase abundance to viable levels in populations at risk of extirpation due to small sizes, when appropriate, through in situ or ex situ captive rearing and/or translocations. Use habitat suitability and hydrodynamic habitat models to identify historically occupied sites that may currently support Foothill Yellow-legged Frogs, or they could with minor habitat improvements or modified management. Re-establish extirpated populations in suitable habitat through captive propagation, rearing, and/or translocations. Prioritize areas in the southern portions of the species' range where extirpations and loss of diversity have been the most severe.

If establishing reserves, prioritize areas containing high genetic variation in Foothill Yellow-legged Frogs (and among various native species) and climatic gradients where selection varies over small geographical area because environmental heterogeneity can provide a means of maintaining phenotypic variability which increases the adaptive capacity of populations as conditions change. These reserves should provide connectivity to other occupied areas to facilitate gene flow and allow for ongoing selection to fire, drought, thermal stresses, and changing species interactions.

Research and Monitoring

Attempt to rediscover potentially remnant populations in areas where they are considered extirpated, prioritizing the southern portions of the species' range. Collect environmental DNA in addition to conducting visual encounter surveys to improve detectability. Concurrently assess presence of threats and habitat suitability to determine if future reintroductions may be possible. Collect genetic samples from any Foothill Yellow-legged Frogs captured for use in landscape genomics analyses and possible future translocation or captive propagation efforts. Attempt to better clarify clade boundaries where there is uncertainty. Study whether small populations are at risk of inbreeding depression, whether genetic rescue should be attempted, and if so, whether that results in hybrid vigor or outbreeding depression.

Continue to evaluate how water operations affect Foothill Yellow-legged Frog population demographics. Establish more long-term monitoring programs in regulated and unregulated (reference) rivers across the species' range but particularly in areas like the Sierra Nevada where most large hydropower dams in the species' range are concentrated. Assess whether the timing of pulse flows influences population dynamics, particularly whether early releases have a disproportionately large adverse effect by eliminating the reproductive success of the largest, most fecund females, who appear to breed earlier in the season. Investigate survival rates in poorly-understood life stages, such as tadpoles, young of the year, and juveniles. Determine the extent to which pulse flows contribute to displacement and mortality of post-metamorphic life stages.

Collect habitat variables that correlate with healthy populations to develop more site-specific habitat suitability and hydrodynamic models. Study the potential synergistic effect of increased flow velocity and decreased temperature on tadpole fitness. Examine the relationship between changes in flow, breeding and rearing habitat connectivity, and scouring and stranding to develop site-specific benign ramping rates. Incorporate these data and demographic data into future PVAs for use in establishing frog-friendly flow regimes in future FERC relicensing or license amendment efforts and habitat restoration projects. Ensure long-term funding for post-license or restoration monitoring to evaluate attainment of expected results and for use in adapting management strategies accordingly.

Evaluate the distribution of other threats such as cannabis cultivation, vineyard expansion, livestock grazing, mining, timber harvest, and urbanization and roads in the Foothill Yellow-legged Frog's range. Study the short- and long-term effects of wildland fires and fire management strategies. Assess the extent to which these potential threats pose a risk to Foothill Yellow-legged Frog persistence in both regulated and unregulated systems.

Investigate how reach-level or short-distance habitat suitability and hydrodynamic models can be extrapolated to a watershed level. Study habitat connectivity needs such as the proximity of breeding sites and other suitable habitats along a waterway necessary to maintain gene flow and functioning meta-population dynamics.

Habitat Restoration and Watershed Management

Remove or update physical barriers like dams and poorly constructed culverts and bridges to improve connectivity and natural stream processes. Remove anthropogenic features that support introduced predators and competitors such as abandoned mine tailing ponds that support bullfrog breeding. Conduct active eradication and management efforts to decrease the abundance of bullfrogs, non-native fish, and crayfish (where they are non-native). In managed rivers, manipulate stream flows to negatively affect non-native species not adapted to a winter flood/summer drought flow regime.

Adopt a multi-species approach to channel restoration projects and managed flow regimes (thermal, velocity, timing) and mimic the natural hydrograph to the greatest extent possible. When this is impractical or infeasible, focus on minimizing adverse impacts by gradually ramping discharge up and down, creating and maintaining gently sloping and sun-lit gravel bars and warm calm edgewater habitats for tadpole rearing, and mixing hypolimnetic water (from the lower colder stratum in a reservoir) with warmer surface water before release if necessary to ensure appropriate thermal conditions for successful metamorphosis. Promote restoration and maintenance of habitat heterogeneity (different depths, velocities, substrates, etc.) and connectivity to support all life stages and gene flow. Avoid damaging Foothill Yellow-legged Frog breeding habitat when restoring habitat for other focal species like anadromous salmonids.

Regulatory Considerations and Best Management Practices

Develop range-wide minimum summer baseflow requirements that protect Foothill Yellow-legged Frogs and their habitat with appropriate provisions to address regional differences using new more ecologically-meaningful approaches such as modified percent-of-flow strategies for watersheds (e.g., Mierau et al. 2018). Limit water diversions during the dry season and construction of new dams by focusing on off-stream water storage strategies.

Ensure and improve protection of riparian systems. Require maintenance of appropriate riparian buffers and canopy coverage (i.e., partly shaded) around occupied habitat or habitat that has been identified for potential future reintroductions. Restrict instream work to dry periods where possible. Prohibit fording in and around breeding habitat. Avoid working near streams after the first major rains in the fall when Foothill Yellow-legged Frogs may be moving upslope toward tributaries and overwintering sites. Use a 3 mm (0.125 in) mesh screen on water diversion pumps and limit the rate and amount of water diverted such that depth and flow remain sufficient to support Foothill Yellow-legged Frogs of all life stages occupying the immediate area and downstream. Install exclusion fencing where appropriate, and if Foothill Yellow-legged Frog relocation is required, conduct it early in the season because moving egg masses is easier than moving tadpoles.

Reduce habitat degradation from sedimentation, pesticides, herbicides, and other non-point source waste discharges from adjacent land uses including along tributaries of rivers and streams. Limit mining to parts of rivers not used for oviposition, such as deeper pools or reaches with few tributaries, and at times of year when frogs are more common in tributaries (i.e., fall and winter). Manage recreational activities in or adjacent to Foothill Yellow-legged Frog habitat (e.g., OHV and hiking trails, camp sites, boating ingress/egress, flows, and speeds) in a way that minimizes adverse impacts. Siting cannabis grows in areas with better access to roads, gentler slopes, and ample water resources could significantly reduce threats to the environment. Determine which, when, and where agrochemicals should be restricted to reduce harm to Foothill Yellow-legged Frogs and other species. Ensure all new road crossings and upgrades to existing crossings (bridges, culverts, fills, and other crossings) accommodate at least 100-year flood flows and associated bedload and debris.

Partnerships and Coordination

Establish collaborative partnerships with agencies, universities, and non-governmental organizations working on salmon and steelhead recovery and stream restoration. Anadromous salmonids share many of the same threats as Foothill Yellow-legged Frogs, and recovery actions such as barrier removal, restoration of natural sediment transport processes, reduction in pollution, and eradication of non-native predators would benefit frogs as well. Ensure Integrated Regional Water Management Plans and fisheries restoration programs take Foothill Yellow-legged Frog conservation into consideration during design, implementation, and maintenance.

Encourage local governments to place conditions on new developments to minimize negative impacts on riparian systems. Promote and implement initiatives and programs that improve water conservation use efficiency, reduce greenhouse gas emissions, promote sustainable agriculture and smart urban growth, and protect and restore riparian ecosystems. Shift reliance from on-stream storage to off-stream storage, resolve frost protection issues (water withdrawals), and ensure necessary flows for all life stages in all water years.

Establish a Department-coordinated staff and citizen scientist program to systematically monitor occupied stream reaches across the species' range.

Education and Enforcement

Support programs to provide educational outreach and local involvement in restoration and watershed stewardship, such as Project Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land and water use on Foothill Yellow-legged Frog survival.

Provide additional funding for increased law enforcement to reduce ecologically harmful stream alterations and water pollution and to ensure adequate protection for Foothill Yellow-legged Frogs at pumps and diversions. Identify and address illegal water diverters and out-of-compliance diverters, seasons of diversion, off-stream reservoirs, well pumping, and bypass flows to protect Foothill Yellow-legged Frogs. Prosecute violators accordingly.

ECONOMIC CONSIDERATIONS

The Department is charged in an advisory capacity in the present context to provide a written report and a related recommendation to the Commission based on the best scientific information available regarding the status of Foothill Yellow-legged Frog in California. The Department is not required to prepare an analysis of economic impacts (See Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

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Patterson, Laura@Wildlife

From: Jim Mcguire <mcguirej@berkeley.edu>
Sent: Monday, June 24, 2019 1:08 PM
To: Patterson, Laura@Wildlife
Subject: Re: Peer Review Request: Foothill Yellow-legged Frog Status Review
Attachments: DRAFT FYLF Status Review-2019.05.21.docx; Untitled attachment 00038.html

Hi Laura,

I've attached the Draft report with my comments incorporated directly in the document via Track Changes. I'm extremely impressed by the depth and detail provided in your report! Although I didn't have much in the way of suggested changes to the document, I gave it a careful read and learned a lot myself. I noted a few typos and and suggested a few updates to the ranid taxonomy section, but you and the various folks that were cited extensively in the report (especially Sarah Kupferberg and Amy Lind) obviously know a ton about these animals (far more than I do)..

I agree whole-heartedly with your assessment of the listing needs for the genetic clades. My question for you now - having never reviewed one of these reports and being naive to the process - is what sort of review you need from me. Will my review simply be used by you to improve your document, or do you need formal reviews that accompany the final document and thus need to be detailed assessments? In other words, am I simply helping you fine-tune your document or is this more like an NSF grant proposal and the review will influence whomever will be evaluating your recommendations? Just let me know!

Cheers,

Jim

STATE OF CALIFORNIA
NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION

A STATUS REVIEW OF THE
FOOTHILL YELLOW-LEGGED FROG
(*Rana boylii*) IN CALIFORNIA

CHARLTON H. BONHAM, DIRECTOR
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
External Peer Review Draft

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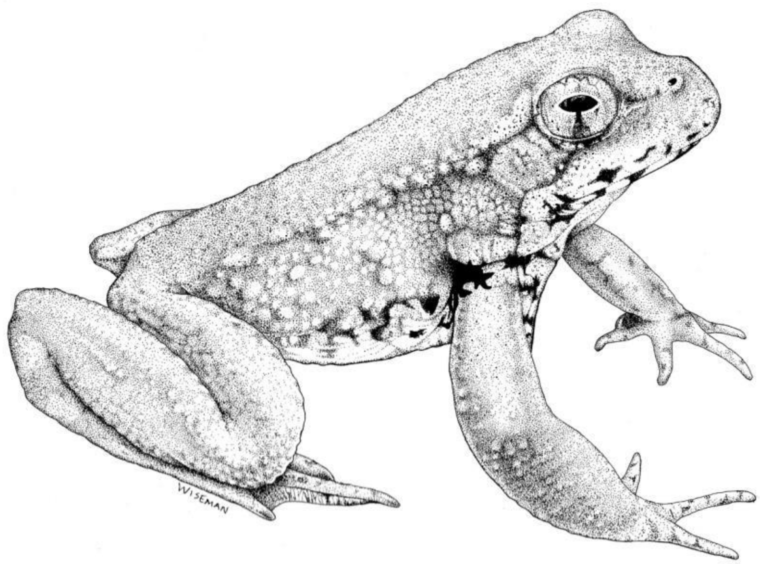

ACKNOWLEDGMENTS

Laura Patterson prepared this report. Stephanie Hogan, Madeleine Wieland, and Margaret Mantor assisted with portions of the report, including the sections on Status and Trends in California and Existing Management. Kristi Cripe provided GIS analysis and figures. Review of a draft document was provided by the following California Department of Fish and Wildlife (Department) staff: Ryan Bourque, Marcia Grefsrud, and Mike van Hattem.

The Department is extremely grateful for the valuable comments provided on this report by the following peer reviewers: Dr. Sarah Kupferberg, Dr. Amy Lind, Dr. Jimmy McGuire, and Dr. Ryan Peek. The conclusions in this report are those of the Department and do not necessarily reflect those of the reviewers.

Cover photograph by Isaac Chellman, used with permission.

Illustration by Kevin Wiseman, used with permission.

EXECUTIVE SUMMARY

[To be completed after external peer review]

REGULATORY SETTING

Petition Evaluation Process

A petition to list the Foothill Yellow-legged Frog (*Rana boylii*) as threatened under the California Endangered Species Act (CESA) was submitted to the Fish and Game Commission (Commission) on December 14, 2016 by the Center for Biological Diversity. Commission staff transmitted the petition to the Department of Fish and Wildlife (Department) pursuant to Fish and Game Code section 2073 on December 22, 2016 and published a formal notice of receipt of the petition on January 20, 2017 (Cal. Reg. Notice Register 2017, No. 3-Z, p. 46). A petition to list or delist a species under CESA must include "information regarding the population trend, range, distribution, abundance, and life history of a species, the factors affecting the ability of the population to survive and reproduce, the degree and immediacy of the threat, the impact of existing management efforts, suggestions for future management, and the availability and sources of information. The petition shall also include information regarding the kind of habitat necessary for species survival, a detailed distribution map, and any other factors that the petitioner deems relevant" (Fish & G. Code, § 2072.3).

On April 17, 2017, the Department provided the Commission with its evaluation of the petition, "Evaluation of the Petition from the Center For Biological Diversity to List the Foothill Yellow-legged Frog (*Rana boylii*) as Threatened under the California Endangered Species Act," to assist the Commission in making a determination as to whether the petitioned action may be warranted based on the sufficiency of scientific information (Fish & G. Code, §§ 2073.5 & 2074.2; Cal. Code Regs., tit. 14, § 670.1, subds. (d) & (e)). Focusing on the information available to the Department relating to each of the relevant categories, the Department recommended to the Commission that the petition be accepted.

At its scheduled public meeting on June 21, 2017, in Smith River, California, the Commission considered the petition, the Department's petition evaluation and recommendation, and comments received. The Commission found that sufficient information existed to indicate the petitioned action may be warranted and accepted the petition for consideration. Upon publication of the Commission's notice of its findings, the Foothill Yellow-legged Frog was designated a candidate species on July 7, 2017 (Cal. Reg. Notice Register 2017, No. 27-Z, p. 986).

Status Review Overview

The Commission's action designating the Foothill Yellow-legged Frog as a candidate species triggered the Department's process for conducting a status review to inform the Commission's decision on whether listing the species is warranted. At its scheduled public meeting on June 21, 2018, in Sacramento, California, the Commission granted the Department a six-month extension to complete the status review and facilitate external peer review.

This status review report is not intended to be an exhaustive review of all published scientific literature relevant to the Foothill Yellow-legged Frog; rather, it is intended to summarize the key points from the best scientific information available relevant to the status of the species. This final report, based upon the best scientific information available to the Department, is informed by independent peer review of a draft report by scientists with expertise relevant to the Foothill Yellow-legged Frog. This review is intended to provide the Commission with the most current information on the Foothill Yellow-legged Frog and to serve as the basis for the Department's recommendation to the Commission on whether the petitioned action is warranted. The status review report also identifies habitat that may be essential to continued existence of the species and provides management recommendations for recovery of the species (Fish & G. Code, § 2074.6). Receipt of this report is to be placed on the agenda for the next available meeting of the Commission after delivery. At that time, the report will be made available to the public for a 30-day public comment period prior to the Commission taking any action on the petition.

Federal Endangered Species Act Review

The Foothill Yellow-legged Frog is currently under review for possible listing as threatened or endangered under the federal Endangered Species Act (ESA) in response to a July 11, 2012 petition submitted by the Center for Biological Diversity. On July 1, 2015, the U.S. Fish and Wildlife Service (USFWS) published its 90-day finding that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted and initiated a status review of the species (USFWS 2015). On March 16, 2016, the Center for Biological Diversity sued the USFWS to compel issuance of a 12-month finding on whether listing under the ESA is warranted. On August 30, 2016, the parties reached a stipulated settlement agreement that the USFWS shall publish its 12-month finding in the Federal Register on or before September 30, 2020 (*Center for Biological Diversity v. S.M.R. Jewell* (D.D.C. Aug. 30, 2016, No. 16-CV-00503)).

BIOLOGY AND ECOLOGY

Species Description and Life History

> *"In its life-history* boylii *exhibits several striking specializations which are in all probability related to the requirements of life of a stream-dwelling species"* – Tracy I. Storer, 1925

The Foothill Yellow-legged Frog is a small- to medium-sized frog; adults range from 38 to 81 mm (1.5-3.2 in) snout to urostyle length (SUL) with females attaining a larger size than males and males possessing paired internal vocal sacs (Zweifel 1955, Nussbaum et al. 1983, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs are typically gray, brown, olive, or reddish with brown-black flecking and mottling, which generally matches the substrate of the stream in which they reside (Nussbaum et al. 1983, Stebbins and McGinnis 2012). They often have a pale triangle between the eyes and snout and broad dark bars on the hind legs (Zweifel 1955, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs have a relatively squat body and granular skin, giving them a rough appearance similar to a toad, and fully webbed feet with slightly expanded toe tips (Nussbaum et al. 1983). The tympanum is also rough

and relatively small compared to congeners at around one-half the diameter of the eye (Zweifel 1955). The dorsolateral folds (glandular ridges extending from the eye area to the rump) in Foothill Yellow-legged Frogs are indistinct compared to other western North American ranids (Stebbins and McGinnis 2012). Ventrally, the abdomen is white with variable amounts of dark mottling on the chest and throat, which are unique enough to be used to identify individuals (Marlow et al. 2016). As their name suggests, the underside of their hind limbs and lower abdomen are often yellow; however, individuals with orange and red have been observed within the range of the California Red-legged Frog (*Rana draytonii*), making hindlimb coloration a poor diagnostic characteristic for this species (Jennings and Hayes 2005).

Adult females likely lay one clutch of eggs per year and may breed every year (Storer 1925, Wheeler et al. 2006). Foothill Yellow-legged Frog egg masses resemble a compact cluster of grapes approximately 45 to 90 mm (1.8-3.5 in) in diameter length-wise and contain anywhere from around 100 to over 3,000 eggs (Kupferberg et al. 2009c, Hayes et al. 2016). The individual embryos are dark brown to black with a lighter area at the vegetative pole and surrounded by three jelly envelopes that range in diameter from approximately 3.9 to 6.0 mm (0.15-0.25 in) (Storer 1925, Zweifel 1955, Hayes et al. 2016).

Foothill Yellow-legged Frog tadpoles hatch out around 7.5 mm (0.3 in) long and are a dark brown or black (Storer 1925, Zweifel 1955). They grow rapidly to 37 to 56 mm (1.5-2.2 in) and turn olive with a coarse brown mottling above and an opaque silvery color below (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012). Their eyes are positioned dorsally when viewed from above (i.e., within the outline of the head), and their mouths are large, downward-oriented, and suction-like with several tooth rows (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012, Hayes et al. 2016). Foothill Yellow-legged Frogs metamorphose at around 14-17 mm (0.55-0.67 in) SUL (Fellers 2005). Sexual maturity is attained at around 30-40 mm (1.2-1.6 in) SUL and 1 year for males and around 40-50 mm (1.6-2.0 in) SUL and 3 years for females, although in some populations this has been accelerated by a year (Zweifel 1955, Kupferberg et al. 2009c, Breedveld and Ellis 2018). During the breeding season, males can be distinguished from females by the presence of nuptial pads (swollen darkened thumb bases that aid in holding females during amplexus) and calling, which frequently occurs underwater but sometimes from the surface (MacTague and Northen 1993, Stebbins 2003, Silver 2017).

The reported lifespan of Foothill Yellow-legged Frogs varies widely by study. Storer (1925) and Van Wagner (1996) estimated a maximum age of 2 years for both sexes and the vast majority of the population. Breedveld and Ellis (2018) calculated the typical lifespan of males at 3-4 years and 5-6 years for females. Bourque (2008), using skeletochronology, found an individual over 7 years old and a mean age of 4.7 and 3.6 years for males and females, respectively. Drennan et al. (2015) estimated maximum age at 13 years for both sexes in a Sierra Nevada population and 12 for males and 11 for females in a Coast Range population.

Range and Distribution

Foothill Yellow-legged Frogs historically ranged from the Willamette River drainage in Oregon west of the Sierra-Cascade crest to at least the San Gabriel River drainage in Los Angeles County, California (Figure 1; Zweifel 1955, Stebbins 2003). In addition, a disjunct population was reported from 2,040 m

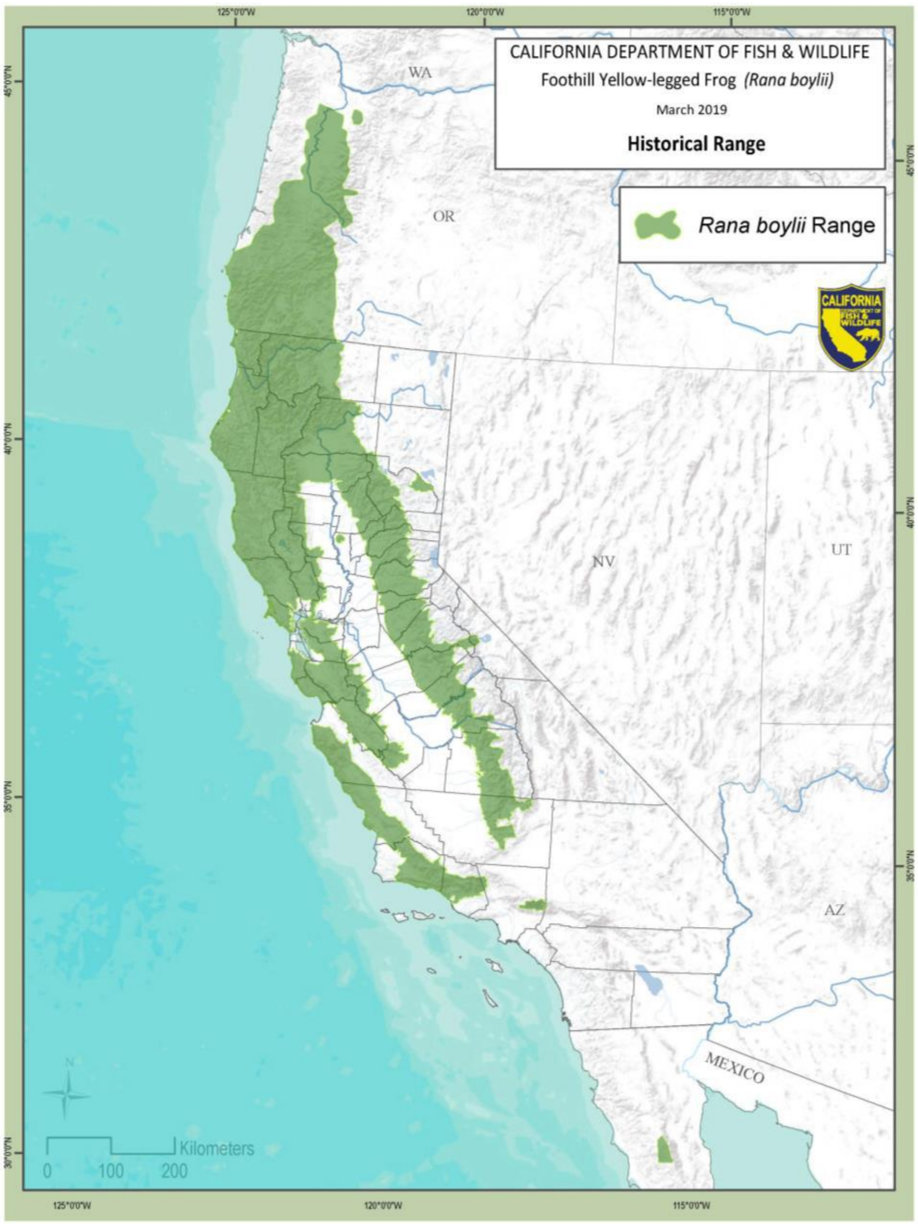

Figure 1. Foothill Yellow-legged Frog historical range (adapted from CWHR, Loomis [1965], Nussbaum et al. [1983])

(6,700 ft) in the Sierra San Pedro Mártir, Baja California Norte, México (Loomis 1965). In California, the species occupies foothill and mountain streams in the Klamath, Cascade, Sutter Buttes, Coast, Sierra Nevada, and Transverse ranges from sea level to 1,940 m (6,400 ft), but generally below 1,525 m (5,000 ft) (Hemphill 1952, Nussbaum et al. 1983, Stebbins 2003, Olson et al. 2016). Zweifel (1955) considered Foothill Yellow-legged Frogs to be present and abundant throughout their range where streams possessed suitable habitat.

Taxonomy and Phylogeny

Foothill Yellow-legged Frogs belong to the family Ranidae (true frogs), which inhabits every continent except Antarctica and contains more than 700 species (Stebbins 2003). The species was first described by Baird (1854) as *Rana boylii*. After substantial taxonomic uncertainty with respect to its relationship to other ranids (frogs in the family Ranidae) and several name changes over the next century, the Foothill Yellow-legged Frog (*R. boylii* with no subspecific epithet) was ~~eventually~~ again recognized as a ~~distinct~~ monotypic species ~~again~~ by Zweifel (1955, 1968). The phylogenetic relationships among the western North American *Rana* spp. have been revised several times and are still not entirely resolved (Thomson et al. 2016). The Foothill Yellow-legged Frog was previously thought to be most closely related to the higher elevation Mountain Yellow-legged Frog (*R. muscosa*) (Zweifel 1955; Green 1986a,b). However, genetic analyses undertaken by Macey et al. (2001) and Hillis and Wilcox (2005) suggest they are more closely related to Oregon Spotted Frogs (*R. pretiosa*) and Columbia Spotted Frogs (*R. luteiventris*), respectively.

Commented [MOU1]: The old Ranidae has been partitioned into several families. The distribution is still as you indicated but the number of species is 407 according to AmphibiaWeb (and they stay completely on top of the taxonomic literature).

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Population Structure and Genetic Diversity

Foothill Yellow-legged Frog populations exhibit varying levels of partitioning and genetic diversity at different spatial scales. At the coarse landscape level across the species' extant range, McCartney-Melstad et al. (2018) genomic data set composed of RadSeq data, analysis of which recovered five deeply divergent, geographically cohesive, genetic clades (Figure 2), while Peek (2018) (using ???? data) recovered six (Figure 3). Genetic divergence ~~is~~ occurs during the process of speciation; it is a measure of the number of mutations accumulated by populations over time from a shared ancestor that differentiate them from the other populations in a species. When genetic divergence among clades is large enough, it can be used as a tool to assist in the ~~define~~ identification of new species or subspecies.

Commented [MOU2]: Genetic divergence definitely takes places within species and is not strictly speaking the same as speciation.

The geographic breaks among the five clades were similar between the studies, but Peek (2018) identified a separate deeply divergent genetic clade in the Feather River watershed that is distinct from the rest of the northern Sierra Nevada clade. The five clades the two studies shared include the following [Note: naming conventions follow McCartney-Melstad et al. (2018) and Peek (2018)]:

(1) Northwest/North Coast: north of San Francisco Bay in the Coast Ranges and east into Tehama County;
(2) Northeast/Northern Sierra: northern El Dorado County (North Fork American River watershed, includes Middle Fork) and north in the Sierra Nevada to southern Plumas County (Upper Yuba River watershed);

114 Evan McCartney-Melstad et al.

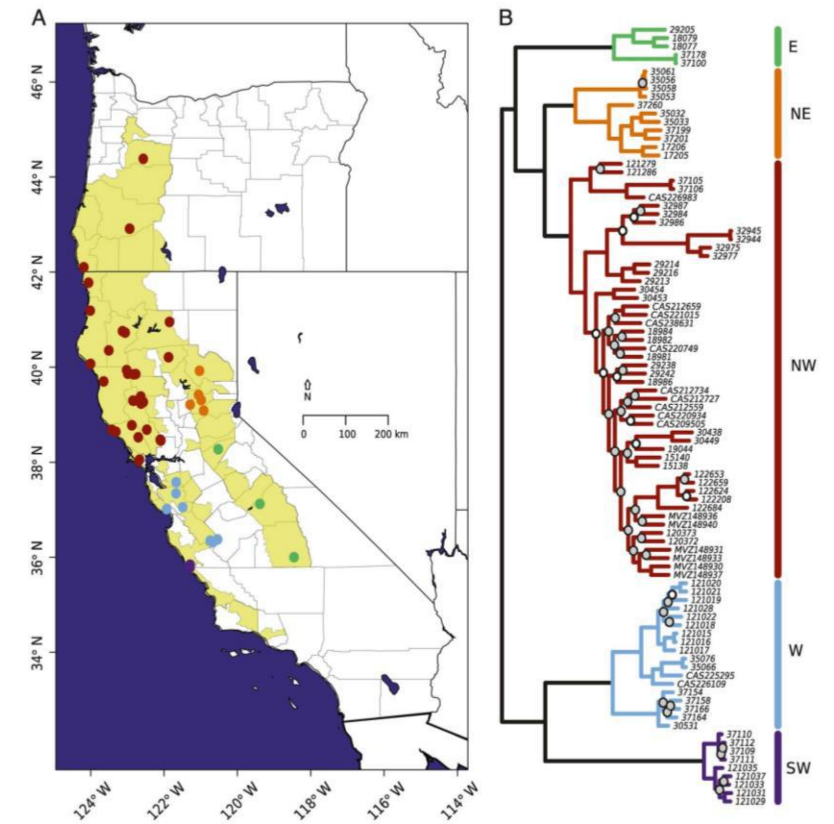


Fig. 1 **a** Map of *Rana boylii* sample localities. County outlines are shown within California and Oregon. Light yellow indicates the IUCN range map of *R. boylii*, excluding a small disjunct population at Sierra San Pedro Martir, Baja California, Mexico. Dots are colored by major grouping as determined in the **b** RAxML phylogeny, with midpoint rooting. Nodes without dots received >95% bootstrap support, those with white dots received <95% but greater than or equal to 75% bootstrap support, while nodes with gray dots received <75% bootstrap support

Figure 2. Foothill Yellow-legged Frog clades by McCartney-Melstad et al. (2018)

(3) East/Southern Sierra: El Dorado County (South Fork American River watershed) and south in the Sierra Nevada [no samples from Amador County were tested, but they would most likely fall within this clade because it is located between two other populations that occur within this clade];

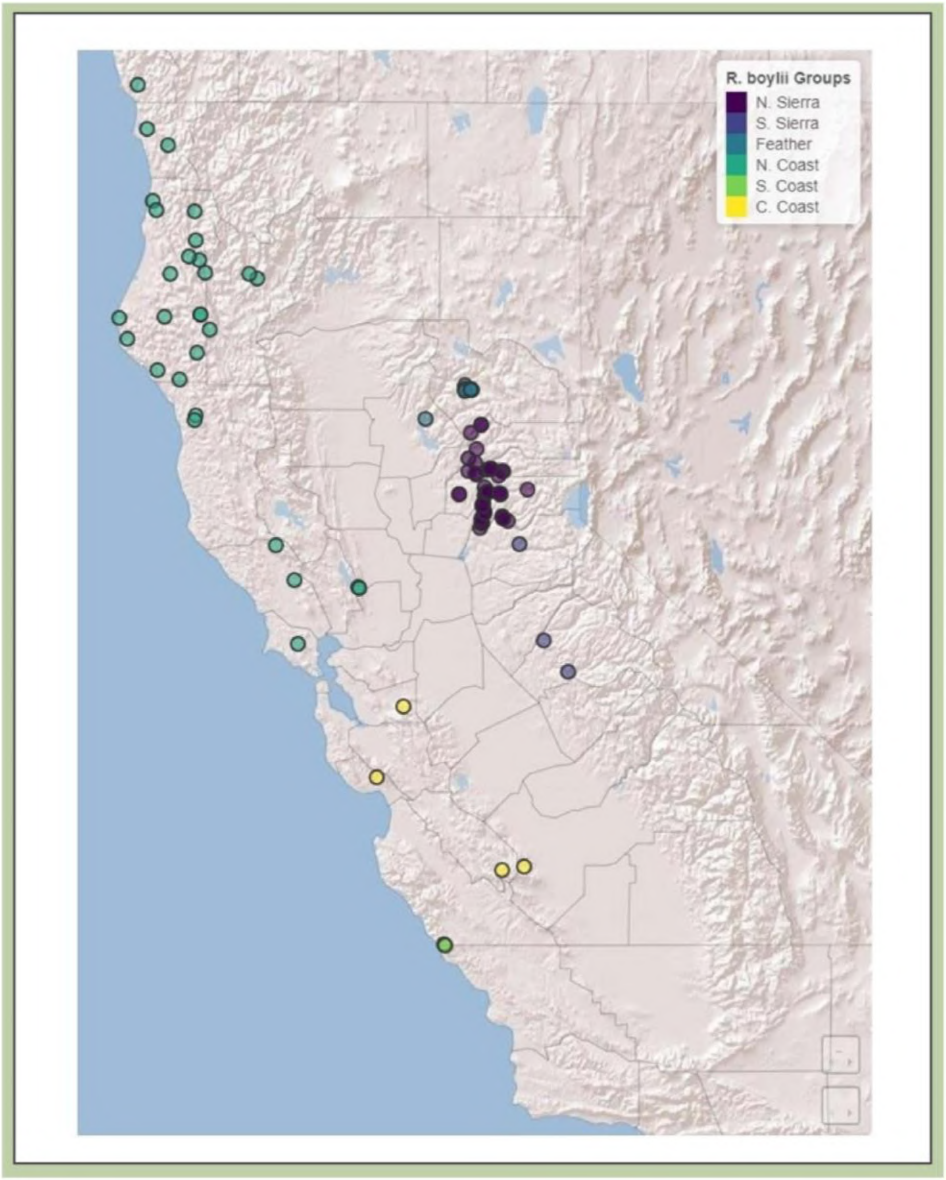


Figure 3. Foothill Yellow-legged Frog clades by Peek (2018)

(4) West/Central Coast: south of San Francisco Bay in the Coast Ranges to San Benito and Monterey counties, presumably east of the San Andreas Fault/Salinas Valley;
(5) Southwest/South Coast presumably west of the San Andreas Fault/Salinas Valley in Monterey County and south in the Coast Ranges.

The Feather River clade is found primarily in Plumas and Butte counties (Peek 2018). Peek's analysis found that this clade is as distinct as the rest of the Sierra Nevada as a cohesive group and all the coastal populations as one group, meaning it was found to be deeply divergent from the rest of the clades. McCartney-Melstad et al. (2018) also recognized the Feather River watershed as distinct from the rest of the northern Sierra but not as deeply divergent from the other clades as Peek. The Feather River watershed is also the only known location where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs (*R. sierrae*) co-occur and where two F1 hybrids (50% ancestry from each species) were found (Peek 2018). In addition, Peek's modeling results only weakly supported dividing the West/Central Coast and Southwest/South Coast groups into separate clades.

Previous work conducted by Lind et al. (2011) based on two mitochondrial genes found a somewhat similar pattern, that populations on the periphery of the species' range are considerably genetically divergent from the rest of the range. Their results suggested that hydrologic regions and river basins were important landscape features that influenced the genetic structure of Foothill Yellow-legged Frog populations. However, using more modern genomic techniques, McCartney-Melstad et al. (2018) found nearly twice the variation among the five phylogenetic clades than among drainage basins, indicating other factors contributed to current population structure. They report that the depth of genetic divergence among Foothill Yellow-legged Frog clades exceeds that of any anuran (frog or toad) for which similar data are available and recommend using them as management units instead of the previously suggested watershed boundaries.

Levels of genetic diversity within the clades differed significantly. Genetic diversity gives species the ability to adapt to changing conditions (i.e., evolve), and its loss often signals extreme population and range reductions as well as potential inbreeding depression that can reduce survival and reproductive success (Lande and Shannon 1996, Hoffmann and Sgrò 2011, McCartney-Melstad et al. 2018). Loss of genetic diversity in Foothill Yellow-legged Frogs largely follows a north-to-south pattern with the southern clades (Southwest/South Coast and East/Southern Sierra) possessing the least amount (McCartney-Melstad et al. 2018, Peek 2018). In addition, these study results demonstrate that Foothill Yellow-legged Frogs have lost genetic diversity over time across their entire range except for the large Northwest/North Coast clade, which appears to have undergone a relatively recent population expansion (McCartney-Melstad et al. 2018, Peek 2018).

At a watershed scale, Dever (2007) found that tributaries to rivers and streams are important for preserving genetic diversity, and populations separated by more than 10 km (6.2 mi) show signs of genetic isolation. In other words, even in the absence of anthropogenic barriers to dispersal (e.g., dams and reservoirs), individuals located more than 10 km (6.2 mi) are not typically considered part of a single interbreeding population (Olson and Davis 2009). Peek (2011, 2018) reported that at this finer-scale, population structure and genetic diversity appear to be more strongly influenced by river regulation type (i.e., dammed or undammed) than to geographic distance or watershed boundaries. In general, regulated (dammed) rivers had limited gene flow and higher genetic divergence among subpopulations compared with unregulated (undammed) rivers (Peek 2011, 2018). In addition, differences in water flow regimes within regulated rivers affected connectivity (Peek 2011, 2018). Subpopulations in hydropeaking reaches, in which pulsed flows are used for electricity generation or whitewater boating, exhibited significantly lower gene flow than those in bypass reaches where water is diverted from upstream in the basin down to power generating facilities (Figure 4; Peek 2018). River regulation had a greater influence on genetic differentiation among sites than geographic distance in the Alameda Creek watershed as well (Stillwater Sciences 2012). Reduced connectivity among sites leads to lower gene flow and a loss of genetic diversity through genetic drift, which can diminish adaptability to changing environmental conditions (Palstra and Ruzzante 2008). Peek (2011) posits that given the *R. boylii* species group is estimated to be 8 million years old (Macey et al. 2001), the significant reductions in connectivity and genetic diversity over short evolutionary time periods in regulated rivers (often less than 50 years from the time of dam construction) is cause for concern, particularly when combined with small population sizes.

Habitat Associations and Use

> *"These frogs are so closely restricted to streams that it is unusual to find one at a greater distance from the water than it could cover in one or two leaps."* – Richard G. Zweifel, 1955

Foothill Yellow-legged Frogs inhabit rivers and streams ranging from primarily rain-fed (coastal populations) to primarily snow-influenced (most Sierra Nevada and Klamath-Cascade populations) from headwater streams to large rivers (Bury and Sisk 1997, Wheeler et al. 2014). Occupied rivers and streams flow through a variety of vegetation types including hardwood, conifer, and valley-foothill riparian forests; mixed chaparral; and wet meadows (Hayes et al. 2016). Because the species is so widespread and can be found in so many types of habitats, the vegetation community is likely less important in determining Foothill Yellow-legged Frog occupancy and abundance than the aquatic biotic and abiotic conditions in the specific river, stream, or reach (Zweifel 1955). The species is an obligate stream-breeder, which sets it apart from other western North American ranids (Wheeler et al. 2014). Foothill Yellow-legged Frog habitat is generally characterized as partly-shaded, shallow, perennial rivers and streams with a low gradient and rocky substrate that is at least cobble-sized (Zweifel 1955, Hayes and Jennings 1988). However, the use of intermittent and ephemeral streams by post-metamorphic Foothill Yellow-legged Frogs may not be all that uncommon in some parts of the species' range in California (R. Bourque pers. comm. 2019). The species has been reported from some atypical habitats as well, including ponds, isolated pools in intermittent streams, and meadows along the edge of streams that lack a rocky substrate (Fitch 1938, Zweifel 1955, J. Alvarez pers. comm. 2017, CDFW 2018a).

As stream-breeding poikilotherms (animals whose internal temperature varies with ambient temperature), appropriate flow velocity, temperature, and water availability are critically important to Foothill Yellow-legged Frogs (Kupferberg 1996a, Van Wagner 1996, Wheeler et al. 2006, Lind et al. 2016). Habitat quality is also influenced by hydrologic regime (regulated vs. unregulated), substrate, presence of non-native predators and competitors, water depth, and availability of high-quality food and basking sites (Lind et al. 1996, Yarnell 2005, Wheeler et al. 2006, Catenazzi and Kupferberg 2017). Habitat suitability and use vary by life stage, sex, geographic location, watershed size, and season and

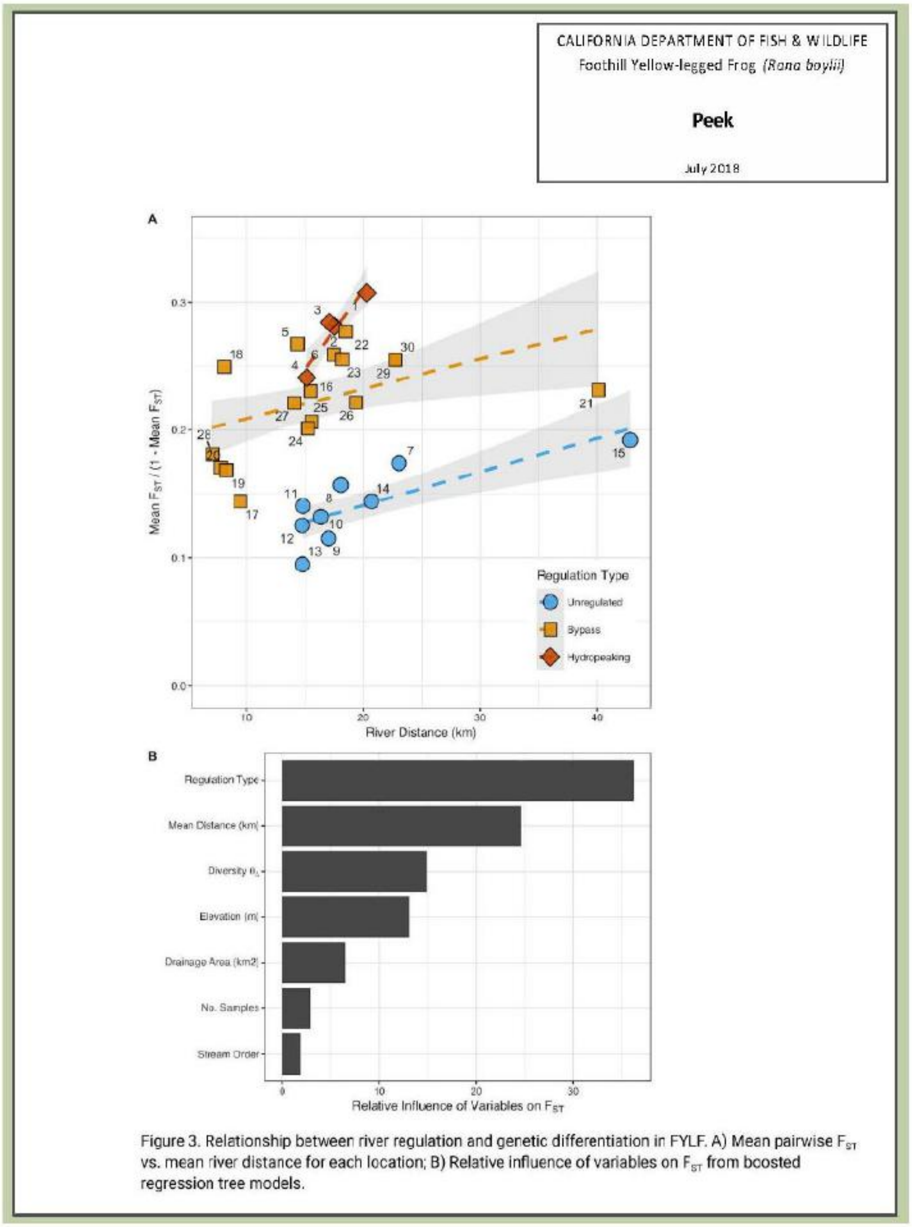


Figure 3. Relationship between river regulation and genetic differentiation in FYLF. A) Mean pairwise F_{ST} vs. mean river distance for each location; B) Relative influence of variables on F_{ST} from boosted regression tree models.

Figure 4. River regulation's relative influence on genetic differentiation from Peek (2018)

can generally be categorized as breeding and rearing habitat, nonbreeding active season habitat, and overwintering habitat (Van Wagner 1996, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011, Hayes et al. 2016, Catenazzi and Kupferberg 2017). Yarnell (2005) located higher densities of Foothill Yellow-legged Frogs in areas with greater habitat heterogeneity and suggested that they were selecting ~~for~~ sites that possessed the diversity of habitats necessary to support each life stage within a relatively short distance.

Breeding and Rearing Habitat

Suitable breeding habitat must be connected to suitable rearing habitat for metamorphosis to be successful. When this connectivity exists, as flows decline through the season, tadpoles can follow the receding shoreline into areas of high productivity and lower predation risk as opposed to becoming trapped in isolated pools with a high risk of overheating, desiccation, and predation (Kupferberg et al. 2009c).

Several studies on Foothill Yellow-legged Frog breeding habitat, carried out across the species' range in California, reported similar findings. Foothill Yellow-legged Frogs select oviposition (egg-laying) sites within a narrow range of depths, velocities, and substrates and exhibit fidelity to breeding sites that consistently possess suitable microhabitat characteristics over time (Kupferberg 1996a, Bondi et al. 2013, Lind et al. 2016). At a coarse-spatial scale, breeding sites in rivers and large streams are often located near the confluence of tributary streams in sunny, wide, shallow reaches (Kupferberg 1996a, Yarnell 2005, GANDA 2008, Peek 2011). These areas are highly productive compared to cooler, deeper, closed-canopy sites (Catenazzi and Kupferberg 2013). At a fine-spatial scale, females prefer to lay eggs in low velocity areas dominated by cobble- and boulder-sized substrates, often associated with sparsely-vegetated point bars (Kupferberg 1996a, Lind et al. 1996, Van Wagner 1996, Bondi et al. 2013, Lind et al. 2016). They tend to select areas with less variable, more stable flows, and in areas with higher flows at the time of oviposition, they place their eggs on the downstream side of large cobblestones and boulders, which protects them from being washed away (Kupferberg 1996a, Wheeler et al. 2006).

Appropriate rearing temperatures are vital for successful metamorphosis. Tadpoles grow faster and larger in warmer water to a point (Zweifel 1955; Catenazzi and Kupferberg 2017, 2018). Zweifel (1955) conducted experiments on embryonic thermal tolerance and determined that the critical low was approximate 6°C (43°F), and the critical high was around 26°C (79°F). Welsh and Hodgson (2011) determined that best the single variable for predicting Foothill Yellow-legged Frog presence was temperature since none were observed below 13°C (55°F), but numbers increased significantly with increasing temperature. Catenazzi and Kupferberg (2013) measured tadpole thermal preference at 16.5-22.2°C (61.7-72.0°F), and the distribution of Foothill Yellow-legged Frog populations across a watershed was consistent within this temperature range. At temperatures below 16°C (61°F), tadpoles were absent under closed canopy and scarce even with an open canopy (Ibid.). Catenazzi and Kupferberg (2017) found regional differences in apparently suitable breeding temperatures. Inland populations from primarily snowmelt-fed systems with relatively cold water were relegated to reaches that are warmer on average during the warmest 30 days of the year than coastal populations in the chiefly rainfall-fed, and thus warmer, systems (17.6-24.2°C [63.7-75.6°F] vs. 15.7-22.0°C [60.3-71.6°F], respectively).

However, experiments on tadpole thermal preference demonstrated that individuals from different source populations selected similar rearing temperatures, which presumably optimized development (Ibid.). In regulated systems, where water released from dams is often colder than normal, suitable rearing temperatures downstream may be limited (Wheeler et al. 2014, Catenazzi and Kupferberg 2017).

Appropriate flow velocities are also critical for survival to metamorphosis. The velocity at which Foothill Yellow-legged Frog egg masses shear away from the substrate they are adhered to varies according to factors such as depth and degree to which the eggs are sheltered (Spring Rivers Ecological Sciences 2003). This critical velocity is expected to decrease as the egg mass ages due to their reduced structural integrity of the protective jelly envelopes (Hayes et al. 2016). Short-duration increases in flow velocity may be tolerated if the egg masses are somewhat sheltered, but sustained high velocities increase the likelihood of detachment (Kupferberg 1996a, Spring Rivers Ecological Sciences 2003). Hatchlings and tadpoles about to undergo metamorphosis are relatively poor swimmers and require especially slow, stable flows during these stages of development (Kupferberg et al. 2011b). Tadpoles respond to increasing flows by swimming against the current to maintain position for a short period of time and eventually swimming to the bottom and seeking refuge in the rocky substrate's interstitial spaces (Ibid.). When tadpoles are exposed to repeated increases in velocities, their growth and development are delayed (Ibid.). Under experimental conditions, the critical velocity at which tadpoles were swept downstream ranged between 20 and 40 cm/s (0.66-1.31 ft/s); however, as they reach metamorphosis it decreases to as low as 10 cm/s (0.33 ft/s) (Ibid.).

Nonbreeding Active Season Habitat

Post-metamorphic Foothill Yellow-legged Frogs utilize a more diverse range of habitats and are much more dispersed during the nonbreeding active season than the breeding season. Microhabitat preferences appear to vary by location and season, but some patterns are common across the species' range. Foothill Yellow-legged Frogs tend to remain close to the water's edge (average < 3 m [10 ft]); select sunny areas with limited canopy cover; and are often associated with riffles and pools (Zweifel 1955, Hayes and Jennings 1988, Van Wagner 1996, Welsh et al. 2005, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011). Adequate water, food resources, cover from predators, ability to thermoregulate (e.g., presence of basking sites and cool refugia), and absence of non-native predators are important components of nonbreeding active season habitat (Hayes and Jennings 1988, Van Wagner 1996, Catenazzi and Kupferberg 2013).

Overwintering Habitat

Overwintering habitat varies depending on local conditions, but as with the rest of the year, Foothill Yellow-legged Frogs are most often found in or near water where they can forage and take cover from predators and high discharge events (Storer 1925, Zweifel 1955). In larger streams and rivers, Foothill Yellow-legged Frogs are often found along tributaries during the winter where the risk of being displaced by heavy flows is reduced (Kupferberg 1996a, Gonsolin 2010). Bourque (2008) found 36.4% of adult females used intermittent and ephemeral tributaries during the overwintering season. Van

Wagner (1996) located most overwintering frogs using pools with cover such as boulders, root wads, and woody debris. During high flow events, they moved to the stream's edge and took cover under vegetation like sedges (*Carex* sp.) or leaf litter (Ibid.). Rombough (2006) found most Foothill Yellow-legged Frogs under woody debris along the high-water line and often using seeps along the stream-edge, which provided them with moisture, a thermally stable environment, and prey.

Exceptions to the pattern of remaining near the stream's edge during winter have been reported. Cook et al. (2012) observed dozens of juvenile Foothill Yellow-legged Frogs traveling over land, as opposed to using riparian corridors. They were found using upland habitats with an average distance of 71.3 m (234 ft) from water (range: 16-331 m [52-1,086 ft]) (Ibid.). In another example, a single subadult that was found adjacent to a large wetland complex 830 m (2,723 ft) straight-line distance from the wetted edge of the Van Duzen River, although it is possible the wetland was connected to the river via a spillway or drainage that may have served as the movement corridor (CDFW 2018a, R. Bourque pers. comm. 2019).

Seasonal Activity and Movements

Because Foothill Yellow-legged Frogs occupy areas with relatively mild winter temperatures, they can be active year-round, although at low temperatures (< 7°C [44 °F], they become lethargic (Storer 1925, Zweifel 1955, Van Wagner 1996, Bourque 2008). They are active both day and night, and during the day adults are often observed basking on warm objects such as sun-heated rocks, although this is also when their detectability is highest (Fellers 2005, Wheeler et al. 2005). By contrast, Gonsolin (2010) tracked radio-telemetered Foothill Yellow-legged Frogs under substrate a third of the time and underwater a quarter of the time, although nearly all his detections of frogs without transmitters were basking.

Adult Foothill Yellow-legged Frogs migrate from their overwintering sites to breeding habitat in the spring, often from a tributary to its confluence with a larger stream or river. In areas where tributaries dry down, juveniles also make this downstream movement (Haggarty 2006). When the tributary itself is perennial and provides suitable breeding habitat, the frogs may not undertake these long-distance movements (Gonsolin 2010). Cues for adults to initiate this migration to breeding sites are somewhat enigmatic and vary by location, elevation, and amount of precipitation (S. Kupferberg and A. Lind pers. comm. 2017). They can also include day length, water temperature, and sex (GANDA 2008, Gonsolin 2010, Yarnell et al. 2010, Wheeler et al. 2018). Males initiate movements to breeding sites where they congregate in leks (areas of aggregation for courtship displays), and females arrive later and over a longer period (Wheeler and Welsh 2008, Gonsolin 2010). Most males utilize breeding sites associated with their overwintering tributaries, but some move substantial distances to other sites and may use more than one breeding site in the same season (Wheeler and Welsh 2006, GANDA 2008).

While the predictable hydrograph in California consists of wet winters with high flows and dry summers with low flows, the timing and quantity of seasonal discharge can vary significantly from year to year. The timing of oviposition can influence offspring growth and survival. Early breeders risk scouring of egg masses from their substrate by late spring storms in wet years or desiccation if waters recede rapidly, but when they successfully hatch, tadpoles benefit from a longer growing season, which can enable them to metamorphose at a larger size and increase their likelihood of survival (Railsback et al. 2016).

Later breeders are less likely to have their eggs scoured away or desiccated because flows are generally more stable, but they have fewer mate choices, and their tadpoles have a shorter growing period before metamorphosis, reducing their chance of survival (Ibid.). Some evidence indicates larger females, who coincidentally lay larger clutches, breed earlier (Kupferberg et al. 2009c, Gonsolin 2010). Consequently, early season scouring or stranding of egg masses or tadpoles can disproportionately impact the population's reproductive output because later breeders produce fewer and smaller eggs per clutch (Kupferberg et al. 2009c, Gonsolin 2010).

Timing of oviposition is often a function of water temperature and flow, but it consistently occurs on the descending limb of the hydrograph which corresponds to high winter discharge gradually receding toward low summer baseflow (Kupferberg 1996a, GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010, Yarnell et al. 2010). Under natural conditions, the timing coincides with intermittent tributaries drying down and increases in algal blooms that provide forage for tadpoles (Haggarty 2006, Power et al. 2008). At lower elevations, breeding can start in late March or early April, and at mid-elevations, breeding typically occurs in mid-May to mid-June (Gonsolin 2010, S. Kupferberg and A. Lind pers. comm. 2017). The time of year a population initiates breeding can vary by a month among water years, occurring later at deeper sites when colder water becomes warmer (Wheeler et al. 2018). In wetter years, delayed breeding into early July can occur in some colder snowmelt systems (S. Kupferberg and A. Lind pers. comm. 2017, GANDA 2018).

A population's period of oviposition can also vary from two weeks to three months, meaning they could be considered explosive breeders at some sites and prolonged breeders at others (Storer 1925, Zweifel 1955, Van Wagner 1996, Ashton et al. 1997, Wheeler and Welsh 2008). Water temperature typically warms to over 10°C (50°F) before breeding commences (GANDA 2008, Gonsolin 2010, Wheeler et al. 2018). Wheeler and Welsh (2008) observed Foothill Yellow-legged Frogs breeding when flows were below 0.6 m/s (2 ft/s), pausing during increased flows until they receded, and GANDA (2008) reported breeding initiated when flow decreased to less than 55% above baseflow.

Male Foothill Yellow-legged Frogs spend more time at breeding sites during the season than females, many of whom leave immediately after laying their eggs (GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010). Daily movements are usually short (< 0.3 m [1 ft]), but some individuals travel substantial distances: median 70.7 m/d (232 ft/d) in spring and 37.1 m/d (104 ft/day) in fall/winter, nearly always using streams as movement corridors (Van Wagner 1996, Bourque 2008, Gonsolin 2010). The maximum reported movement rate is 1,386 m/d (0.86 mi/d), and the longest seasonal (post-breeding) daily distance reported is 7.04 km (4.37 mi) by a female that traveled up a dry tributary and over a ridge before returning to and moving up the mainstem creek (Bourque 2008). Movements during the non-breeding season are typically in response to drying channels or during rain events (Bourque 2008, Gonsolin 2010, Cook et al. 2012).

Hatchling Foothill Yellow-legged Frogs tend to remain with what is left of the egg mass for several days before dispersing into the interstitial spaces in the substrate (Ashton et al. 1997). They often move downstream in areas of moderate flow and will follow the location of warm water in the channel throughout the day (Brattstrom 1962, Ashton et al. 1997, Kupferberg et al. 2011a). Tadpoles usually

metamorphose in late August or early September (S. Kupferberg and A. Lind pers. comm. 2017). Twitty et al. (1967) reported that newly metamorphosed Foothill Yellow-legged Frogs mostly migrated upstream, which may be an evolutionary mechanism to return to their natal site after being washed downstream (Ashton et al. 1997).

Home Range and Territoriality

Foothill Yellow-legged Frogs exhibit a lek-type mating system in which males aggregate at the breeding site and establish calling territories (Wheeler and Welsh 2008, Bondi et al. 2013). The species has a relatively large calling repertoire for western North American ranids with seven unique vocalizations recorded (Silver 2017). Some of these can be reasonably attributed to territory defense and mate attraction communications (MacTeague and Northen 1993, Silver 2017). Physical aggression among males during the breeding season has been reported (Rombough and Hayes 2007, Wheeler and Welsh 2008). In addition, Wheeler and Welsh (2008) observed a non-random mating pattern in which males engaged in amplexus with females were larger than males never seen in amplexus, suggesting either physical competition or female preference for larger individuals. Very little information has been published on Foothill Yellow-legged Frog home range size. Wheeler and Welsh (2008) studied males during a 17-day period during breeding season and classified some of them as "site faithful" based on their movements and calculated their home ranges. Two-thirds of males tracked were site faithful, and their mean home range size was 0.58 m^2 (SE = 0.10 m^2; 6.24 ft^2 [SE = 1.08 ft^2]) (Ibid.). In contrast, perhaps because the study took place over a longer time period, Bourque (2008) reported approximately half of the males he tracked during the spring were mobile, and the other half were sedentary. The median distances traveled along the creek (a proxy for home range size since they rarely leave the riparian corridor) for mobile and sedentary males were 149 m (489 ft) and 5.5 m (18 ft), respectively.

Diet and Predators

Foothill Yellow-legged Frog diet varies by life stage and likely body size. Tadpoles graze on periphyton (algae growing on submerged surfaces) scraped from rocks and vegetation and grow faster, and to a larger size, when it contains a greater proportion of epiphytic diatoms with nitrogen-fixing endosymbionts (*Epithemia* spp.), which are high in protein and fat (Kupferberg 1997b, Fellers 2005, Hayes et al. 2016, Catennazi and Kupferberg 2017). Tadpoles may also forage on necrotic tissue from dead bivalves and other tadpoles, or more likely the algae growing on them (Ashton et al. 1997, Hayes et al. 2016). Post-metamorphic Foothill Yellow-legged Frogs primarily feed on a wide variety of terrestrial arthropods but also some aquatic invertebrates (Fitch 1936, Van Wagner 1996, Haggarty 2006). Most of their diet consists of insects and arachnids (Van Wagner 1996, Haggarty 2006, Hothem et al. 2009). Haggarty (2006) did not identify any preferred taxonomic groups, but she noted larger Foothill Yellow-legged Frogs consumed a greater proportion of large prey items compared to smaller individuals, suggesting the species may be gape-limited generalist predators. Hothem et al. (2009) found mammal hair and bones in a Foothill Yellow-legged Frog. Adult Foothill Yellow-legged Frogs, like many other ranids, also cannibalize conspecifics (Wiseman and Bettaso 2007). In the fall when young-of-year are abundant, they may provide an important source of nutrition for adults prior to overwintering (Ibid.).

Foothill Yellow-legged Frogs are preyed upon by several native and introduced species, including each other as described above. Some predators target specific life stages, while others may consume multiple stages. Several species of garter snakes (genus *Thamnophis*) are the primary and most widespread group of native predators on Foothill Yellow-legged Frog~~s~~ tadpoles through adults ~~is~~ (Fitch 1941, Fox 1952, Zweifel 1955, Lind and Welsh 1994, Ashton et al. 1997, Wiseman and Bettaso 2007, Gonsolin 2010). Table 1 lists other known and suspected predators of Foothill Yellow-legged Frogs.

Table 1. Confirmed and potential Foothill Yellow-legged Frog predators in California in addition to gartersnakes (*Thamnophis* spp.)

Common Name	Scientific Name	Classification	Native	Prey Life Stage(s)	Sources
Caddisfly (larva)	*Dicosmoecus gilvipes*	Insect	Yes	Embryos (eggs)	Rombough and Hayes 2005
Dragonfly (nymph)	*Aeshna walker*	Insect	Yes	Larvae	Catenazzi and Kupferberg 2018
Waterscorpion	*Ranatra brevicollis*	Insect	Yes	Larvae	Catenaazi and Kupferberg 2018
Signal Crayfish	*Pacifastacus leniusculus*	Crustacean	No	Embryos (eggs) and Larvae	Rombough and Hayes 2005; Wiseman et al. 2005
Speckled Dace	*Rhinichthys osculus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Reticulate Sculpin	*Cottus perplexus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Sacramento Pike Minnow	*Ptychocheilus grandis*	Fish	Yes*	Embryos (eggs) and Adults	Ashton and Nakamoto 2007
Sunfishes	Family Centrachidae	Fish	No	Larvae	Moyle (1973); Hayes and Jennings 1986
Catfishes	Family Ictaluridae	Fish	No	Larvae	Moyle (1973); Hayes and Jennings 1986
Rough-skinned Newt	*Taricha granulosa*	Amphibian	Yes	Embryos (eggs)	Evenden 1948
California Giant Salamander	*Dicamptodon ensatus*	Amphibian	Yes	Larvae	Fidenci 2006
American Bullfrog	*Rana catesbeiana*	Amphibian	No	Larvae to Adults	Crayon 1998; Hothem et al. 2009
California Red-legged Frog	*Rana draytonii*	Amphibian	Yes	Larvae to Adults	Gonsolin 2010
American Robin	*Turdus migratorius*	Bird	Yes	Larvae	Gonsolin 2010
Common Merganser	*Mergus merganser*	Bird	Yes	Larvae	Gonsolin 2010
American Dipper	*Cinclus mexicanus*	Bird	Yes	Larvae	Ashton et al. 1997
Mallard	*Anas platyrhynchos*	Bird	Yes	Adults	Rombough et al. 2005
Raccoon	*Procyon lotor*	Mammal	Yes	Larvae to Adults	Zweifel 1955; Ashton et al. 1997
River Otter	*Lontra canadensis*	Mammal	Yes	Adults	T. Rose pers. comm. 2014

* Introduced to the Eel River, location of documented predation; Foothill Yellow-legged Frogs are extirpated from most areas of historical range overlap

STATUS AND TRENDS IN CALIFORNIA

Administrative Status

Sensitive Species

The Foothill Yellow-legged Frog is listed as a Sensitive Species by the U.S. Bureau of Land Management (BLM) and U.S. Forest Service (Forest Service). These agencies define Sensitive Species as those species that require special management consideration to promote their conservation and reduce the likelihood and need for future listing under the ESA.

California Species of Special Concern

The Department's Species of Special Concern (SSC) designation is similar to the federal Sensitive Species designation. It is administrative, rather than regulatory in nature, and intended to focus attention on animals at conservation risk. The designation is used to stimulate needed research on poorly known species and to target the conservation and recovery of these animals before they meet the CESA criteria for listing as threatened or endangered (Thomson et al. 2016). The Foothill Yellow-legged Frog is listed as a Priority 1 (highest risk) SSC (Ibid.).

Trends in Distribution and Abundance

Range-wide in California

Range is the general geographical area in which an organism occurs. For purposes of CESA and this Status Review, the range is the species' California range (*Cal. Forestry Assn. v. Cal. Fish and Game Com.* (2007) 156 Cal.App.4th 1535, 1551). Systematic, focused, range-wide assessments of Foothill Yellow-legged Frog distribution and abundance are rare, both historically and contemporarily. A detailed account of what has been documented within the National Parks and National Forests in California can be found in Appendix 3 of the *Foothill Yellow-legged Frogs Conservation Assessment in California* (Hayes et al. 2016).

Most Foothill Yellow-legged Frog records are incidental observations made during stream surveys for ESA-listed salmonids and simply document presence at a particular date and location, although some include counts or estimates of abundance by life stage. This makes assessing trends in distribution and abundance difficult despite a relatively large number of observations compared to many other species tracked by the California Natural Diversity Database (CNDDB). The CNDDB contained 2,366 Foothill Yellow-legged Frog occurrences in its March 2019 edition, 500 of which are documented from the past 5 years.

A few wide-ranging survey efforts that included Foothill Yellow-legged Frogs exist. Reports from early naturalists suggest Foothill Yellow-legged Frogs were relatively common in the Coast Ranges as far south as central Monterey County, in eastern Tehama County, and in the foothills in and near Yosemite National Park (Grinnell and Storer 1924, Storer 1925, Grinnell et al. 1930, Martin 1940). In addition to

these areas, relatively large numbers of Foothill Yellow-legged Frogs (17-35 individuals) were collected at sites in the central and southern Sierra Nevada and the San Gabriel Mountains between 1911 and 1950 (Hayes et al. 2016). Widespread disappearances of Foothill Yellow-legged Frog populations were documented as early as the 1970s and 80s in southern California, the southern Coast Range, and the central and southern Sierra Nevada foothills (Moyle 1973, Sweet 1983).

Twenty-five years ago, the Department published the first edition of *Amphibians and Reptile Species of Special Concern in California* (Jennings and Hayes 1994). The authors revisited hundreds of localities between 1988 and 1991 that had historically been occupied by Foothill Yellow-legged Frogs ~~between 1988 and 1991~~ and consulted local experts to determine presumed extant or extirpated status. Based on these survey results and stressors observed on the landscape, they considered Foothill Yellow-legged Frogs endangered in central and southern California south of the Salinas River in Monterey County. They considered the species threatened in the west slope drainages of the Cascade Mountains and Sierra Nevada east of the Central Valley, and they considered the remainder of the range to be of special concern (Ibid.).

Fellers (2005) and his field crews conducted surveys for Foothill Yellow-legged Frogs throughout California. They visited 804 sites across 40 counties with suitable habitat within the species' historical range. They detected at least one individual at 213 sites (26.5% of those surveyed) over 28 counties. They located Foothill Yellow-legged Frogs in approximately 40% of streams in the North Coast, 30% in the Cascade Mountains and south of San Francisco in the Coast Range, and 12% in the Sierra Nevada. Fellers estimated population abundance was 20 or more adults at only 14% of the sites where the species was found and noted the largest and most robust populations occurred along the North Coast. In addition, to determine status of Foothill Yellow-legged Frogs across the species' range and potential causes for declines, Lind (2005) used previously published status accounts, species expert and local biologist professional opinions, and field visits to historically occupied sites between 2000-2002. She determined that Foothill Yellow-legged Frogs had disappeared from 201 of 394 of the sites, representing just over 50%. The coarse-scale trend in California is one of greater population declines and extirpations in lower elevations and latitudes (Davidson et al. 2002).

Few site-specific population trend data are available from which to evaluate status. However, long-term monitoring efforts often use egg mass counts as a proxy to estimate adult breeding females. The results of these studies often reveal extreme interannual variability in number of egg masses laid (Ashton et al. 2010, S. Kupferberg and M. Power pers. comm. 2015, Peek and Kupferberg 2016). In a meta-analysis of egg mass count data collected across the species' range in California over the past 25 years, Peek and Kupferberg (2016) reported declines in two unregulated rivers and an increase in another. Their models did not detect any significant trends in abundance across different locations or regulation type (dammed or undammed); however, high interannual variability can render trend detection difficult. Interannual variability was substantially greater in regulated rivers vs. unregulated; the median coefficient of variation was 66.9% and 41.6%, respectively (Ibid.). The greater variability in regulated rivers decreases the probability of detecting significant declines, and coupled with low abundance, it can lead to populations dropping below a density necessary for persistence without detection, resulting in extirpation.

Regional differences in Foothill Yellow-legged Frog persistence across its range have been recognized for nearly 50 years (i.e., more extirpations documented in the south). Because of these differences and the recent availability of new landscape genomic data, more detailed descriptions of trends in Foothill Yellow-legged Frog population distribution and abundance in California are evaluated by clade below. Figure 5 depicts Foothill Yellow-legged Frog localities across all clades in California by the most recent confirmed sighting in the datasets available to the Department within a Public Lands Survey System (PLSS) section. "Transition Zones" are those areas where the exact clade boundaries are unknown due to a lack of samples. In addition, while not depicted as an area of uncertainty, no genetic samples have been tested south of the extant population in northern San Luis Obispo County, in the Sutter Buttes in Sutter County, or northeastern Plumas County. It is possible there were historically more clades than currently understood.

Caution should be exercised in comparing the following observation data across the species' range and across time since survey effort and reporting are not standardized. These data can be useful for making some general inferences about distribution, abundance, and trends. For instance, assuming the observation correctly identifies the species, the date on the record is the last time the species was confirmed to have occurred at that location. However, this only works in the affirmative. For example, at a site where the last time the species was seen was 75 years ago, the species may still persist there if no one has surveyed it since the original observation. CNDDB staff use information on land use conversion, follow-up visits, and biological reports to categorize an occurrence location as "extirpated" or "possibly extirpated".

Northwest/North Coast Clade

This clade extends from north of San Francisco Bay through the Coast Range and Klamath Mountains to the northern limit of the Foothill Yellow-legged Frog's range and east through the Cascade Range. It includes Del Norte, Siskiyou, Humboldt, Trinity, Shasta, Tehama, Mendocino, Glenn, Colusa, Lake, Sonoma, Napa, Yolo, Solano, and Marin counties. This clade covers the largest geographic area and contains the greatest amount of genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). In addition, it is the only clade with an increasing trend in genetic diversity (Peek 2018).

Early records note the comparatively high abundance of Foothill Yellow-legged Frogs in this area. Storer (1925) described Foothill Yellow-legged Frogs as very common in many of Coast Range streams north of San Francisco Bay, and Cope (1879,1883 as cited in Hayes et al. 2016) noted they were "rather abundant in the mountainous regions of northern California." In addition, relatively large collections occurred over short periods of time in this region in the late 1800s and the first half of the 20th century (Hayes et al. 2016). Nineteen were taken over two weeks in 1893 along Orrs Creek, a tributary to the Russian River, and 40 from near Willits (both in Mendocino County) in 1911; 112 were collected over three days at Skaggs Spring (Sonoma County) in 1911; 57 were taken in one day along Lagunitas Creek (Marin County) in 1928; and 50 were collected in one day near Denny (Trinity County) in 1955 (Ibid.).

A few long-term Foothill Yellow-legged Frog egg mass monitoring efforts undertaken within this clade's boundaries found densities vary significantly, often based on river regulation type, and documented

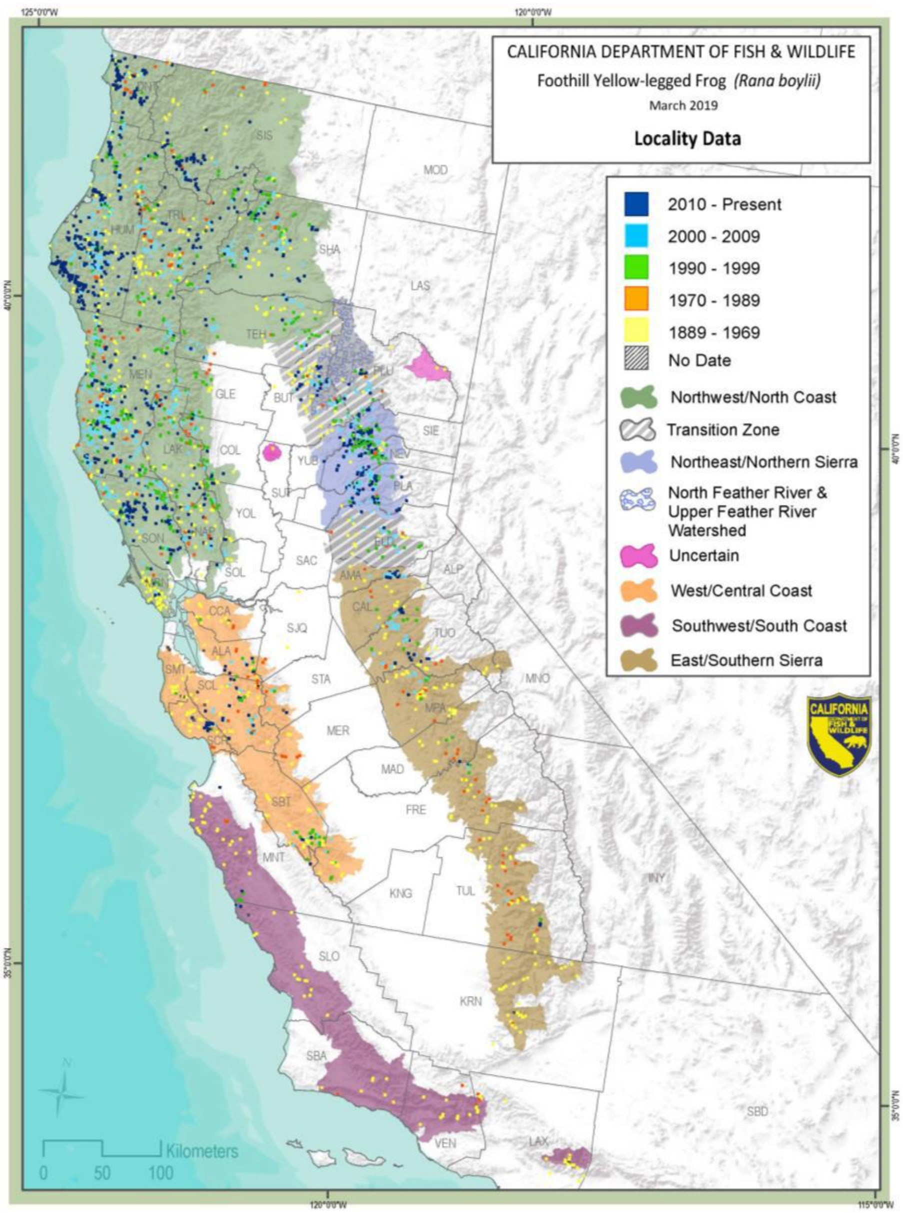


Figure 5. Foothill Yellow-legged Frog occurrence data from 1889-2019 overlaying the six clades by most recent sighting in a Public Lands Survey System section (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

several robust populations. The Green Diamond Resources Company has been monitoring a stretch of the Mad River near Blue Lake (Humboldt County) since 2008 (GDRC 2018). The greatest published density of Foothill Yellow-legged Frog egg masses was documented here in 2009 at 323.6 egg masses/km (520.7/mi) (Bourque and Bettaso 2011). However, in 2017, surveyors counted 625.1 egg masses/km (1,006/mi) along the same reach (GDRC 2018). At its lowest during this period, egg mass density was calculated at 71.54/km (115.1/mi) in 2010, although this count occurred after a flooding event that likely scoured over half of the egg masses laid that season (GDRC 2018, R. Bourque pers. comm. 2019). During a single day survey in 2017 along approximately 2 km (1.3 mi) of Redwood Creek in Redwood National Park (Humboldt County), 2,009 young and 126 adult Foothill Yellow-legged Frogs were found (D. Anderson pers. comm. 2017). Some reaches of the South Fork Eel River (Mendocino County) also support high densities of Foothill Yellow-legged Frogs. Kupferberg (pers. comm. 2018) recorded 206.9 and 106.2 egg masses/km (333 and 171/mi) along two stretches in 2016, and 201.7 and 117.5 egg masses/km (324 and 189/mi) in 2017. However, other reaches yielded counts as low as 6.1 and 8.4 egg masses/km (9.8 and 13.5/mi) (Ibid.). In the Angelo Reserve (an unregulated reach), the 24-year mean density was 109 egg masses/km (175.4/mi) (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015). In contrast, a 10-year mean density of egg masses below Lewiston Dam on the Trinity River (Trinity County) was 0.89/km (1.43/mi) (Ibid.).

Figure 6 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, Biological Information Observation System datasets, and personal communications that are color coded by the most recent date of detection. Within this clade, Foothill Yellow-legged Frogs were observed in at least 343 areas in the past 5 years (CNDDB 2019). The species remains widespread within many watersheds, although most observations only verify presence, or fewer than ten individuals or egg masses are recorded (Ibid.). Documented extirpations are comparatively rare, but also likely undetected or under-reported, and nearly all occurred just north of the high-populated San Francisco Bay area (Figure 7; Ibid.).

West/Central Coast

This clade extends south from the San Francisco Bay through the Diablo Range and down the peninsula through the Santa Cruz and Gabilan Mountains in the Coast Range east of the Salinas Valley. It includes most of Contra Costa, Alameda, San Mateo, Santa Cruz, Santa Clara, and San Benito counties; western San Joaquin, Stanislaus, Merced, and Fresno counties; and a small portion of eastern Monterey County. Records of Foothill Yellow-legged Frogs occurring south of San Francisco Bay did not exist until specimens were collected in 1918 around what is now Pinnacles National Park in San Benito County, and little information exists on historical distribution and abundance within this clade (Storer 1923).

Within this clade, Foothill Yellow-legged Frogs were observed in at least 24 areas in the past five years (Figure 8; CNDDB 2019). Documented and possible extirpations are concentrated around the San Francisco Bay and sites at the southern portion of the clade's range, although these may not have been resurveyed since their original observations in the 1940s through 1960s, except for a site in Pinnacles National Park that was surveyed in 1994 (Figure 9; Ibid.). In addition, although not depicted,

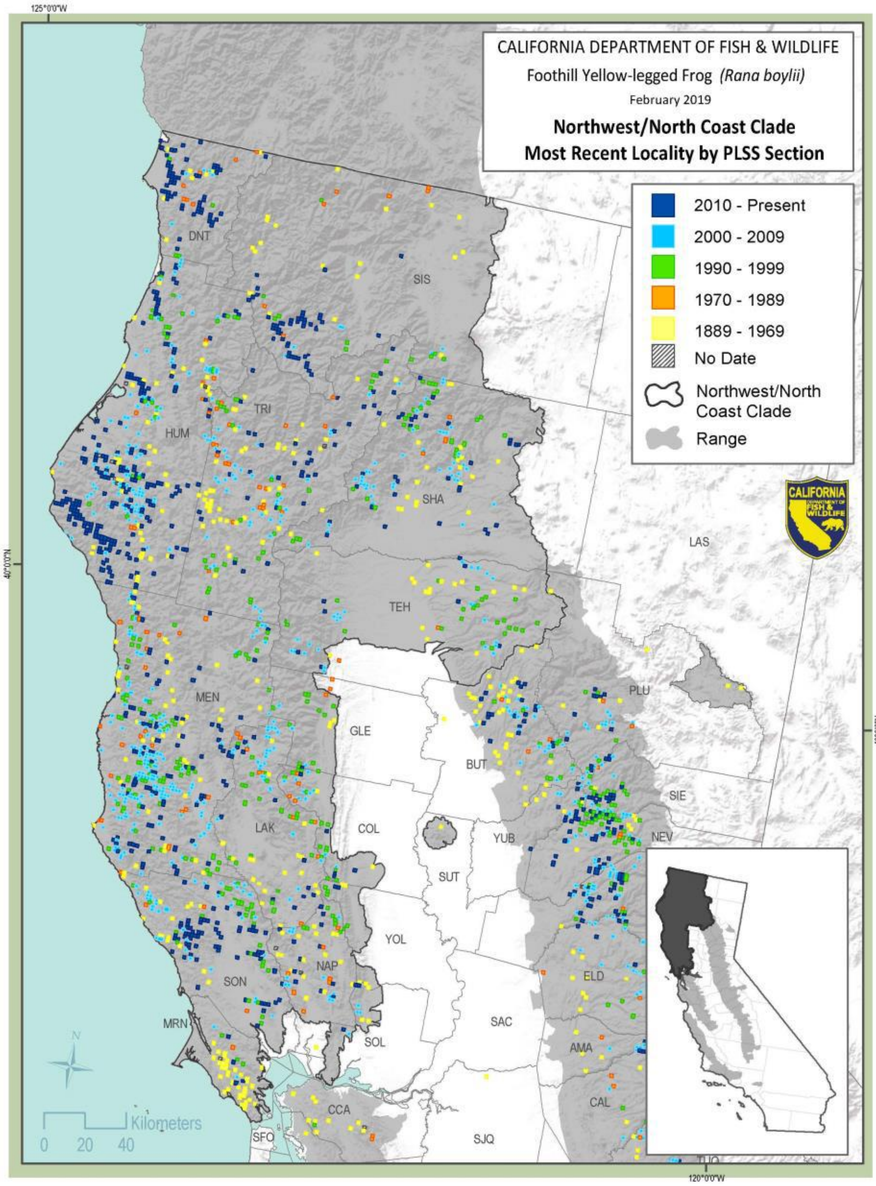


Figure 6. Close-up of Northwest/North Coast Foothill Yellow-legged Frog clade observations from 1889-2019 (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

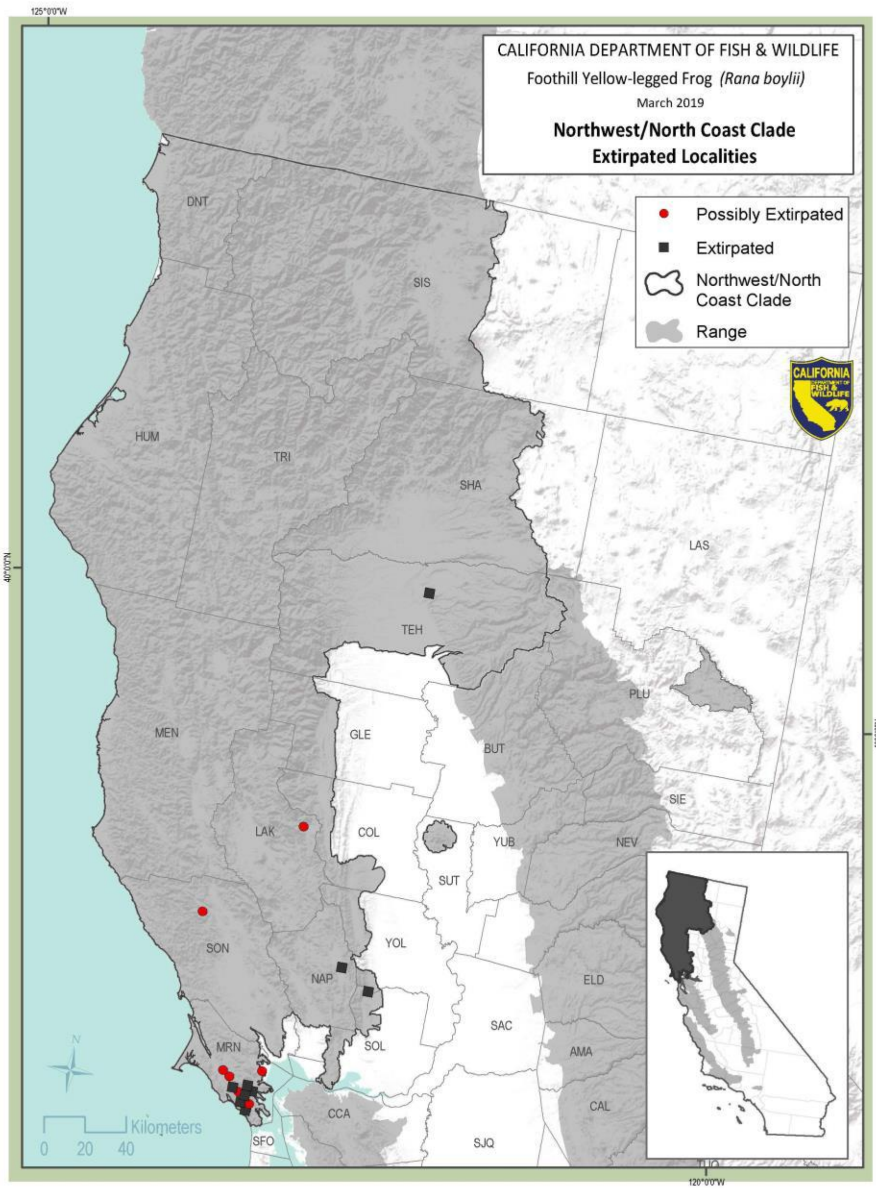


Figure 7. Possibly extirpated and extirpated Northwest/North Coast Foothill Yellow-legged Frog clade sites (CNDDB)

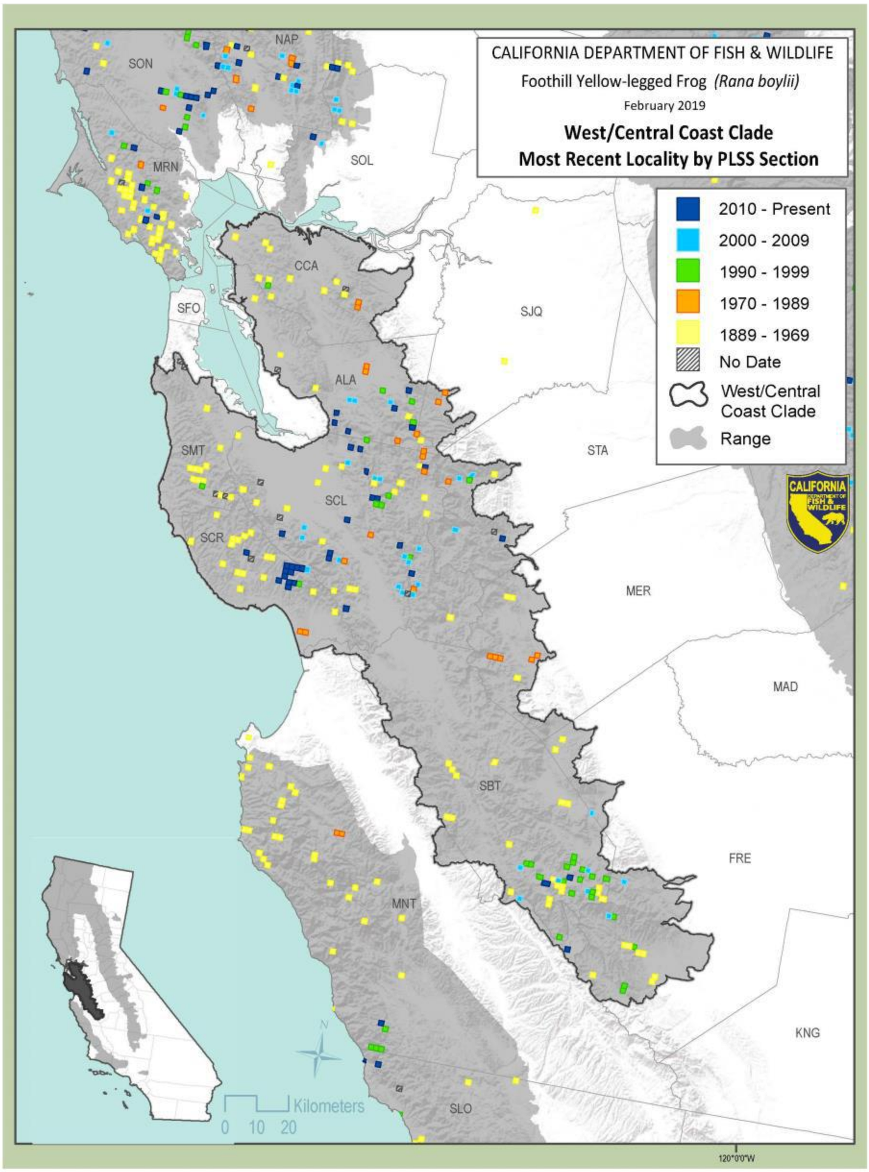


Figure 8. Close-up of West/Central Coast clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

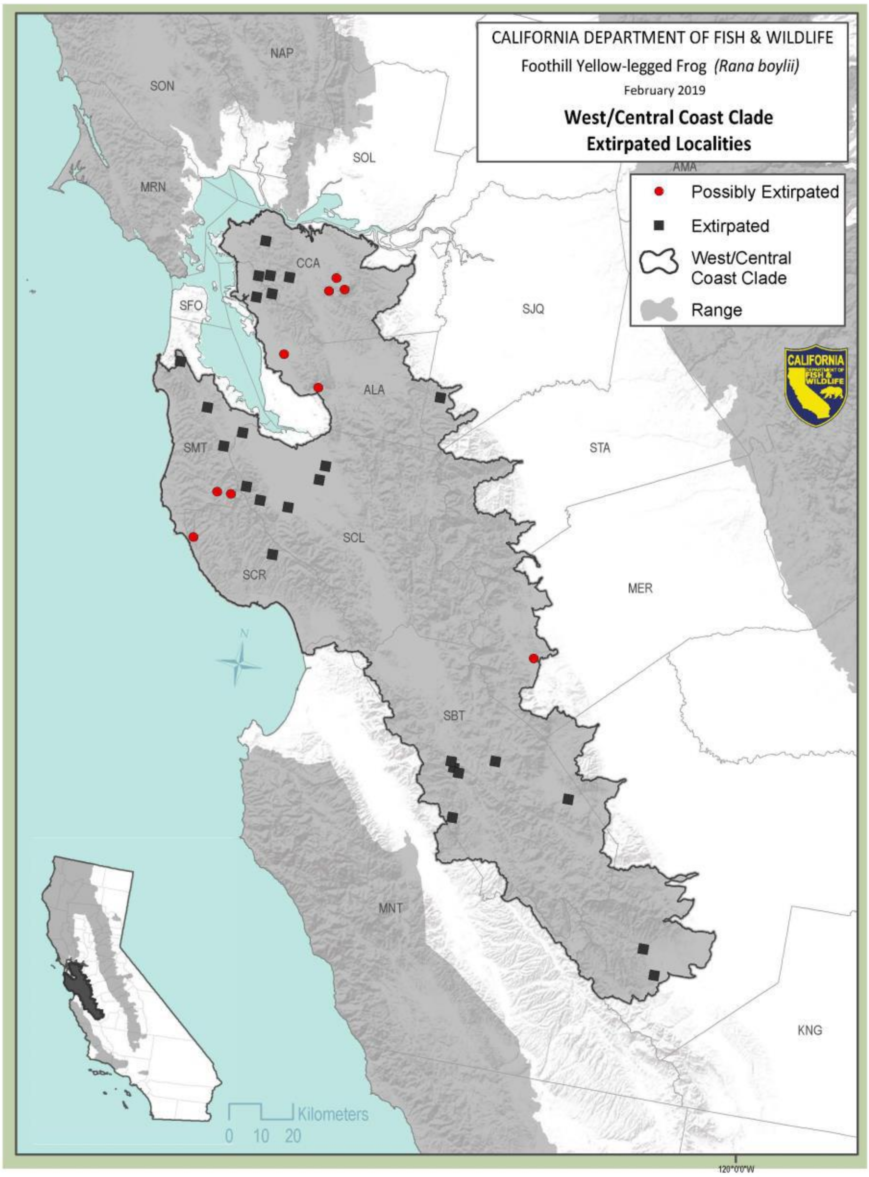


Figure 9. Possibly extirpated and extirpated West/Central Coast Foothill Yellow-legged Frog clade sites (CNDDB)

two populations on Arroyo Mocho and Arroyo Valle south of Livermore (Alameda County) are also likely extirpated (M. Grefsrud pers. comm. 2019).

The San Francisco Bay Area is heavily urbanized. Foothill Yellow-legged Frogs may be gone from Contra Costa County; eight of the nine CNDDB records from the county are museum specimens collected between 1891 and 1953, and the most recent observation was two adults in a plunge pool in an intermittent tributary to Moraga Creek in 1997. No recent (2010 or later) observations exist from San Mateo County (Ibid.). Historically occupied lower-elevation sites surrounding the San Francisco Bay and inland appear to be extirpated, but there are (or were) some moderately abundant breeding populations remaining at higher elevations in Arroyo Hondo (Alameda County), Alameda Creek (Alameda and Santa Clara counties), Coyote and Upper Llagas creeks (Santa Clara County), and Soquel Creek (Santa Cruz County) with some scattered smaller populations also persisting in these counties (J. Smith pers. comm. 2016, 2017; CNDDB 2019). The Alameda Creek and Coyote Creek populations recently underwent large-scale mortality events, so their numbers are likely substantially lower than what is currently reported in the CNDDB (Adams et al. 2017a, Kupferberg and Catenazzi 2019). In addition, the Arroyo Hondo population will lose approximately 1.6 km (1 mi) of prime breeding habitat (i.e., ~~supported~~ supporting the highest density of egg masses on the creek) as the Calaveras Reservoir is refilled following its dam replacement project in 2019 (M. Grefsrud pers. comm. 2019). Foothill Yellow-legged Frogs may be extirpated from Corral Hollow Creek in San Joaquin County, but a single individual was observed five years ago further up the drainage in Alameda County within an Off-Highway Vehicle park (CNDDB 2019). Few recent sightings of Foothill Yellow-legged Frogs in the east-flowing creeks are documented. They may still be extant in the headwaters of Del Puerto Creek (western Stanislaus County), but the records further downstream indicate bullfrogs (known predators and disease reservoirs) are moving up the system (Ibid.). Several locations in southern San Benito, western Fresno, and eastern Monterey counties have relatively recent (2000 and later) detections (Ibid.). However, while many of these sites supported somewhat large populations in the 1990s, the more recent records report fewer than ten individuals (Ibid.). The exception is a Monterey County site where around 25 to 30 were observed in 2012 (Ibid.).

Southwest/South Coast

Widespread extirpations occurred decades ago, primarily in the 1960s and 1970s, in this area (Adams et al. 2017b). As a result, genetic samples were largely unavailable, and the boundaries are speculative. The clade is presumed to include the Coast Range from Monterey Bay south to the Transverse Range across to the San Gabriel Mountains. This clade includes portions of Monterey, San Luis Obispo, Santa Barbara, Ventura, and Los Angeles counties. Storer (1923) reported that Foothill Yellow-legged Frogs were collected for the first time in Monterey County in 1919 and that a specimen collected by Cope in 1889 in Santa Barbara and listed as *Rana temporaria pretiosa* may refer to the Foothill Yellow-legged Frog because as previously mentioned, the taxonomy of this species changed several times over the first century after it was named.

Foothill Yellow-legged Frogs had been widespread and fairly abundant in this area until the late 1960s (Figure 10) but were rapidly extirpated throughout the southern Coast Ranges and western Transverse

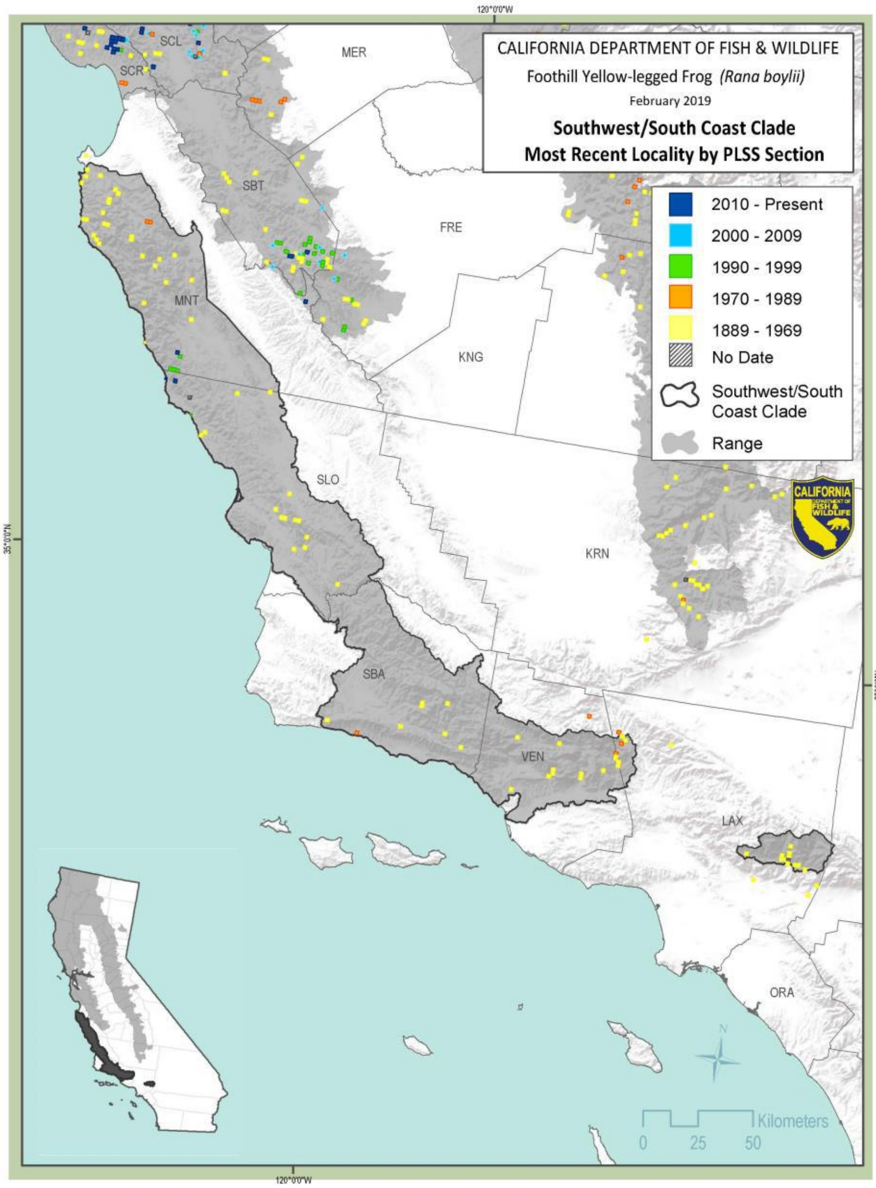


Figure 10. Close-up of Southwest/South Coast clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

Ranges by the mid-1970s (Figure 11; Sweet 1983, Adams et al. 2017b). Only two known extant populations exist from this clade, located near the border of Monterey and San Luis Obispo counties (S. Sweet pers. comm. 2017, McCartney-Melstad et al. 2018, Peek 2018, CNDDB 2019). They appear to be extremely small and rapidly losing genetic diversity, making them at high risk of extirpation (McCartney-Melstad et al. 2018, Peek 2018).

Northeast/Feather River and Northern Sierra

The exact clade boundaries in the Sierra Nevada are unclear and will require additional sampling and testing to define (Figure 12). The Northeast clade presumably encompasses the Feather River and Northern Sierra clades. The Feather River clade is located primarily in Plumas and Butte counties. The Northern Sierra clade roughly extends from the Feather River watershed south to the Middle Fork American River. It includes portions of El Dorado, Placer, Nevada, Sierra, and Plumas counties. It may also include portions of Amador, Butte, and eastern Tehama counties. No genetic samples were available to test in the Sutter Buttes or the disjunct population in northeastern Plumas County to determine which clades they belonged to before they were extirpated (Figure 13; Olson et al. 2016, CNDDB 2019).

In general, there is a paucity of historical Foothill Yellow-legged Frog data for west-slope Sierra Nevada streams, particularly in the lower elevations of the Sacramento Valley, and no quantitative abundance data exist prior to major changes in the landscape (i.e., mining, dams, and diversions) or the introduction of non-native species (Hayes et al. 2016). Foothill Yellow-legged Frogs ~~have been~~were collected frequently from the Plumas National Forest area in small numbers from the turn of the 20th century through the 1970s (Ibid.). Estimates of relative abundance are not clear from the records, but they suggest the species was somewhat widespread in this area.

More recently, Foothill Yellow-legged Frog populations in the Sierra Nevada have been the subject of a substantial number of surveys and focused research associated with recent and ongoing relicensing of hydroelectric power generating dams by the Federal Energy Regulatory Commission (FERC). Consequently, Foothill Yellow-legged Frogs have been observed in at least 30 areas in Plumas and Butte counties (roughly the Feather River clade) over the past five years (CNDDB 2019). As with the rest of the range, most records are observations of only a few individuals; however, many observations occurred over multiple years, and in some cases all life stages were observed over multiple years (Ibid). The populations appear to persist even with the small numbers reported. The only long-term consistent survey effort has been occurring on the North Fork Feather River along the Cresta and Poe reaches (GANDA 2018). The Cresta reach's subpopulation declined significantly in 2006 and never recovered despite modification of the flow regime to reduce egg mass and tadpole scouring and some habitat restoration (Ibid.). A pilot project to augment the Cresta reach's subpopulation through in situ captive rearing was initiated in 2017 (Dillingham et al. 2018). It resulted in the highest number of young-of-year Foothill Yellow-legged Frogs recorded during fall surveys since researchers started keeping count (Ibid.). The number of egg masses laid in the Poe reach varies substantially year-to-year from a low of 26 in 2001 to a high of 154 in 2015 and back down to 36 in 2017 (GANDA 2018).

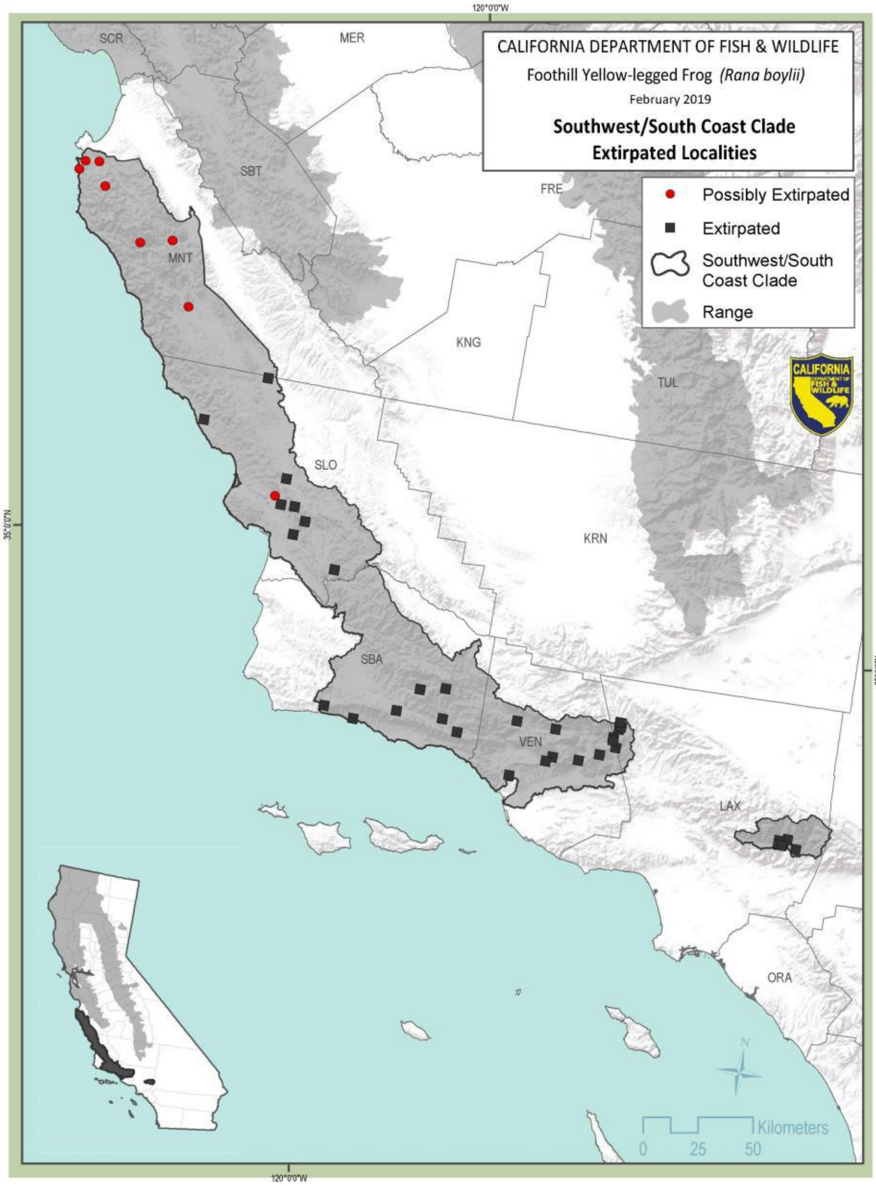


Figure 11. Possibly extirpated and extirpated Southwest/South Coast Foothill Yellow-legged Frog clade sites (CNDDB)

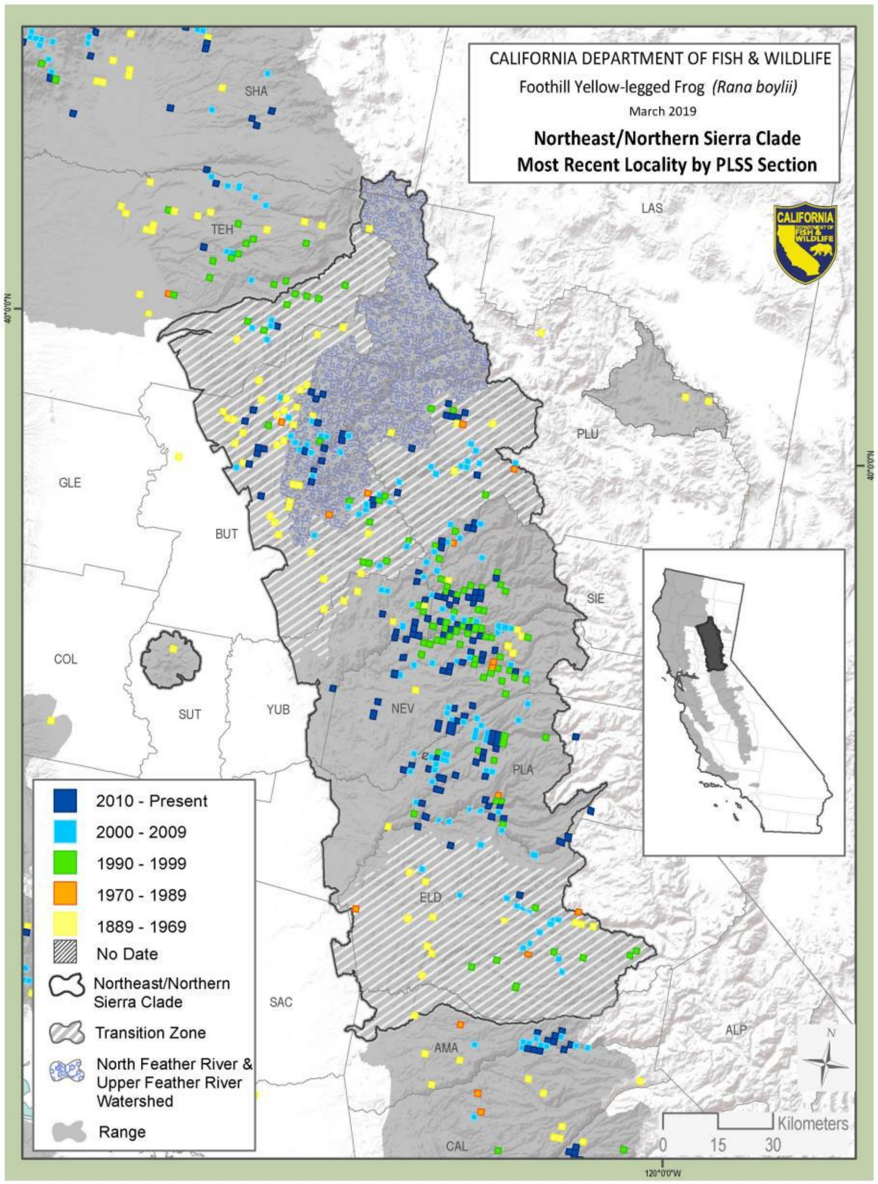


Figure 12. Close-up of Northeast/Feather River and Northern Sierra clades observations from 1889-2019 (ARSSC, BIOS, CNDDB)

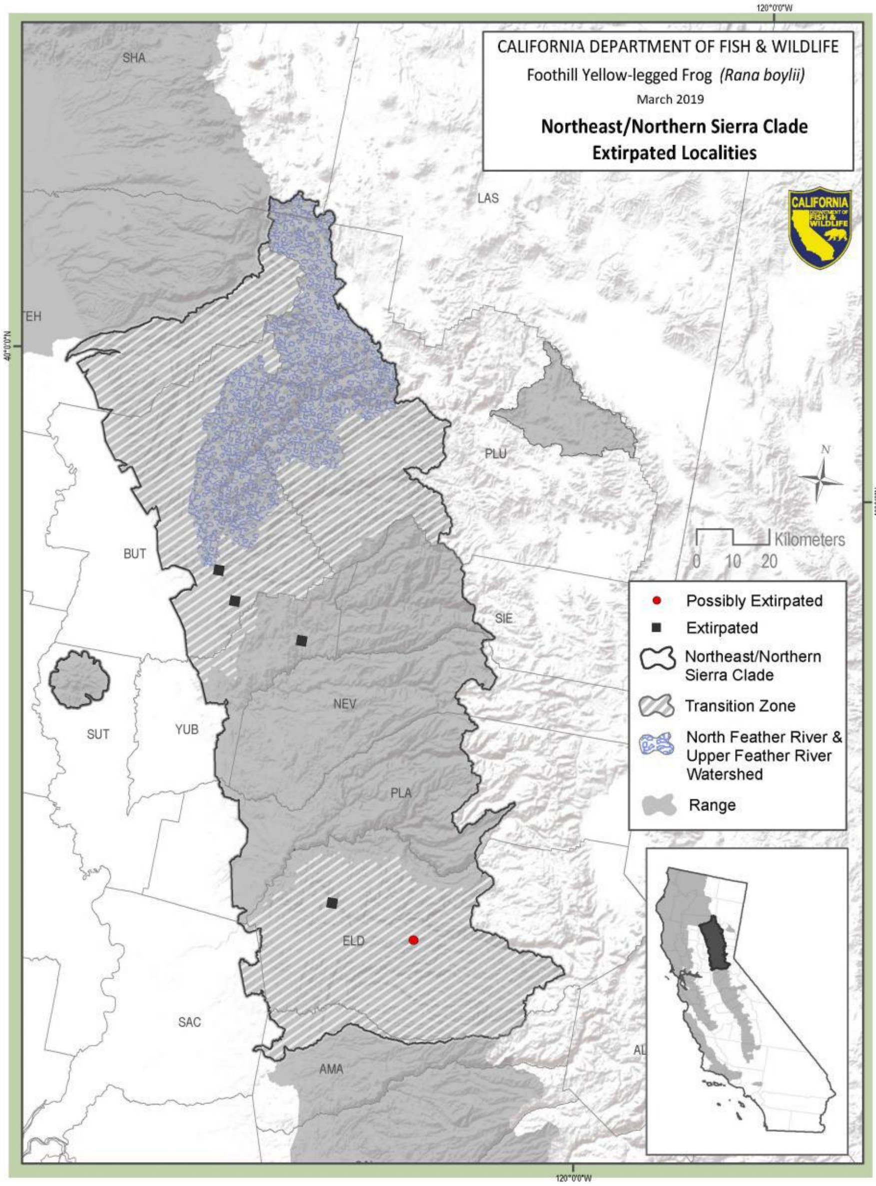


Figure 13. Possibly extirpated and extirpated Northeast/Feather River and Northern Sierra Foothill Yellow-legged Frog clades sites (CNDDB)

Foothill Yellow-legged Frogs have been observed in at least 71 areas in the past 5 years in the presumptive Northeast/Northern Sierra clade. The general pattern in this clade, and across the range for that matter, is that unregulated rivers or reaches have more areas that are occupied more consistently and in larger numbers than regulated rivers or reaches (CNDDB 2019, S. Kupferberg pers. comm. 2019). Foothill Yellow-legged Frogs were rarely observed in the hydropeaking reach of the Middle Fork American River and were observed in low numbers in the bypass reach, but they were present and breeding in small tributary populations (PCWA 2008). Relatively robust populations appear to inhabit the North Fork American River and Lower Rubicon River (Gaos and Bogan 2001, PCWA 2008, Hogan and Zuber 2012, K. Kundargi pers. comm. 2014, S. Kupferberg pers. comm. 2019). Additional apparently sufficiently large and relatively stable populations occur on Clear Creek, South Fork Greenhorn Creek, and Shady Creek (Nevada County) and the North and Middle Yuba River (Sierra County), but the remaining observations are of small numbers in tributaries with minimal connectivity among them (CNDDB 2019, S. Kupferberg pers. comm. 2019).

East/Southern Sierra

The East/Southern Sierra clade is presumed to range from the South Fork American River watershed, the northernmost site where individuals from this clade were collected, south to where the Sierra Nevada meets the Tehachapi Mountains. It likely includes El Dorado, Amador, Calaveras, Tuolumne, Mariposa, Madera, Fresno, Tulare, and Kern counties (Figure 14; Peek 2018). The proportion of extirpated sites in this clade is second only to the Southwest/South Coast and follows the pattern of greater losses in the south (Figure 15). Like the southern coastal clade, the southern Sierra clade has low genetic variability and a trajectory of continued loss of diversity (Ibid.).

Historical collections of small numbers of Foothill Yellow-legged Frogs occurred in every major river system within this clade beginning as early as the turn of the 20th century, indicating widespread distribution but little information on abundance (Hayes et al. 2016). By the early 1970s, declines in Foothill Yellow-legged Frog populations from this area were already apparent; Moyle (1973) found them at 30 of 95 sites surveyed in 1970. Notably bullfrogs inhabited the other 65 sites formerly occupied by Foothill Yellow-legged Frogs, and they co-occurred at only 3 sites (Ibid.). In 1992, Drost and Fellers (1996) revisited the sites around Yosemite National Park (Tuolumne and Mariposa counties) that Grinnell and Storer (1924) surveyed in 1915 and 1919. Foothill Yellow-legged Frogs had disappeared from all seven historically occupied sites and were not found at any new sites surveyed surrounding the park (Ibid.). Resurveys of previously occupied sites on the Stanislaus (Tuolumne County), Sierra (Fresno County), and Sequoia (Tulare County) National Forests were also undertaken (Lind et al. 2003b). Foothill Yellow-legged Frogs were absent from the sites in Sierra and Sequoia National Forests, six at each forest; however, a new population was discovered in the Sierra and two in the Sequoia forests (Ibid.). These populations remain extant but are small and isolated (CNDDB 2019). Two of the six sites on the Stanislaus were still occupied, and 19 new populations were found with evidence of breeding at seven of them (Lind et al. 2003b). Twenty of the 24 populations extant at the time inhabited unregulated waterways (Ibid.). Most of the CNDDB (2019) records of Foothill Yellow-legged Frogs on the Stanislaus are at least a decade old and are represented by low numbers.

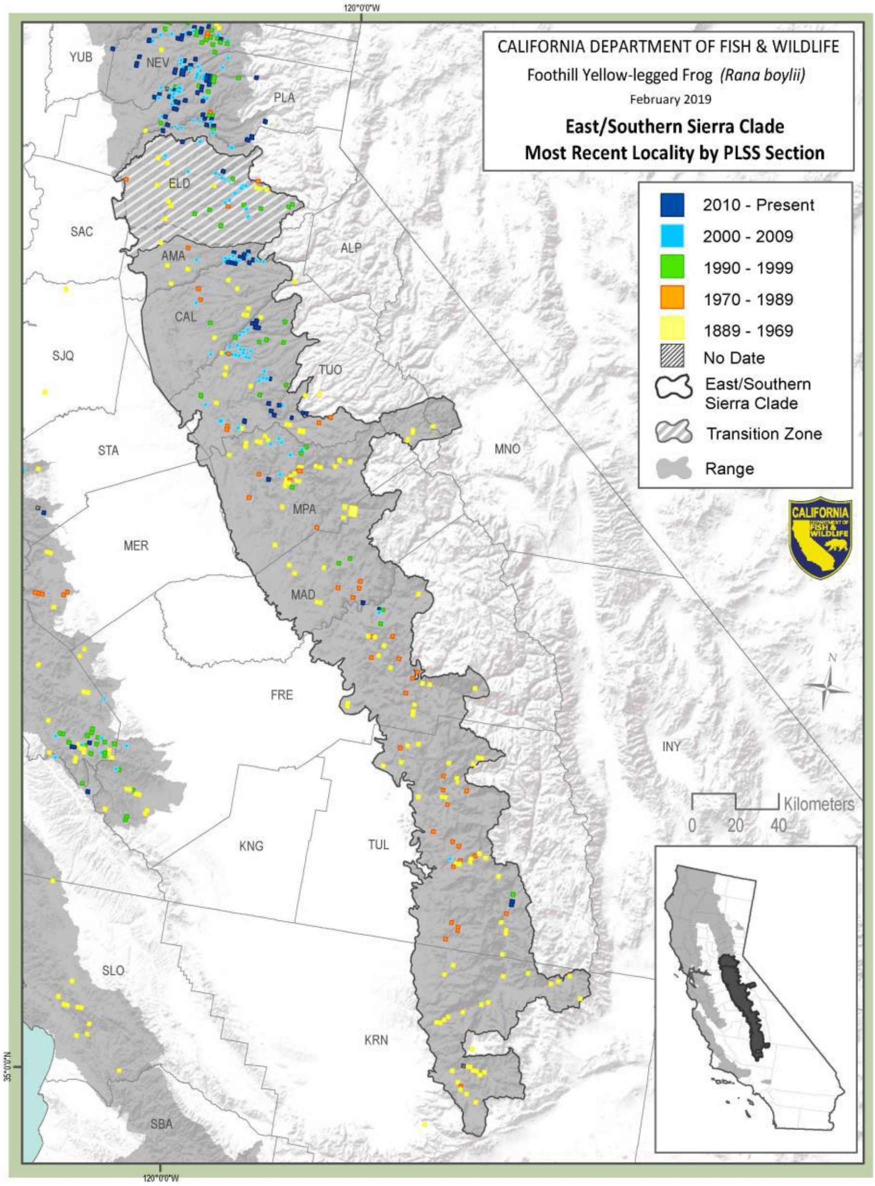


Figure 14. Close-up of East/Southern Sierra clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

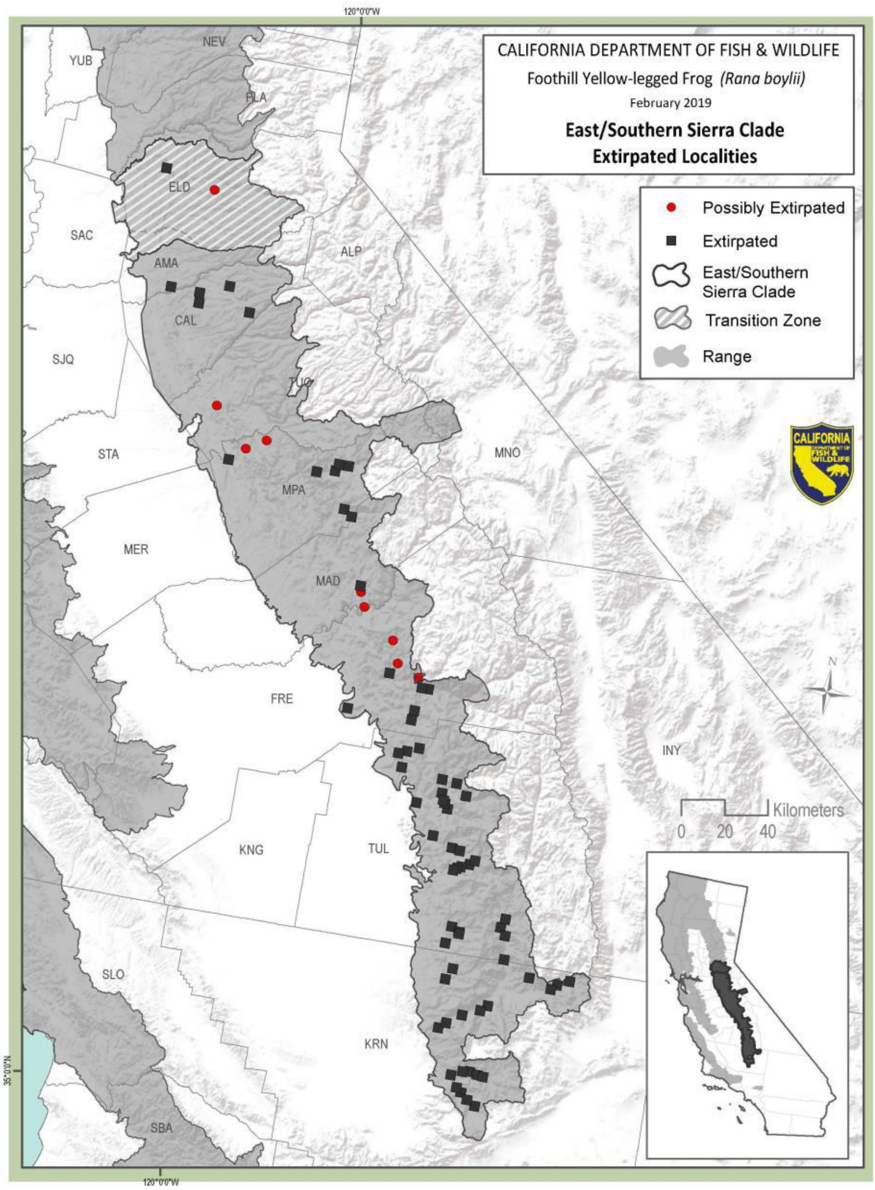


Figure 15. Possibly extirpated and extirpated East/Southern Sierra Foothill Yellow-legged Frog clade sites (CNDDB)

More recently, surveys for Foothill Yellow-legged Frogs were conducted along the South Fork American River as part of the El Dorado Hydroelectric Project's FERC license amphibian monitoring requirements (GANDA 2017). Between 2002 and 2016 counts of different life stages varied significantly by year but the trend for every life stage was a decline over that period (Ibid.). There appears to be a small population persisting along the North Fork Mokelumne River (Amador and Calaveras counties), but it was only productive during the 2012-2014 drought years (Ibid.). Small numbers have also been observed recently in several locations on private timberlands in Tuolumne County (CNDDB 2019).

FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE

"The fortunes of the boylii *population fluctuate with those of the stream"* - Tracy I. Storer, 1925

Several past and ongoing activities have changed the watersheds upon which Foothill Yellow-legged Frogs depend, and many interact with each other exacerbating their adverse impacts. With such an expansive range in California, the degree and severity of these impacts on the species often vary by location. To the extent feasible based on the best scientific information available, those differences are discussed below.

Dams, Diversions, and Water Operations

Foothill Yellow-legged Frogs evolved in a Mediterranean climate with predictable cool, wet winters and hot, dry summers, ~~with~~ and their life cycle is adapted to these conditions. In California and other areas with a Mediterranean climate, human demands for water are at the highest when runoff and precipitation are lowest, and annual water supply varies significantly but always follows the general pattern of peak discharge declining to baseflow in the late spring or summer (Grantham et al. 2010). The Foothill Yellow-legged Frog's life cycle depends on this discharge pattern and the specific habitat conditions it produces (see the Breeding and Rearing Habitat section). Dams are ubiquitous, but not evenly distributed, in California. Figure 16 depicts the locations of dams under the jurisdiction of the Army Corps of Engineers (ACOE) and the California Department of Water Resources (DWR). Figure 17 depicts the number of surface diversions per PLSS section within the Foothill Yellow-legged Frog's range (eWRIMS 2019).

Dam operations frequently change the amount and timing of water availability; its temperature, depth, and velocity; and its sediment transport and channel morphology altering functions, which can result in dramatic consequences ~~on~~ for the Foothill Yellow-legged Frog's ability to survive and successfully reproduce. Several studies comparing Foothill Yellow-legged Frog populations in regulated and unregulated reaches within the same watershed investigate potential dam-effects. These studies demonstrated that dams and their operations can result in several factors that contribute to population declines and possible extirpation. These factors include confusing breeding cues, scouring and stranding of egg masses and tadpoles, reduced quality and quantity of breeding and rearing habitat, reduced tadpole growth rate, barriers to gene flow, and establishment and spread of non-native species (Hayes et al. 2016). In addition, as previously discussed in the Population Structure and Genetic Diversity section, subpopulations of Foothill Yellow-legged Frogs on regulated rivers are more isolated, and the

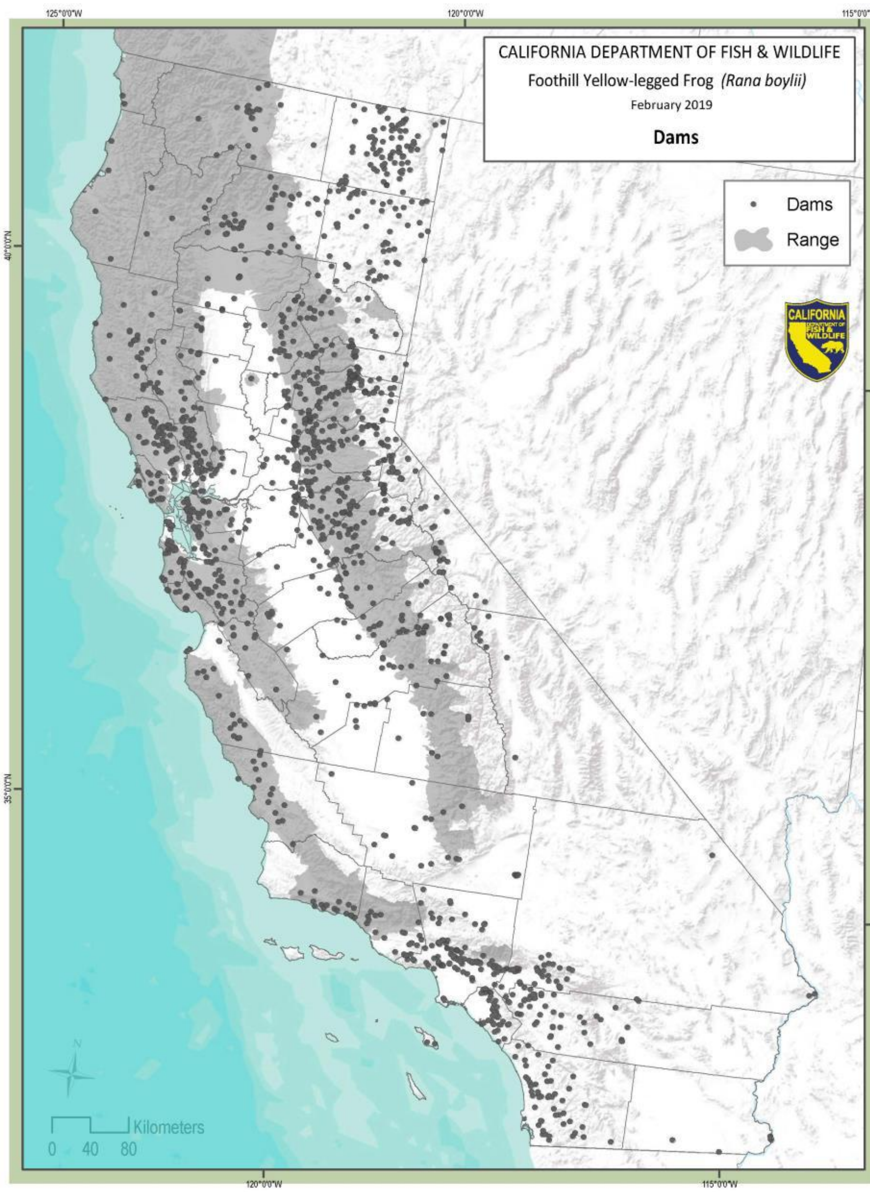


Figure 16. Locations of ACOE and DWR jurisdictional dams (DWR, FRS)

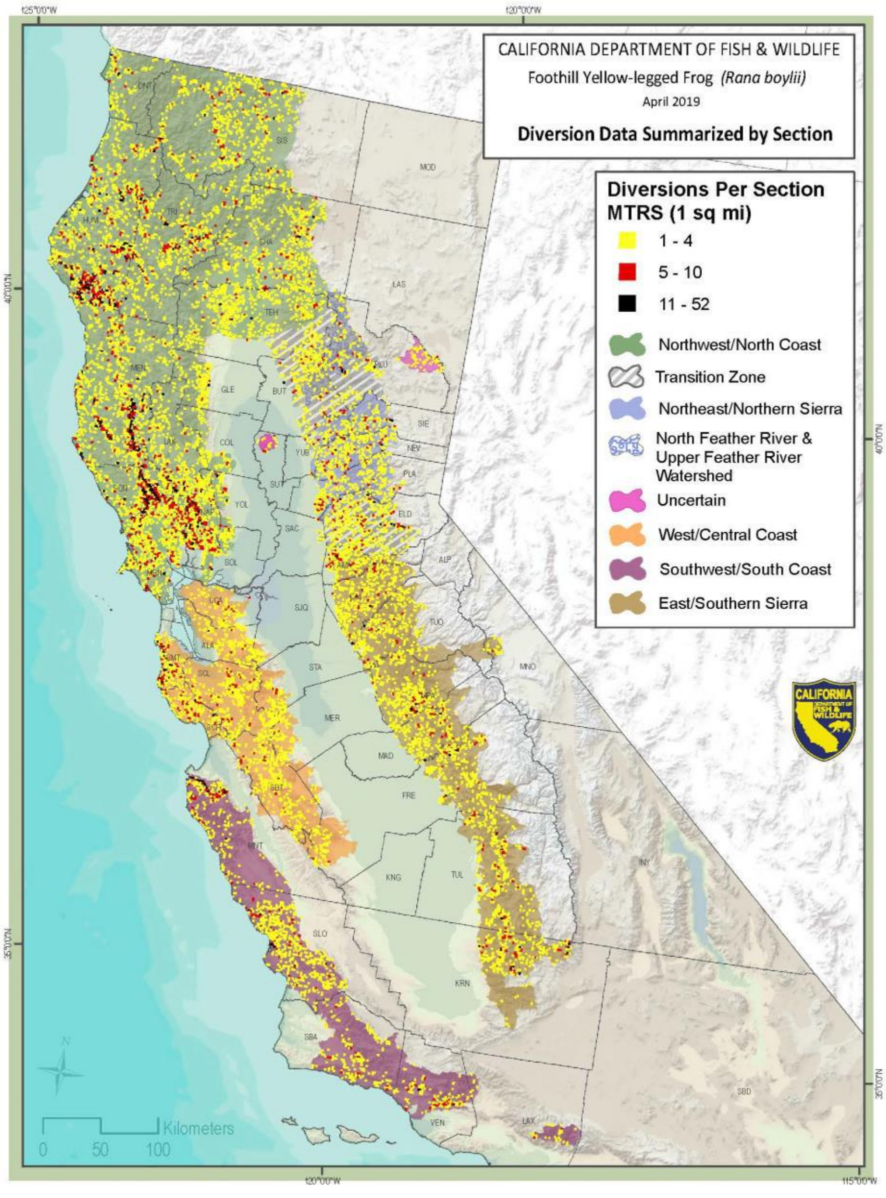


Figure 17. Number of surface water diversions per Public Lands Survey System section within the Foothill Yellow-legged Frog's range in California (eWRIMs)

type of water operations (hydropeaking vs. bypass flows) significantly affects the degree of gene flow loss among them (Peek 2011, 2018). Figure 18 depicts the locations of hydroelectric power plants.

As discussed in the Seasonal Activity and Movements section, cues for Foothill Yellow-legged Frogs to start breeding appear to involve water temperature and velocity, two features altered by dams. Dam operations typically result in reduced flows that are more stable over the course of a year than unimpaired conditions, and dam managers are frequently required to maintain thermally appropriate water temperatures and flows for cold-water-adapted salmonids (USFWS and Hoopa Valley Tribe 1999, Wheeler et al. 2014). For example, late-spring and summer water temperatures on the mainstem Trinity River below Lewiston Dam have been reported to be up to 10°C (20°F) cooler than average pre-dam temperatures, while average winter temperatures are slightly warmer (USFWS and Hoopa Valley Tribe 1999). As a result, Foothill Yellow-legged Frogs breed later on the mainstem Trinity River compared to six nearby tributaries, and some mainstem reaches may never attain the minimum required temperature for breeding (Wheeler et al. 2014, Snover and Adams 2016). In addition, annual discharges past Lewiston Dam have been 10-30% of pre-dam flows and do not mimic the natural hydrograph (Lind et al. 1996).

Aseasonal discharges from dams occur for several reasons including increased flow in late-spring and early summer to facilitate outmigration of salmonids, channel maintenance pulse flows, short-duration releases for recreational whitewater boating, rapid reductions after a spill (uncontrolled flows released down a spillway when reservoir capacity is exceeded) to retain water for power generation or water supply later in the year, peaking flows for hydroelectric power generation, and sustained releases to maintain the seismic integrity of the dam (Lind et al. 1996, Jackman et al. 2004, Kupferberg et al. 2011b, Kupferberg et al. 2012, Snover and Adams 2016). The results of a Foothill Yellow-legged Frog population viability analysis (PVA) suggest that the likelihood a population will persist is very sensitive to early life stage mortality; the 30-year probability of extinction increases significantly with high levels of egg or tadpole scouring or stranding (Kupferberg et al. 2009c). For instance, in 1991 and 1992, all egg masses laid before high flow releases to encourage outmigration of salmonids on the Trinity River were scoured away (Lind et al. 1996). According to the PVA, even a single annual pulse flow such as this or for recreational boating, can result in a three- to five-fold increase in the 30-year extinction risk based on amount of tadpole mortality experienced (Kupferberg et al. 2009c). Management after natural spills can also lead to substantial mortality. For example, in 2006, Foothill Yellow-legged Frogs on the North Fork Feather River bred during a prolonged spill, and the rapid recession below Cresta Dam that followed stranded and desiccated all the eggs laid (Kupferberg et al. 2009b). Rapid flows can also increase predation risk if tadpoles are forced to seek shelter under rocks where crayfish and other invertebrate predators are more common or if they are displaced into the water column where their risk of predation by fish is greater (Ibid.).

The overall reduction of flows and frequency of large winter floods below dams can produce extensive changes to Foothill Yellow-legged Frog habitat quality. They reduce the formation of river bars that are regularly used as breeding habitat, and they create deeper and steeper channels with less complexity and fewer warm, calm, shallow edge-water habitats for tadpole rearing (Lind et al. 1996, Wheeler and Welsh 2008, Kupferberg et al. 2011b, Wheeler et al. 2014). For example, 26 years after construction of

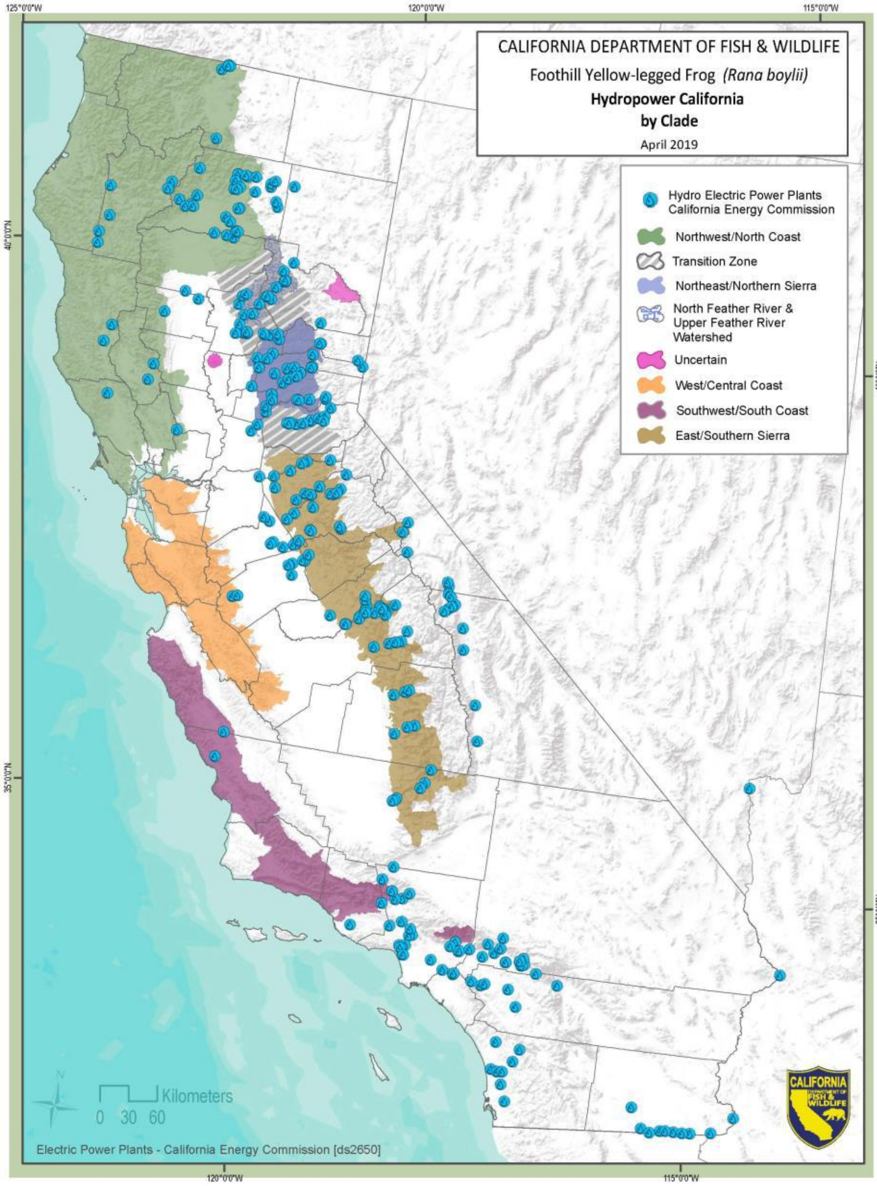


Figure 18. Locations of hydroelectric power generating dams (BIOS)

the Lewiston Dam on the Trinity River, habitat changes in a 63 km (39 mi) stretch from the dam downstream were evaluated (Lind et al. 1996). Riparian vegetation went from covering 30% of the riparian area pre-dam to 95% (Ibid.). Additionally, river bars made up 70% of the pre-dam riparian area compared to 4% post-dam, amounting to a 94% decrease in available Foothill Yellow-legged Frog breeding habitat (Ibid.).

Several features of riverine habitat below dams can decrease tadpole growth rate and other measures of fitness. As ectotherms, Foothill Yellow-legged Frogs require temperatures that support their metabolism, food conversion efficiency, growth, and development, and these temperatures may not be reached until late in the season, or not at all, when the water released is colder than their lower thermal limit (Kupferberg et al. 2011a, Catenazzi and Kupferberg 2013, Wheeler et al. 2014). Colder temperatures and higher flows reduce time spent feeding and efficiency at food assimilation, resulting in slower growth and development (Kupferberg et al. 2011a,b; Catenazzi and Kupferberg 2018). Large bed-scouring winter floods promote greater *Cladophora glomerate* blooms, the filamentous green alga that dominates primary producer biomass during the tadpole rearing season (Power et al. 2008, Kupferberg et al. 2011a). The period of most rapid tadpole growth often coincides with blooms of highly nutritious and more easily assimilated epiphytic diatoms, so reduced flows can have food-web impacts on tadpole growth and survival (Power et al. 2008, Kupferberg et al. 2011a, Catenazzi and Kupferberg 2018). In addition, colder temperatures and fluctuating summer flows, such as those released for hydroelectric power generation, can reduce the amount of algae available for grazing and can change the algal assemblage to one dominated by mucilaginous stalked diatoms like *Didymosphenia geminate* that have low nutritional value (Spring Rivers Ecological Sciences 2003, Kupferberg et al 2011a, Furey et al. 2014). Altered temperatures, flows, and food quality can contribute to slower growth and development, longer time to metamorphosis, smaller size at metamorphosis, and reduced body condition, which adversely impact fitness (Kupferberg et al. 2011b, Catenazzi and Kupferberg 2018).

As discussed in more detail in the Population Structure and Genetic Diversity section, both are strongly affected by river regulation (Peek 2011, 2018; Stillwater Sciences 2012). Foothill Yellow-legged Frogs primarily use watercourses as movement corridors, so the reservoirs created behind dams are often uninhabitable and represent barriers to gene flow (Bourque 2008; Peek 2011, 2018). This decreased connectivity can lead to loss of genetic diversity, ~~inducing~~ reducing a species' ability to adapt to changing conditions (Palstra and Ruzzante 2008).

Decreased winter discharge below dams facilitates establishment and expansion of invasive bullfrogs, whose tadpoles require overwintering and are not well-adapted to flooding events (Lind et al. 1996, Doubledee et al. 2003). Where they occur, bullfrogs tend to dominate areas more altered by dam operations than less impaired areas that support a higher proportion of native species (Moyle 1973, Fuller et al. 2011). In addition to downstream effects, the reservoirs created behind dams directly destroy lotic (flowing) Foothill Yellow-legged Frog habitat, typically do not retain natural riparian communities due to fluctuating water levels, are often managed for human activities not compatible with the species' needs, and act as a source of introduced species upstream and downstream (Brode and Bury 1984, PG&E 2018). Moyle and Randall (1998) identified characteristics of sites with low native biodiversity in the Sierra Nevada foothills; they were often drainages that had been dammed and

diverted in lower- to middle-elevations and dominated by introduced fishes and bullfrogs. Even small-scale operations can have significant effects. Some farming operations divert water during periods of high flows and store it in small impoundments for use during low flow-high need times; these ponds can serve as sources for introduced species like bullfrogs to spread into areas where the habitat would otherwise be unsuitable (Kupferberg 1996b).

The mechanisms described above result in the widespread pattern of greater Foothill Yellow-legged Frog density in unregulated rivers and in reaches far enough downstream of a dam to experience minimal effects from it (Lind et al. 1996, Kupferberg 1996a, Bobzien and DiDonato 2007, Peek 2011). Abundance in unregulated rivers averages five times greater than population abundance downstream of large dams (Kupferberg et al. 2012). Figure 19 depicts a comprehensive collection of egg mass density data where at least four years of surveys have been undertaken, showing much lower abundance in regulated rivers (S. Kupferberg pers. comm. 2019). In California, Foothill Yellow-legged Frog presence is associated with an absence of dams or with only small dams far upstream (Lind 2005, Kupferberg et al. 2012). Hydroelectric power generation from Sierra Nevada rivers accounts for nearly half its statewide production and about 9% of all electrical power used in California (Dettinger et al. 2018). Every major stream below 600 m (1968 ft) in the Sierra Nevada has at least one large reservoir (≥ 0.12 km^3 [100,000 ac-ft]), and many have multiple medium and small ones (Hayes et al. 2016). Because of this, Catenazzi and Kupferberg (2017) posit that the dam-effect on Foothill Yellow-legged Frog populations is likely greater in the Sierra Nevada than the Coast Range because dams are more often constructed in a series along a river in the former and spaced close enough together such that suitable breeding temperatures may never occur in the intervening reaches.

Pathogens and Parasites

Perhaps the most widely recognized amphibian disease is chytridiomycosis, which is caused by the fungal pathogen *Batrachochytrium dendroabatidis* (Bd). Implicated in the decline of over 500 amphibian species, including 90 presumed extinctions, it represents the greatest recorded loss of biodiversity attributable to a disease (Scheele et al. 2019). The global trade in American Bullfrogs (primarily for food) is connected to the disease's spread because the species can persist with low-level Bd infections without developing chytridiomycosis (Yap et al. 2018). Previous studies suggested Foothill Yellow-legged Frogs may not be susceptible to Bd-associated mass mortality; skin peptides strongly inhibited growth of the fungus in the lab, and the only detectable difference between Bd+ and Bd- juvenile Foothill Yellow-legged Frogs was slower growth (Davidson et al. 2007). At Pinnacles National Park in 2006, 18% of post-metamorphic Foothill Yellow-legged Frogs tested positive for Bd; all were asymptomatic and at least one Bd+ Foothill Yellow-legged Frog subsequently tested negative, demonstrating an ability to shed the fungus (Lowe 2009). However, recent studies have found historical evidence of Bd contributing to the extirpation of Foothill Yellow-legged Frogs in southern California, an acute die-off in 2013 in the Alameda Creek watershed, and another in 2018 in Coyote Creek (Adams et al. 2017a,b; Kupferberg and Catenazzi 2019). Evaluation of museum specimens indicates lower Bd prevalence (proportion of individuals infected) in Foothill Yellow-legged Frogs than most other co-occurring amphibians in southern California in the first part of the 20th century, but it spiked in the 1970s just prior to the last observation of an individual in 1977 (Adams et al. 2017b). Two museum specimens collected in 1966,

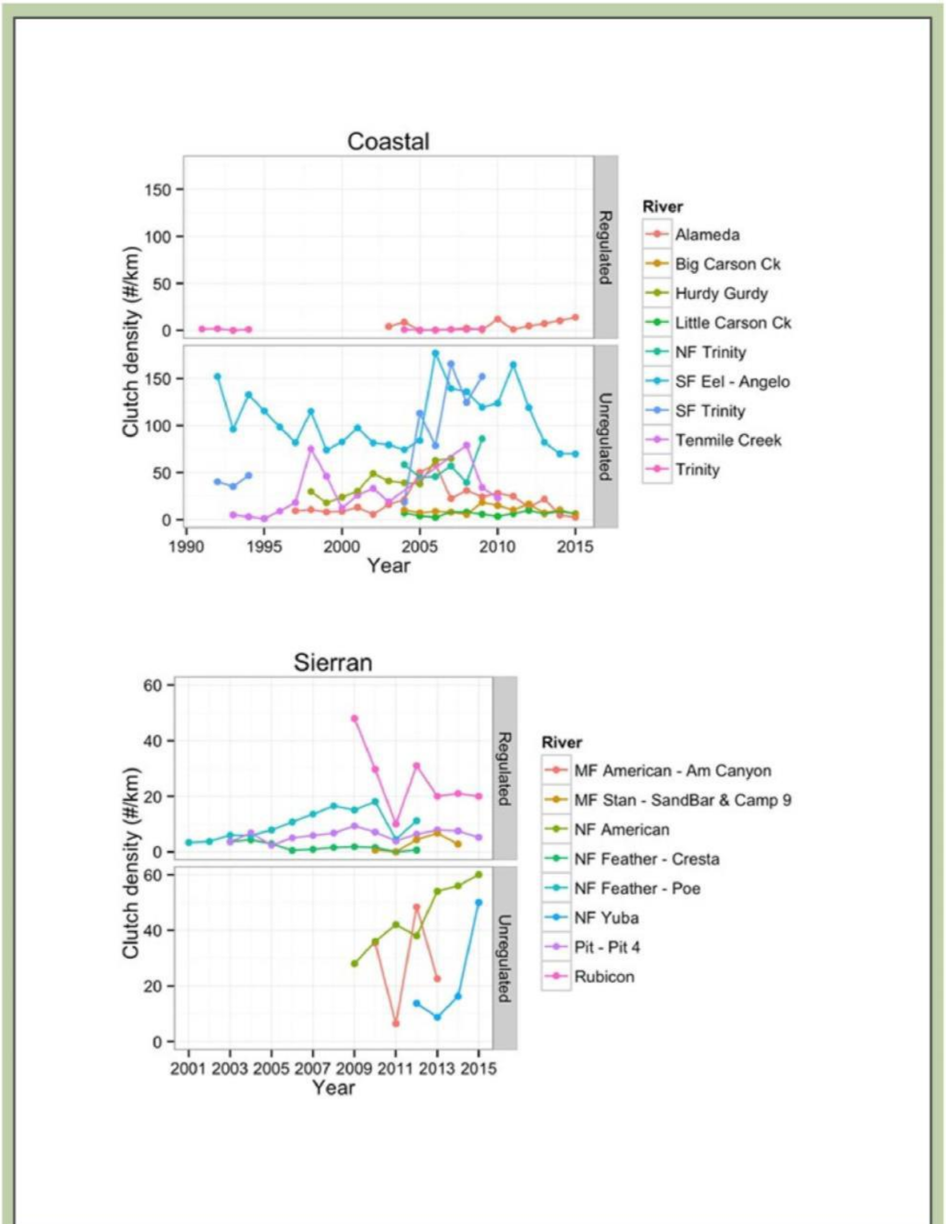


Figure 19. Foothill Yellow-legged Frog Egg mass density estimates along the coast from 1990-2015 and the Sierra Nevada from 2001-2015 from multiple studies compiled by S. Kupferberg (2019)

one from Santa Cruz County and the other from Alameda County, provide the earliest evidence of Bd in Foothill Yellow-legged Frogs in central California (Padgett-Flohr and Hopkins 2009). In contrast to the southern California results, Foothill Yellow-legged Frogs possessed the highest Bd prevalence among all amphibians tested in coastal Humboldt County in 2013 and 2014; however, zoospore (the aquatic dispersal agent) loads were well below the presumed lethal density threshold (Ecoclub Amphibian Group et al. 2016).

In addition to bullfrogs, the native Pacific Treefrog (~~*Pseudacris*~~ *Hyliola* ***regilla***) seems immune to the lethal effects of chytridiomycosis, and owing to its broad ecological tolerances, more terrestrial lifestyle, and relatively large home range size and dispersal ability, the species is ubiquitous across California (Padgett-Flohr and Hopkins 2009). In a laboratory experiment, Bd-infected Pacific Treefrogs shed an average of 68 zoospores per minute, making them the prime candidate for spreading and maintaining Bd in areas where bullfrogs do not occur (Padgett-Flohr and Hopkins 2009, Reeder et al. 2012). In the wild, Pacific Treefrog populations persisted at 100% of sites in the Sierra Nevada (above 1500 m [4920 ft]) where a sympatric ranid species had been extirpated from 72% of its formerly occupied sites due to a Bd outbreak (Reeder et al. 2012). This is consistent with the results of a model that incorporated Bd habitat suitability, host availability, and invasion history in North America, which concluded west coast mountain ranges were at the greatest risk from the disease (Yap et al. 2018).

Several other pathogens and parasites have been encountered with Foothill Yellow-legged Frogs, but none have been ascribed to large-scale mortality events. Another fungus, a water mold (*Saprolegnia* sp.) carried by fish, is an important factor in amphibian embryo mortality in the Pacific Northwest (Blaustein et al. 1994, Kiesecker and Blaustein 1997). Fungal infections of Foothill Yellow-legged Frog egg masses, potentially from *Saprolegnia*, have been observed in the mainstem Trinity River (Ashton et al. 1997). *Saprolegnia* infection is more likely to occur in ponds and lakes, particularly if stocked by hatchery-raised fish into previously fishless areas and when frogs use communal oviposition sites, so it likely does not represent a major source of mortality in Foothill Yellow-legged Frogs (Blaustein et al. 1994, Kiesecker and Blaustein 1997). However, they may be more susceptible to *Saprolegnia* infection when exposed to other environmental stressors that compromise their immune defenses (Blaustein et al. 1994, Kiesecker and Blaustein 1997).

The trematode parasite *Ribeiroia ondatrae* is responsible for limb malformations in ranids (Stopper et al. 2002). *Ribeiroia ondatrae* was detected on a single Foothill Yellow-legged Frog during a study on malformations, but its morphology was normal (Kupferberg et al. 2009a). The results of the study instead linked malformations in Foothill Yellow-legged Frog tadpoles and young-of-year to the Anchor Worm (*Lernae cyprinacea*), a parasitic copepod from Eurasia (Ibid.). Prevalence of malformations was low, under 4% of the population in both years of study, but there was a pattern of infected individuals metamorphosing at a smaller size, which as previously mentioned can have implications on fitness (Ibid.). Three other species of helminths (parasitic worms) were encountered during the study (*Echinostoma* sp., *Manodistomum* sp., and *Gyrodactylus* sp.); their relative impact on their hosts is unknown, but at least one Foothill Yellow-legged Frog had 700 echinstome cysts in its kidney (Ibid.). Bursey et al. (2010) discovered 13 species of helminths in and on Foothill Yellow-legged Frogs from

Humboldt County. Most are common in anurans, and some are generalists with multiple possible hosts, but studies on their impact on Foothill Yellow-legged Frogs are lacking (Ibid.).

Introduced Species

Species not native to an area, but introduced, can alter food webs and ecosystem processes through predation, competition, hybridization, disease transmission, and habitat modification. Native species lack evolutionary history with introduced species, and early life stages of native anurans are particularly susceptible to predation by aquatic non-native species (Kats and Ferrer 2003). Because introduced species often establish in highly modified habitats, it can be difficult to differentiate between impacts from habitat degradation and the introduced species (Fisher and Shaffer 1996). However, native amphibians have been frequently found successfully reproducing in heavily altered habitats when introduced species were absent, suggesting introduced species themselves can impose an appreciable adverse effect (Ibid.). Numerous introduced species have been documented to adversely impact Foothill Yellow-legged Frogs or are suspected of doing so.

American Bullfrogs were introduced to California from the eastern U.S. around the turn of the 20th century, likely in response to overharvest of native ranids by the frog-leg industry that accompanied the Gold Rush (Jennings and Hayes 1985). Nearly 50 years ago, Moyle (1973) reported that distributions of Foothill Yellow-legged Frogs and bullfrogs in the Sierra Nevada foothills were nearly mutually exclusive. He speculated that bullfrog predation and competition may be causal factors in their disparate distributions in addition to the habitat degradation from dams and diversions that facilitated the bullfrog invasion in the first place. In a study along the South Fork Eel River and one of its tributaries, Foothill Yellow-legged Frog abundance was nearly an order of magnitude lower in reaches were bullfrogs were well established (Kupferberg 1997a). At a site in Napa Valley, after bullfrogs were eradicated, Foothill Yellow-legged Frogs, among other native species, recolonized the area (J. Alvarez pers. comm. 2018). In a mesocosm experiment, Foothill Yellow-legged Frog survival in control enclosures measured half that of enclosures containing bullfrog and Foothill Yellow-legged Frog tadpoles, and they weighed approximately one-quarter lighter at metamorphosis (Kupferberg 1997a). The mechanism for these declines appeared to be the reduction of high quality algae by bullfrog tadpole grazing, as opposed to any behavioral or chemical interference (Ibid.). Adult bullfrogs, which can get very large (9.0-15.2 cm [3.5-6.0 in]), also directly consume Foothill Yellow-legged Frogs, including adults (Moyle 1973, Crayon 1998, Powell et al. 2016). Silver (2017) noted that she never heard Foothill Yellow-legged Frogs calling in areas with bullfrogs, which has implications for breeding success; she speculated the lack of vocalizations may have been a predator avoidance strategy.

As discussed briefly in the Pathogens and Parasites section, American Bullfrogs act as reservoirs and vectors of the lethal chytrid fungus. In museum specimens from both southern and central California, Bd was detected in bullfrogs before it was detected in Foothill Yellow-legged Frogs in the same area (Padgett-Flohr and Hopkins 2009, Adams et al. 2017b). During a die-off from chytridiomycosis that commenced in 2013, Bd prevalence and load in Foothill Yellow-legged Frogs was positively predicted by bullfrog presence (Adams et al. 2017a). A similar die-off in 2018 from a nearby county appears to be related to transmission by bullfrogs as well (Kupferberg and Catenazzi 2019). In addition, male Foothill

Yellow-legged Frogs have been observed amplexing female bullfrogs, which may not only constitute wasted reproductive effort but could serve to increase their likelihood of contracting Bd (Lind et al. 2003a). In fact, adult males were more likely to be infected with Bd than females or juveniles during the recent die-off in Alameda Creek (Adams et al. 2017a). African Clawed Frogs (*Xenopus laevis*) have also been implicated in the spread of Bd in California because like bullfrogs, they are asymptomatic carriers (Padgett-Flohr and Hopkins 2009). However, African Clawed-Frog distribution only minimally overlaps with the Foothill Yellow-legged Frog's range unlike the widespread bullfrog (Stebbins and McGuinness 2012).

Hayes and Jennings (1986) observed a negative association between the abundance of introduced fish and Foothill Yellow-legged Frogs. Rainbow trout (*Onchorynchus mykiss*) and green sunfish (*Lepomis cyanellus*) are suspected of destroying egg masses (Van Wagner 1996). Bluegill sunfishes (*L. macrochirus*) are likely predators; in captivity when offered eggs and tadpoles of two ranid species, they consumed both life stages but a significantly greater number of tadpoles (Werschkul and Christensen 1977). Common hatchery-stocked fish like brook (*Salvelinus fontinalis*) and rainbow trout commonly carry of *Saprolegnia* (Blaustein et al. 1994). In addition, presence of non-native fish can facilitate bullfrog invasions by reducing the density of macroinvertebrates that prey on their tadpoles (Adams et al. 2003). Foothill Yellow-legged Frog tadpoles raised from eggs from sites with and without smallmouth bass (*Micropterus dolomieu*) did not differ in their responses to exposure to the non-native, predatory bass and a native, non-predatory fish (Paoletti et al. 2011). This result suggests that Foothill Yellow-legged Frogs have not yet evolved a recognition of bass as a threat, which makes them more vulnerable to predation (Ibid.).

Introduced into several areas within the Coast Range and Sierra Nevada, signal crayfish have been recorded preying on Foothill Yellow-legged Frog egg masses and are suspected of preying on their tadpoles based on observations of tail injuries that looked like scissor snips (Riegel 1959, Wiseman et al. 2005). The introduced red swamp crayfish (*Procambarus clarkii*) likely also preys on Foothill Yellow-legged Frogs. Because Foothill Yellow-legged Frogs evolved with native crayfish in northern California, individuals from those areas may more effectively avoid crayfish predation than in other parts of the state where they are not native (Riegel 1959, USFWS 1998, Kats and Ferrer 2003). The Foothill Yellow-legged Frog's naivety to crayfish was demonstrated in a study that showed they did not change behavior when exposed to signal crayfish chemical cues, but once the crayfish was released and consuming Foothill Yellow-legged Frog tadpoles, the survivors, likely reacting to chemical cues from dead tadpoles, did respond (Kerby and Sih 2015).

Sedimentation

Several anthropogenic activities, some of which are described in greater detail below, can artificially increase sedimentation into waterways occupied by Foothill Yellow-legged Frogs and adversely impact biodiversity (Moyle and Randall 1998). These activities include but are not limited to mining, agriculture, overgrazing, timber harvest, and poorly constructed roads (Ibid.). Increased fine sediments can substantially degrade Foothill Yellow-legged Frog habitat quality. Heightened turbidity decreases light penetration that phytoplankton and other aquatic plants require for photosynthesis (Cordone and Kelley

1961). When silt particles fall out of the water column, they can destroy algae by covering the bottom of the stream (Ibid.). Algae are not only important for Foothill Yellow-legged Frog tadpoles as forage but also oxygen production (Ibid.). Sedimentation may impede attachment of egg masses to substrate (Ashton et al. 1997). The effect of silt accumulation on embryonic development is unknown, but it does make them less visible, which could decrease predation risk (Fellers 2005). Fine sediments can fill interstitial spaces between rocks that tadpoles use for shelter from high velocity flows and cover from predators and that serve as sources for aquatic invertebrate prey for post-metamorphic Foothill Yellow-legged Frogs (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b).

Mining

Current mining practices, as well as legacy effects from historical mining operations, may adversely impact Foothill Yellow-legged Frogs through contaminants, direct mortality, habitat destruction and degradation, and behavioral disruption. While mercury in streams can result from atmospheric deposition, storm-induced runoff of naturally occurring mercury, agricultural runoff, and geothermal springs, runoff from historical mine sites mobilizes a significant amount of mercury (Foe and Croyle 1998, Alpers et al. 2005, Hothem et al. 2010). Beginning in the mid-1800s, extensive mining occurred in the Coast Range to supply mercury for gold mining in the Sierra Nevada, causing widespread contamination of both mountain ranges and the rivers in the Central Valley (Foe and Croyle 1998). Studies on Foothill Yellow-legged Frog tissues collected from the Cache Creek (Coast Ranges) and Greenhorn Creek (Sierra Nevada) watersheds revealed mercury bioaccumulation concentrations as high as 1.7 and 0.3 µg/g (ppm), respectively (Alpers et al. 2005, Hothem et al. 2010). For context, the U.S. Environmental Protection Agency's mercury criterion for issuance of health advisories for fish consumption is 0.3 µg/g; concentrations exceeded this threshold in Foothill Yellow-legged Frog tissues at 62% of sampling sites in the Cache Creek watershed (Hothem et al. 2010). Bioaccumulation of this powerful neurotoxin can cause deleterious impacts on amphibians including inhibited growth, decreased survival to metamorphosis, increased malformations, impaired reproduction, and other sublethal effects (Zillioux et al. 1993, Unrine et al. 2004). In a study measuring Sierra Nevada watershed health, Moyle and Randall (1998) reportedly found very low biodiversity in streams that were heavily polluted by acidic water leaching from historical mines. Acidic drainage measured as low as pH 3.4 ~~pH~~ from some mined areas in the northern Sierra Nevada (Alpers et al. 2005).

Widespread suction dredging for gold occurred in the Foothill Yellow-legged Frog's California range until enactment of a moratorium on issuing permits in 2009 (Hayes et al. 2016). Suction dredging vacuums up the contents of the streambed, passes them through a sluice box to separate the gold, and then deposits the tailings on the other side of the box (Harvey and Lisle 1998). While most habitat disturbance is localized and minor, it can be especially detrimental if it degrades or destroys breeding and rearing habitat through direct disturbance or sedimentation (Ibid.). In addition, this activity can lead to direct mortality of early life stages through entrainment, and those eggs and tadpoles that do survive passing through the suction dredge may experience greater mortality due to subsequent unfavorable physiochemical conditions and possible increased predation risk (Ibid.). Suction dredging can also reduce the availability of invertebrate prey, although this impact is typically short-lived (Ibid.). Suction dredging alters stream morphology, and relict tailing ponds can serve as breeding habitat for bullfrogs in areas

that would not normally support them (Fuller et al. 2011). However, in some areas these mining holes have reportedly benefited Foothill Yellow-legged Frogs by creating cool persistent pools that adult females appeared to prefer at one Sierra Nevada site (Van Wagner 1996). Senate Bill 637 (2015) directs the Department to work with the State Water Resources Control Board (SWRCB) to develop a statewide water quality permit that would authorize the use of vacuum or suction dredge equipment in California under conditions set forth by the two agencies. SWRCB staff, in coordination with Department staff, are in the process of collecting additional information to inform the next steps that will be taken by the SWRCB (SWRCB 2019).

Instream aggregate (gravel) mining continues today and can have similar impacts to suction dredge mining by removing, processing, and relocating stream substrates (Olson and Davis 2009). This type of mining typically removes bars used as Foothill Yellow-legged Frog breeding habitat and reduces habitat heterogeneity by creating flat wide channels (Kupferberg 1996a). Typically when listed salmonids are present, mining must be conducted above the wetted edge, but this practice can create perennial off-channel bullfrog breeding ponds (M. van Hattem pers. comm. 2018).

Agriculture

Direct loss of Foothill Yellow-legged Frog habitat from wildland conversion to agriculture is rare because the typically rocky riparian areas they inhabit are usually not conducive to farming, but removal of riparian vegetation directly adjacent to streams for agriculture is more common and widespread. The U.S. Department of Agriculture classifies 3.9 million ha (9.6 million ac) in California as cropland, which amounts to less than 10% of the state's land area, and 70% of this occurs in the Central Valley between Redding and Bakersfield (Martin et al. 2018). In addition, several indirect impacts can adversely affect Foothill Yellow-legged Frogs at substantial distances from agricultural operations such as effects from runoff (sediments and agrochemicals), drift and deposition of airborne pollutants, water diversions, and creation of novel habitats like impoundments that facilitate spread of detrimental non-native species. As sedimentation and introduced species impacts were previously discussed, this section instead focuses on the other possible adverse impacts.

Agrochemicals

Many species of amphibians, particularly ranids, have experienced declines throughout California, but the most dramatic declines have occurred in the Sierra Nevada east of the San Joaquin Valley where 60% of the total pesticide usage in the state was sprayed (Sparling et al. 2001). Agrochemicals applied to crops in the Central Valley can volatilize and travel in the atmosphere and deposit in higher elevations (LeNoir et al. 1999). Pesticide concentrations diminish as elevations increase in the lower foothills but change little from 533 to 1,920 m (1,750-6,300 ft), which coincides with the Foothill Yellow-legged Frog's elevational range (Ibid). Foothill Yellow-legged Frog absence at historically occupied sites in California significantly correlated with agricultural land use within 5 km (3 mi), and a positive relationship exists between Foothill Yellow-legged Frog declines and the amount of upwind agriculture, suggesting airborne agrochemicals may be a contributing factor (Figure 20; Davidson et al. 2002). Cholinesterase-inhibitors (most organophosphates and carbamates), which disrupt nerve impulse transmission, were

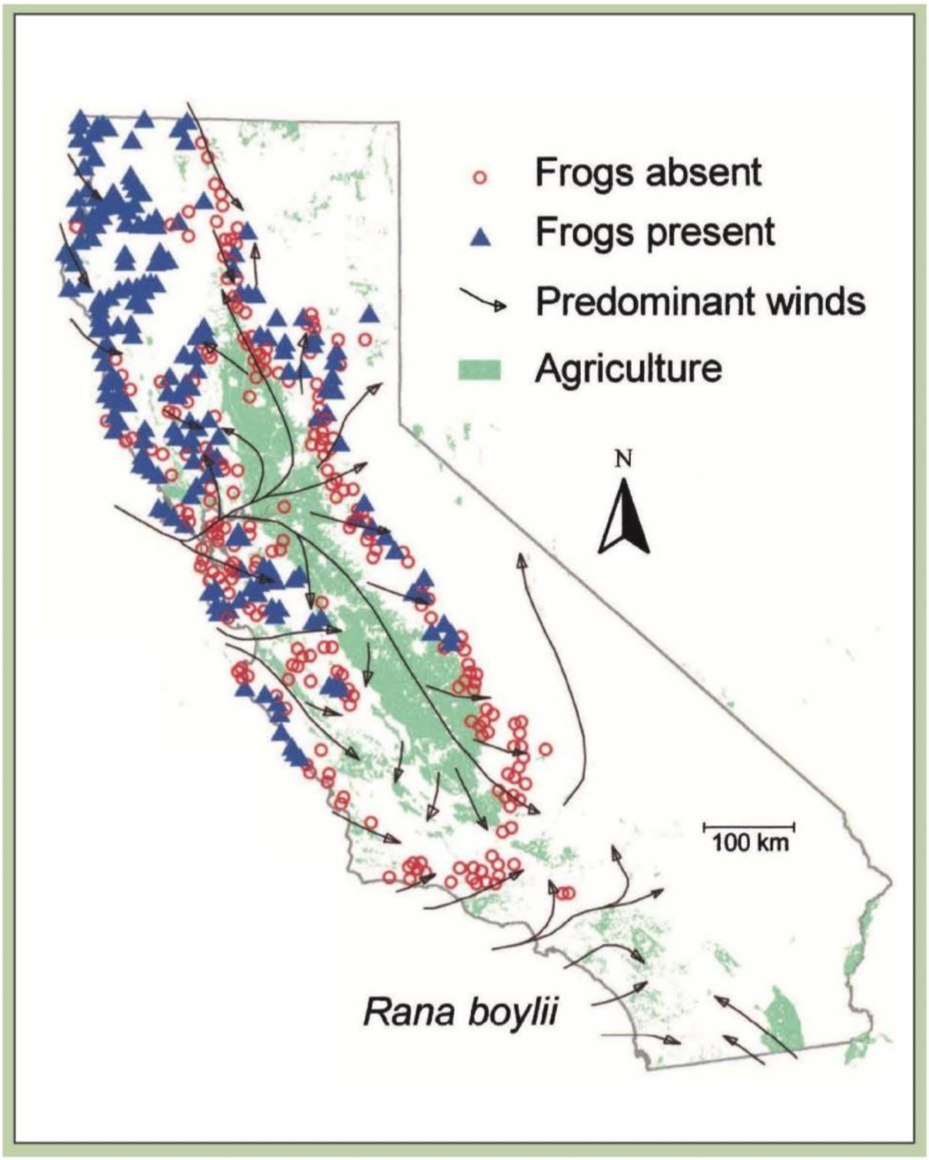


Figure 20. Relationship of Foothill Yellow-legged Frog occupancy to agriculture from Davidson et al. (2002)

more strongly associated with population declines than other pesticide types (Davidson 2004). Olson and Davis (2009) and Lind (2005) also reported a negative correlation between Foothill Yellow-legged Frog presence and proximity and quantity of nearby agriculture in Oregon and across the species' entire range, respectively.

Lethal and sublethal effects of agrochemicals on amphibians can take two general forms: direct toxicity and food-web effects. Sublethal doses of agrochemicals can interact with other environmental stressors to reduce fitness. Foothill Yellow-legged Frog tadpoles showed significantly greater vulnerability to the lethal and sublethal effects of carbaryl than Pacific Treefrogs (Kerby and Sih 2015). An inverse relationship exists between carbaryl concentration and Foothill Yellow-legged Frog activity, and their 72-h LC_{50} (concentration at which 50% die) measured one-fifth that of Pacific Treefrogs (Ibid.). Carbaryl slightly decreased Foothill Yellow-legged Frog development rate, but it significantly increased susceptibility to predation by signal crayfish despite nearly no mortality in the pesticide- and predator-only treatments (Ibid.). Sparling and Fellers (2009) also found Foothill Yellow-legged Frogs were significantly more sensitive to pesticides (chlorpyrifos and endosulfan in this study) than Pacific Treefrogs; their 96-hr LC_{50} was nearly five-times less than for treefrogs. Endosulfan was nearly 121 times more toxic to Foothill Yellow-legged Frogs than chlorpyrifos, and water samples from the Sierra Nevada have contained endosulfan concentrations within their lethal range and sometimes greater than the LC_{50} for the species (Ibid.). Sublethal effects included smaller body size, slower development rate, and increased time to metamorphosis (Ibid.). Sparling and Fellers (2007) determined the organophospates chlorpyrifos, malathion, and diazinon can harm Foothill Yellow-legged Frog populations, and their oxon derivatives (the resultant compounds once they begin breaking down in the body) were 10 to 100 times more toxic than their respective parental forms.

Extrapolating the results of studies on other ranids to Foothill Yellow-legged Frogs should be undertaken with caution; however, those studies can demonstrate additional potential adverse impacts of exposure to agrochemicals. Relyea (2005) discovered that Roundup®, a common herbicide, could cause rapid and widespread mortality in amphibian tadpoles via direct toxicity, and overspray at the manufacturer's recommended application concentrations would be highly lethal. Atrazine, another common herbicide, has been implicated in disrupting reproductive processes in male Northern Leopard Frogs (*Rana pipiens*) by slowing gonadal development, inducing hermaphroditism, and even oocyte (egg) growth (Hayes et al. 2003). However, recent research on sex reversal in wild populations of Green Frogs (*R. clamitans*) suggests it may be a relatively common natural process unrelated to environmental contaminants, requiring more research (Lambert et al. 2019). Malathion, a common organophosphate insecticide, that rapidly breaks down in the environment, applied at low concentrations caused a trophic cascade that resulted in reduced growth and survival of two species of ranid tadpoles (Relyea and Diecks 2008). Malathion caused a reduction in the amount of zooplankton, which resulted in a bloom of phytoplankton and an eventual decline in periphyton, an important food source for tadpoles (Ibid.). In contrast, Relyea (2005) found that some insecticides increased amphibian tadpole survival by reducing their invertebrate predators. Runoff from agricultural areas can contain fertilizers that input nutrients into streams and increase productivity, but they can also result in harmful algal blooms (Cordone and

Kelley 1961). In addition, exposure to pesticides can result in immunosuppression and reduce resistance to the parasites that cause limb malformations (Kiesecker 2002, Hayes et al. 2006).

Cannabis

An estimated 60-70% of the cannabis (*Cannabis indica* and *C. sativa*) used in the U.S. from legal and illegal sources is grown in California, and most comes from the Emerald Triangle, an area comprised of Humboldt, Mendocino, and Trinity counties (Ferguson 2019). Small-scale illegal cannabis farms have operated in this area since at least the 1960s but have expanded rapidly, particularly trespass grows on public land primarily by Mexican cartels, since the passage of the Compassionate Use Act in 1996 (Mallery 2010, Bauer et al. 2015). Like other forms of agriculture, it involves clearing the land, diverting water, and using herbicides and pesticides; however, in addition, many of these illicit operations use large quantities of fertilizers and highly toxic banned pesticides to kill anything that may threaten the crop, and they leave substantial amounts of non-biodegradable trash and human excrement (Mallery 2010, Thompson et al. 2014, Carah et al. 2015).

Measurements of environmental impacts of illegal cannabis grows have been hindered by the difficult and dangerous nature of accessing many of these sites; however, some analyses have been conducted, often using aerial images and geographic information systems (GIS). An evaluation of 54% of watersheds within and bordering Humboldt County revealed that while cannabis grow sites are generally small (< 0.5 ha [1.2 ac]) and comprised a tiny fraction of the study area (122 ha [301 ac]), they were widespread (present in 83% of watersheds) but unevenly distributed, indicating impacts are concentrated in certain watersheds (Butsic and Brenner 2016, Wang et al. 2017). The results also showed that 68% of grows were > 500 m (0.3 mi) from developed roads, 23% were located on slopes steeper than 30%, and 5% were within 100 m (328 ft) of critical habitat for threatened salmonids (Butsic and Brenner 2016). These characteristics suggest wildlands adjacent to cannabis cultivations are at heightened risk of habitat fragmentation, erosion, sedimentation, landslides, and impacts to waterways critical to imperiled species (Ibid.).

A separate analysis in the same general area estimated potentially significant impacts from water diversions alone. Cannabis requires a substantial amount of water during the growing season, so it is often cultivated near sources of perennial surface water for irrigation, commonly diverting from springs and headwater streams (Bauer et al. 2015). In the least impacted of the study watersheds, Bauer et al. (2015) calculated that diversions for cannabis cultivation could reduce the annual seven-day low flow by up to 23%, and in some of the heavily impacted watersheds, water demands for cannabis could exceed surface water availability. If not regulated carefully, cannabis cultivation could have substantial impacts on sensitive aquatic species like Foothill Yellow-legged Frogs in watersheds in which it is concentrated.

For context, cannabis cultivation was responsible for approximately 1.1% of forest cover lost within study watersheds in Humboldt County from 2000 to 2013, while timber harvest accounted for 53.3% (Wang et al. 2017). Cannabis requires approximately two times as much water per day as wine grapes, the other major irrigated crop in the region (Bauer et al. 2015). Impacts from cannabis cultivation have been observed by Foothill Yellow-legged Frog researchers working on the Trinity River and South Fork

Eel River in the form of lower flows in summer, increased egg stranding, and more algae earlier in the season in recent years (S. Kupferberg and M. Power pers. comm. 2015; D. Ashton pers. comm. 2017; S. Kupferberg, M. van Hattem, and W. Stokes pers. comm. 2017). In addition, Gonsolin (2010) reported illegal cannabis cultivations on four headwater streams that drained into his study area along Coyote Creek, three of which were occupied by Foothill Yellow-legged Frogs. The cultivators had removed vegetation adjacent to the creeks, terraced the slopes, diverted water, constructed small water impoundments, poured fertilizers directly into the impoundments, and applied herbicides and pesticides, as evidenced by leftover empty containers littering the site.

Commercial sale of cannabis for recreational use became legal in California on January 1, 2018, through passage of the Control, Regulate and Tax Adult Use of Marijuana Act (2016), and with it an environmental permitting system and habitat restoration fund was established. The number of applications for temporary licenses per watershed is depicted in Figure 21. Two of the expected outcomes of passage of this law were that the profit-margin on growing cannabis would fall to the point that it would discourage illegal trespass grows and move the bulk of the cultivation out of remote forested areas into existing agricultural areas like the Central Valley (CSOS 2016). However, until cannabis is legalized at the federal level, these results may not occur since banks are reluctant to work with growers due to federal prohibitions subjecting them to prosecution for money laundering (ABA 2019). Additional details on cannabis permitting at the state level can be found under the Existing Management section.

Vineyards

Vineyard operators historically built on-stream dams and removed almost all the riparian vegetation to make room for vines and for ease of irrigation (M. van Hattem pers. comm. 2019). They still divert a substantial amount of water for irrigation, and they build on- and off-stream impoundments that support bullfrogs (Ibid.). The acreage of land planted in wine grapes in California began rising dramatically in the 1970s and now accounts for 90% of wine produced in the U.S. (Geisseler and Horwath 2016, Alston et al. 2018). The number of wineries in California rose from approximately 330 to nearly 2,500 between 1975 and 2006; however, expansion slowed and has reversed slightly recently with 24,300 ha (60,000 ac), or 6.5% of total area planted, removed between 2015 and 2017 (Volpe et al. 2010, CDFA 2018). In 2015, 347,000 ha (857,000 ac) were planted in grapes with 70% located in the San Joaquin Valley; 66%, 21%, and 13% were planted in wine, raisin, and table grapes, respectively (Alston et al. 2018).

Expansion of wineries in the coastal counties converted natural areas such as oak woodlands and forests to vineyards (Merenlender 2000, Napa County 2010). The area of Sonoma County covered in grapes increased by 32% from 1990 to 1997, and 42% of these new vineyards were planted above 100 m (328 ft) with 25% on slopes greater than 18% (Merelender 2000). For context, only 18% of vineyards planted before 1990 occurred above 100 m (328 ft) and less than 6% on slopes greater than 18% (Ibid.). This conversion took place on approximately 773 ha (1,909 ac) of conifer and dense hardwood forest, 149 ha (367 ac) of shrubland, and 2,925 ha (7,229 ac) of oak grassland savanna (Ibid.).

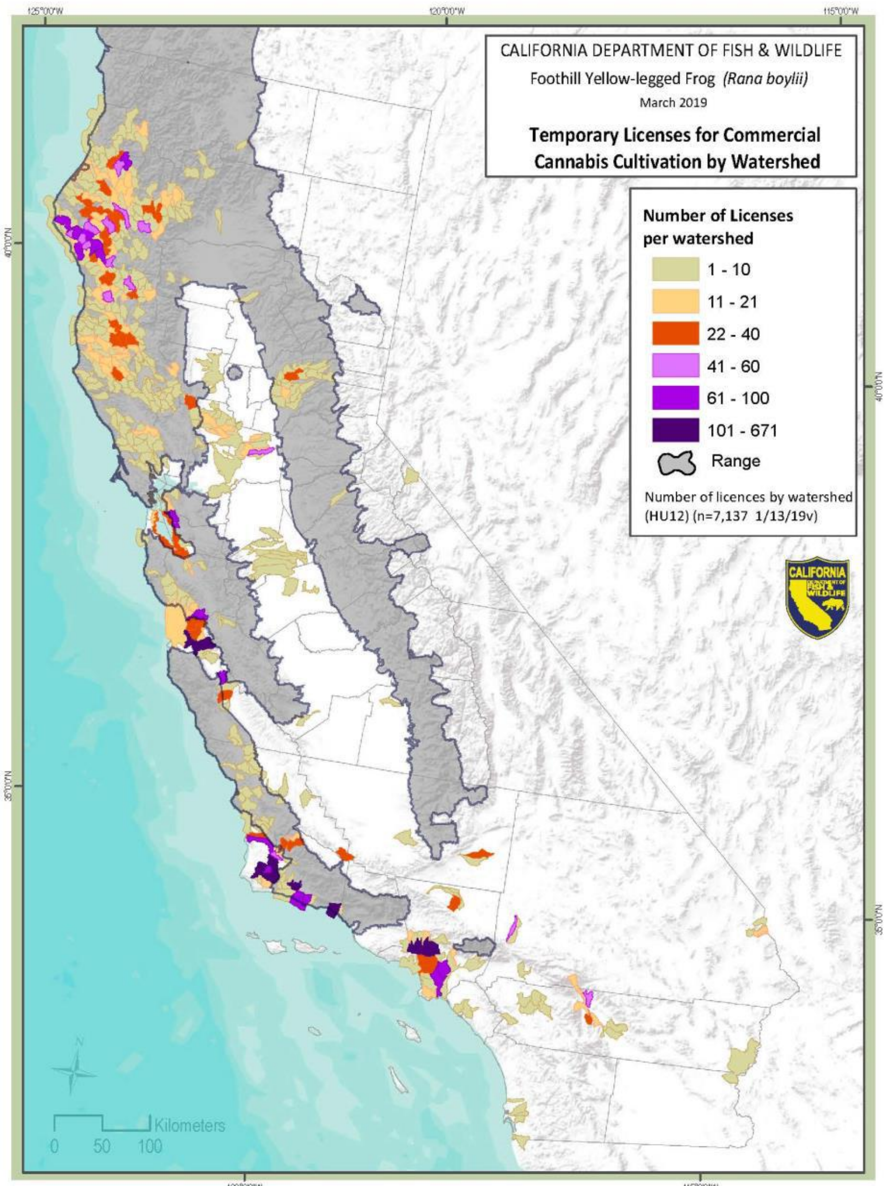


Figure 21. Cannabis cultivation temporary licenses by watershed in California (CDFA, NHD)

Recent expansion of oak woodland conversion to vineyards in Napa County was highest in its eastern hillsides (Napa County 2010). The County estimates that 1,085 and 1,240 ha (2,682-3,065 ac) of woodlands will be converted to vineyards between 2005 and 2030 (Ibid.). For context, 297 ha (733 ac) were converted from 1992 to 2003 (Ibid.). In addition, wine grapes were second only to almonds in terms of overall quantity of pesticides applied in California in 2016, but the quantity per unit area (2.9 kg/ha [2.6 lb/ac]) was 160% greater for the wine grapes (CDPR 2018). Vineyard expansion into hillsides has continued into sensitive headwater areas, and like cannabis cultivation, even small vineyards can have substantial impacts on Foothill Yellow-legged Frog habitat through sedimentation, water diversions, spread of harmful non-native species, and pesticide contamination (Merelender 2000, K. Weiss pers. comm. 2018).

Livestock Grazing

Livestock grazing can be an effective habitat management tool, including control of riparian vegetation encroachment, but overgrazing can significantly degrade the environment (Siekert et al. 1985). Cattle display a strong preference for riparian areas and have been implicated as a major source of habitat damage in the western U.S. where the adverse impacts of overgrazing on riparian vegetation are intensified by arid and semi-arid climates (Behnke and Raleigh 1978, Kauffman and Krueger 1984, Belsky et al. 1999). The severity of grazing impacts on riparian systems can be influenced by the number of animals, duration and time of year, substrate composition, and soil moisture (Benhke and Raleigh 1978, Kauffman et al. 1983, Marlow and Pogacnik 1985, Siekert et al. 1985). In addition to habitat damage, cattle can directly trample any life stage of Foothill Yellow-legged Frog.

Signs of overgrazing include impacts to the streambanks such as increased slough-offs and cave-ins that collapse undercuts used as refuge (Kauffman et al. 1983). Overgrazing reduces riparian cover, increases erosion and sedimentation, which as described above can result in silt degradation of breeding, rearing, and invertebrate food-producing areas (Cordone and Kelley 1961, Behnke and Raleigh 1978, Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). Loss of streamside and instream vegetative cover and changes to channel morphology can increase water temperatures and velocities (Behnke and Raleigh 1978). Water quality can be affected by increased turbidity and nutrient input from excrement, and seasonal water quantity can be impacted through changes to channel morphology (Belsky et al. 1999). In addition, increased nutrients and temperatures can promote blooms of harmful cyanobacteria like *Microcystis aeruginosa*, which releases a toxin when it expires that can cause liver damage to amphibians as well as other animals including humans (Bobzien and DiDonato 2007, Zhang et al. 2013).

While some recent studies indicate livestock grazing continues to damage stream and riparian ecosystems, its impact on Foothill Yellow-legged Frogs in California is unknown (Belsky et al. 1999, Hayes et al. 2016). In Oregon, the species' presence was correlated with significantly less grazing than where they were absent according to Borisenko and Hayes's 1999 report (as cited in Olson and Davis 2009). However, Fellers (2005) reported that apparently some Coast Range foothill populations occupying streams draining east into the San Joaquin Valley were doing well at the time of publication despite being heavily grazed.

Urbanization and Road Effects

Habitat conversion and fragmentation combined with modified environmental disturbance regimes can substantially jeopardize biological diversity (Tracey et al. 2018). This threat is most severe in areas like California with Mediterranean-type ecosystems that are biodiversity hot spots, fire-prone, and heavily altered by human land use (Ibid.). From 1990 to 2010, the fastest-growing land use type in the conterminous U.S. was new housing construction, which rapidly expanded the wildland-urban interface (WUI) where houses and natural vegetation meet or intermix on the landscape (Radeloff et al. 2018).

Of several variables tested, proportion of urban land use within a 5 km (3.1 mi) radius of a site was associated with Foothill Yellow-legged Frog declines (Davidson et al. 2002). Lind (2005) also found significantly less urban development nearby and upwind of sites occupied by Foothill Yellow-legged Frogs, suggesting pollutant drift may be a contributing factor. Changes in wildfires may also contribute to the species' declines; 95% of California's fires are human-caused, and wildfire issues are greatest at the WUI (Syphard et al. 2009, Radeloff et al. 2018). Population density, intermix WUI (where wildland and development intermingle as opposed to an abrupt interface), and distance to WUI explained the most variability in fire frequency (Syphard et al. 2007). In addition to wildfires, habitat loss, and fragmentation, urbanization can impact adjacent ecosystems through non-native species introduction, native predator subsidization, and disease transmission (Bar-Massada et al. 2014).

Projections show growth in California's population to 51 million people by 2060 from approximately 40 million currently (PPIC 2019). This will increase urbanization, the WUI, and habitat fragmentation. The Department of Finance projects the Inland Empire, the San Joaquin Valley, and the Sacramento metropolitan area will be the fastest-growing regions of the state over the next several decades (Ibid.). This puts the greatest pressure in areas outside of the Foothill Yellow-legged Frog's range; however, because the environmental stressors associated with urbanization can span far beyond its physical footprint, they may still adversely affect the species.

Highways are frequently recognized as barriers to dispersal that fragment habitats and populations; however, single-lane roads can pose significant risks to wildlife as well (Cook et al. 2012, Brehme et al. 2018). Foothill Yellow-legged Frogs are at risk of being killed by vehicles when roads are located near their habitat (Cook et al. 2012, Brehme et al. 2018). Fifty-six juvenile Foothill Yellow-legged Frogs were found on a road adjacent to Sulphur Creek (Mendocino County), seven of which had been struck and killed (Cook et al. 2012). When fords (naturally shallow areas) are used as vehicle crossings, they can create sedimentation and poor water quality, and in some cases, the fords are gravel or cobble bars used by Foothill Yellow-legged Frogs for breeding that could result in direct mortality (K. Blanchard pers. comm. 2018, R. Bourque pers. comm. 2018). Construction of culverts under roads to keep vehicles out of the streambed can result in varying impacts. In some cases, they can impede dispersal and create deep scoured pools that support predatory fish and frogs, but when properly constructed, they can facilitate frog movement up and down the channel with reduced road mortality (Van Wagner 1996, GANDA 2008). In areas where non-native species are not a threat, but premature drying is, pools created by culverts can provide habitat in otherwise unsuitable areas (M. Grefsrud pers. comm. 2019). An evaluation of the impact of roads on 166 native California amphibians and reptiles through direct

morality and barriers to movement concluded that Foothill Yellow-legged Frogs, at individual and population levels, were at moderate risk of road impacts in aquatic habitat but very low risk of impacts in terrestrial habitat (Brehme et al. 2018). For context, all chelonids (turtles and tortoises), 72% of snakes, 50% of anurans, 18% of lizards, and 17% of salamander species in California were ranked as having a high or very high risk of negative road impacts in the same evaluation (Ibid.).

Poorly constructed roadways near rivers and streams can result in substantial erosion and sedimentation, leading to reduced amphibian densities (Welsh and Ollivier 1998). Proximity of roads to Foothill Yellow-legged Frog habitat contributes to petrochemical runoff and poses the threat of spills (Ashton et al. 1997). A diesel spill on Hayfork Creek (Trinity County) resulted in mass mortality of Foothill Yellow-legged Frog tadpoles and partial metamorphs (Bury 1972). Roads have also been implicated in the spread of disease and may have aided in the spread of Bd in California (Adams et al. 2017b).

Frogs use auditory and visual cues to defend territories and attract mates, and some studies reveal that realistic levels of traffic noise can impede transmission and reception of these signals (Bee and Swanson 2007). Some male frogs have been observed changing the frequency of their calls to increase the distance they can be heard over traffic noise, but if females have evolved to recognize lower pitched calls as signs of superior fitness, this potential trade-off between audibility and attractiveness could have implications for reproductive success (Parris et al. 2009). In a separate study, traffic noise caused a change in male vocal sac coloration and an increase in stress hormones, which changed sexual selection processes and suppressed immunity (Troïanowski et al. 2017). Because Foothill Yellow-legged Frogs mostly call underwater and are not known to use color displays, communication cues may not be adversely affected by traffic noise, but their stress response is unknown.

Timber Harvest

Because Foothill Yellow-legged Frogs tend to remain close to the water channel (i.e., within the riparian corridor) and current timber harvest practices minimize disturbance in riparian areas for the most part, adverse effects from timber harvest are expected to be relatively low (Hayes et al. 2016, CDFW 2018b). However, some activities have a potential to negatively impact Foothill Yellow-legged Frogs or their habitat, including direct mortality and increased sedimentation during construction and decommissioning of watercourse crossings and infiltration galleries, tree felling, log hauling, and entrainment by water intakes or desiccation of eggs and tadpoles through stranding from dewatering during drafting operations (CDFW 2018b,c). In addition to impacts previously described under the Sedimentation and Road Effects section, when silt runoff into streams is accompanied by organic materials, such as logging debris, impaired water quality can result, including reduced dissolved oxygen, which is important in embryonic and tadpole development (Cordone and Kelley 1961).

Because Foothill Yellow-legged Frogs are heliotherms (i.e, they bask in the sun to raise their body temperature) and sensitive to thermal extremes, some moderate timber harvest may benefit the species (Zweifel 1955, Fellers 2005). Ashton (2002) reported 85% of his Foothill Yellow-legged Frog observations occurred in second-growth forests (37-60 years post-harvest) as opposed to late-seral forests and postulated that the availability of some open canopy areas played a major part in this

disparity. Foothill Yellow-legged Frogs are typically absent in areas with closed canopy (Welsh and Hodgson 2011). Reduced canopy also raises stream temperatures, which could improve tadpole development and promote algal and invertebrate productivity in otherwise cold streams (Olson and Davis 2009; Catenazzi and Kupferberg 2013,2017).

Recreation

Several types of recreation can adversely impact Foothill Yellow-legged Frogs, and some are more severe and widespread than others. One of the main potential factors identified by herpetologists as contributing to disappearance of Foothill Yellow-legged Frogs in southern California was increased and intensified recreation in streams (Adams et al. 2017b). The greater number of people traveling into the backcountry may have facilitated the spread Bd to these areas, and while no evidence shows stress from disturbance or other environmental pressures increases susceptibility to Bd, the stress hormone corticosterone has been implicated in immunosuppression (Hayes et al. 2003, Adams et al. 2017b).

The amount of Foothill Yellow-legged Frog habitat disturbed by off-highway motor vehicles (OHV) throughout its range in California is unknown, but its impacts can be significant, particularly in areas with small isolated populations (Kupferberg et al. 2009c, Kupferberg and Furey 2015). An example is the Carnegie State Vehicular Recreation Area (CVSRA), located in the hills southwest of Tracy in the Corral Hollow Creek watershed (Alameda and San Joaquin counties). The above-described road effects apply: sedimentation, crushing along trail crossings, and potential noise effects (Ibid.). In addition, dust suppression activities employed by CSVRA use magnesium chloride ($MgCl_2$), which has the potential to harm developing embryos and tadpoles (Karraker et al. 2008, Hopkins et al. 2013, OHMVRC 2017). Based on museum records, Foothill Yellow-legged Frogs were apparently abundant in Corral Hollow Creek, but they are extremely rare now and are already extirpated or at risk of extirpation (Kupferberg et al. 2009c, Kupferberg and Furey 2015).

Motorized and non-motorized recreational boating can also impact Foothill Yellow-legged Frogs. The impacts of jet boat traffic were investigated in Oregon; in areas with frequent use and high wakes breaking on shore, Foothill Yellow-legged Frogs were absent (Borisenko and Hayes 1999 as cited in Olson and Davis 2009). This wake action had the potential to dislodge egg masses, strand tadpoles, disrupt adult basking behavior, and erode shorelines (Ibid.). Jet boat tours and races on the Klamath River (Del Norte and Humboldt counties) may have an impact on Foothill Yellow-legged Frog use of the mainstem (M. van Hattem pers. comm. 2019). In addition, using gravel bars as launch and haul out sites for boat trailers, kayaks, or river rafts can result in direct loss of egg masses and tadpoles or damage to breeding and rearing habitat and can disrupt post-metamorphic frog behavior (Ibid.). As described above, pulse flows released for whitewater boating in the late spring and summer can result in scouring and stranding of egg masses and tadpoles (Borisenko and Hayes 1999 as cited in Olson and Davis 2009, Kupferberg et al. 2009b). In addition, the velocities that resulted in stunted growth and increased vulnerability to predation in Foothill Yellow-legged Frog tadpoles were less than the increased velocities experienced in nearshore habitats during intentional release of recreational flows for whitewater boating, as well as hydropeaking for power generation (Kupferberg et al. 2011b).

Hiking, horse-riding, camping, fishing, and swimming, particularly in sensitive breeding and rearing habitat can also adversely impact Foothill Yellow-legged Frog populations (Borisenko and Hayes 1999 in Olson and Davis 2009). Because Foothill Yellow-legged Frog breeding activity was being disturbed and egg masses were being trampled by people and dogs using Carson Falls (Marin County), the land manager established an educational program, including employing docents on weekends that remind people to stay on trails and tread lightly to try to reduce the loss of Foothill Yellow-legged Frog reproductive effort (Prado 2005). In addition, within his study site, Van Wagner (1996) reported that a property owner moved rocks that were being used as breeding habitat to create a swimming hole. The extent to which this is more than a small, local problem is unknown, but as the population of California increases, recreational pressures in Foothill Yellow-legged Frog habitat are likely to increase commensurately.

Drought

Drought is a common phenomenon in California and is characterized by lower than average precipitation. Lower precipitation in general results in less surface water, and water availability is critical for obligate stream-breeding species. Even in the absence of drought, a positive relationship exists between precipitation and latitude within the Foothill Yellow-legged Frog's range in California, and mean annual precipitation has a strong influence on Foothill Yellow-legged Frog presence at historically occupied sites (Davidson et al. 2002, Lind 2005). Figure 22 depicts the recent historical annual average precipitation across the state as well as during the most recent drought and how they differ. Southern California is normally drier than northern California, but the severity of the drought was even greater in the south.

Reduced precipitation can result in deleterious effects to Foothill Yellow-legged Frogs beyond the obvious premature drying of aquatic habitat. When stream flows recede during the summer and fall, sometimes the isolated pools that stay perennially wet are the only remaining habitat. This phenomenon concentrates aquatic species, resulting in several potentially significant adverse impacts. Stream flow volume was negatively correlated with Bd load during a recent chytridiomycosis outbreak in the Alameda Creek watershed (Adams et al. 2017a). The absence of high peak flows in winter coupled with wet years allowed bullfrogs to expand their distribution upstream, and the drought-induced low flows in the fall concentrated them with Foothill Yellow-legged Frogs in the remaining drying pools (Ibid.). This mass mortality event appeared to have been the result of a combination of drought, disease, and dam effects (Ibid.). This die-off occurred in a regulated reach that experiences heavy recreational use and presence of crayfish and bass (Ibid.). Despite these threats, the density of breeding females in this reach was greater in 2014 and 2015 than the in the unregulated reach upstream because the latter dried completely before tadpoles could metamorphose during the preceding drought years (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015).

In addition to increasing the spread of pathogens, drought-induced stream drying can increase predation and competition by introduced fish and frogs in the pools they are forced to share (Moyle 1973, Hayes and Jennings 1988, Drost and Fellers 1996). This concentration in isolated pools can also result in increased native predation as well as facilitate spread of Bd. An aggregation of six adult Foothill

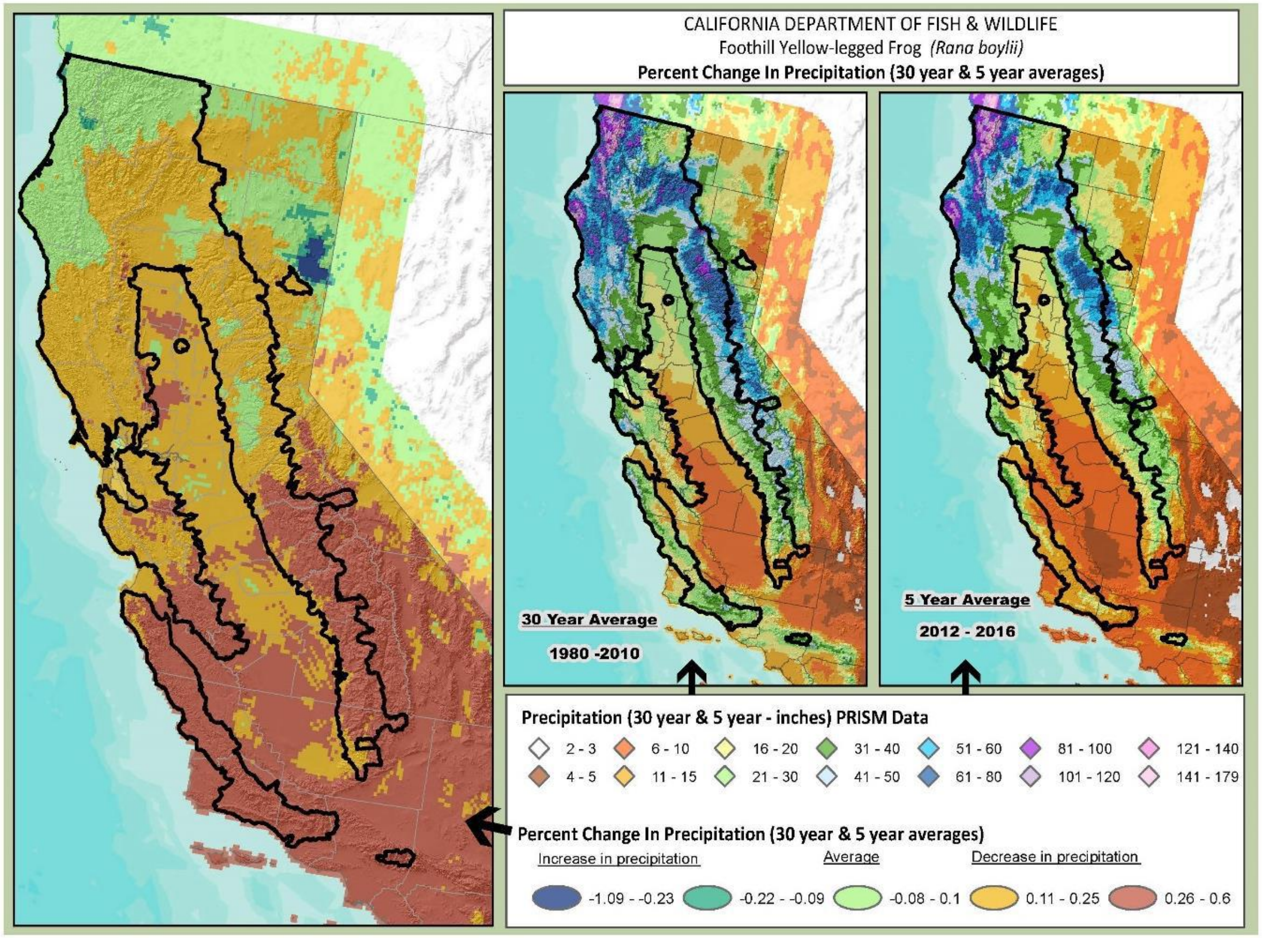


Figure 22. Change in precipitation from 30-year average and during the recent drought (PRISM)

Yellow-legged Frogs was observed perched on a rock above an isolated pool where a garter snake was foraging on tadpoles during the summer; this close contact may reduce evaporative water loss when they are forced out of the water during high temperatures, but it can also increase disease transmission risk (Leidy et al. 2009.). Gonsolin (2010) also documented a late summer aggregation of juvenile Foothill Yellow-legged Frogs out of water during extremely high temperatures. In addition, drought-induced low flow, high water temperatures, and high densities of tadpoles were associated with outbreaks of malformation-inducing parasitic copepods (Kupferberg et al. 2009a).

Rapidly receding spring flows can result in stranding egg masses and tadpoles. However, this risk is likely less significant when it is drought-induced on an unregulated stream vs. a result of dam operations since Foothill Yellow-legged Frogs have evolved to initiate breeding earlier and shorten the breeding period in drought years (Kupferberg 1996a). If pools stay wet long enough to support metamorphosis, complete drying at the end of the season may benefit Foothill Yellow-legged Frogs if it eliminates introduced species like warm water fish and bullfrogs. Moyle (1973) noted that the only intermittent streams occupied by Foothill Yellow-legged Frogs in the Sierra Nevada foothills had no bullfrogs. At a long-term study site in upper Coyote Creek in 2015, Foothill Yellow-legged Frogs had persisted in reaches that had at least some summer water through the three preceding years of the most severe drought in over a millennium, albeit at much lower abundance than a decade before (Gonsolin 2010, Griffin and Anchokaitis 2014, J. Smith pers. comm. 2015). The population's abundance appeared to have never recovered from the 2007-2009 drought before the 2012-2016 drought began (J. Smith pers. comm. 2015). In 2016, after a relatively wet winter, Foothill Yellow-legged Frogs bred en masse, and only a single adult bullfrog was detected, an unusually low number for that area (CDWR 2016, J. Smith pers. comm. 2016). It appeared the population may rebound; however, in 2018, it experienced lethal chytridiomycosis outbreak, and like the Alameda Creek die-off probably resulted from crowding during drought, presence of bullfrogs as Bd-reservoirs and predators and competitors, and the stress associated with the combination of the two (Kupferberg and Catenazzi 2019).

Drought effects can also exacerbate other environmental stressors. During the most recent severe drought, tree mortality increased dramatically from 2014 to 2017 and reached approximately 129 million dead trees (OEHHA 2018). Multiple years of high temperatures and low precipitation left them weakened and more susceptible to pathogens and parasites (Ibid.). Vast areas of dead and dying trees are more prone to severe wildfires, and they lose their carbon sequestration function while also emitting methane, which is an extremely damaging greenhouse gas (CNRA 2016). Post-wildfire storms can result in erosion of fine sediments from denuded hillsides into the stream channel (Florsheim et al. 2017). If the storms are short duration and low precipitation, as happens during droughts, their magnitude may not be sufficient to transport the material downstream, resulting in a longer temporal loss or degradation of stream habitat (Ibid.). Reduced rainfall may also infiltrate the debris leading to subsurface flows rather than the surface water Foothill Yellow-legged Frogs require (Ibid.). Extended droughts increase risk of the stream being uninhabitable or inadequate for breeding for multiple years, which would result in population-level impacts and possible extirpation (Ibid.).

Wildland Fire and Fire Management

Fire is an important element for shaping and maintaining the species composition and integrity of many California ecosystems (Syphard et al. 2007, SBFFP 2018). Prior to European settlement, an estimated 1.8 to 4.9 million ha (4.5-12 million ac) burned annually (4-11% of total area of the state), ignited both deliberately by Native Americans and through lightning strikes (Keeley 2005, SBFFP 2018). The impacts of wildland fires on Foothill Yellow-legged Frogs are poorly understood and likely vary significantly across the species' range with differences in climate, vegetation, soils, stream-order, slope, frequency, and severity (Olson and Davis 2009). Mortality from direct scorching is unlikely because Foothill Yellow-legged Frogs are highly aquatic, and most wildfires occur during the dry period of the year when the frogs are most likely to be in or near the water (Pilliod et al. 2003, Bourque 2008). Field observations support this presumption; sightings of post-metamorphic Foothill Yellow-legged Frogs immediately after fires in the northern Sierra Nevada and North Coast indicate they are not very vulnerable to the direct effects of fire (S. Kupferberg and R. Peek pers. comm. 2018). Similarly, Foothill Yellow-legged Frogs were observed two months, and again one year, after a low- to moderate-intensity fire burned an area in the southern Sierra Nevada in 2002, and the populations were extant and breeding as recently as 2017 (Lind et al. 2003b, CNDDB 2019). While water may provide a refuge during the fire, it is also possible for temperatures during a fire, or afterward due to increased solar exposure, to near or exceed a threshold resulting in lethal or sublethal harm; this would likely impact embryos and tadpoles with limited dispersal abilities (Pilliod et al. 2003).

Intense fires remove overstory canopy, which provides insulation from extreme heat and cold, and woody debris that increases habitat heterogeneity (Pilliod et al. 2003, Olson and Davis 2009). If this happens frequently enough, it can permanently change the landscape. For example, frequent high-severity burning of crown fire-adapted ecosystems can prevent forest regeneration since seeds require sufficient time between fires to mature, and repeated fires can deplete the seed bank (Stephens et al. 2014). Smoke and ash change water chemistry through increased nutrient and heavy metal inputs that can reach concentrations harmful to aquatic species during the fire and for days, weeks, or years thereafter (Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Erosion rates on granitic soils, which make up a large portion of the Foothill Yellow-legged Frog's range, can be over 60 times greater in burned vs. unburned areas and can increase sedimentation for over 10 years (Megahan et al. 1995, Hayes et al. 2016). Post-fire nutrient inputs into streams could benefit Foothill Yellow-legged Frogs through increased productivity and more rapid growth and development (Pilliod et al. 2003). While the loss of leaf litter that accompanies fire alters the food web, insects are expected to recolonize rapidly, and the lack of cover could increase their vulnerability to predation by Foothill Yellow-legged Frogs (Ibid.).

Low-intensity fires likely have no adverse effect on Foothill Yellow-legged Frogs (Olson and Davis 2009). If they occur in areas with dense canopy, wildfires can improve habitat quality for Foothill Yellow-legged Frogs by reducing riparian cover, providing areas to bask, and increasing habitat heterogeneity, which is likely to outweigh any adverse effects from some fire-induced mortality (Russell et al. 1999, Olson and Davis 2009). In a preliminary analysis of threats to Foothill Yellow-legged Frogs in Oregon, proximity to stand-replacing fires was not associated with absence (Olson and Davis 2009).

Euro-American colonization of California significantly altered the pattern of periodic fires with which California's native flora and fauna evolved through fire exclusion, land use practices, and development (OEHHA 2018). Fire suppression can lead to canopy closure, which reduces habitat quality by limiting thermoregulatory opportunities (Olson and Davis 2009). In addition, fire suppression and its subsequent increase in fuel loads combined with expanding urbanization and rising temperatures have resulted in a greater likelihood of catastrophic stand-replacing fires that can significantly alter riparian systems for decades (Pilliod et al. 2003). Firebreaks, in which vegetation is cleared from a swath of land, can result in similar impacts to roads and road construction (Ibid.). Fire suppression can also include bulldozing within streams to create temporary reservoirs for pumping water, which can cause more damage than the fire itself to Foothill Yellow-legged Frogs in some cases (S. Kupferberg and R. Peek pers. comm. 2018). In addition, fire suppression practices can involve applying hundreds of tons of ammonia-based fire retardants and surfactant-based fire suppressant foams from air tankers and fire engines (Pilliod et al. 2003). Some of these chemicals are highly toxic to some anurans (Little and Calfee 2000).

Fire suppression has evolved into fire management with a greater understanding of its importance in ecosystem health (Keeley and Syphard 2016). Several strategies are employed including prescribed burns, mechanical fuels reduction, and allowing some fires to burn instead of necessarily extinguishing them (Pilliod et al. 2003). Like wildfires themselves, fire management strategies have the potential to benefit or harm Foothill Yellow-legged Frogs. Prescribed fires and mechanical fuels removal lessen the likelihood of catastrophic wildfires, but they can also result in loss of riparian vegetation, excessive sedimentation, and increased water temperatures (Ibid.). Salvage logging after a fire may result in similar impacts to timber harvest but with higher rates of erosion and sedimentation (Ibid.). A balanced approach to wildland fires is likely to have the greatest beneficial impact on species and ecosystem health (Stephens et al. 2012).

Floods and Landslides

As previously described, Foothill Yellow-legged Frog persistence is highly sensitive to early life stage mortality (Kupferberg et al. 2009c). While aseasonal dam releases are a major source of egg mass and tadpole scouring, storm-driven floods are also capable of ~~it~~ inducing the same effects (Ashton et al. 1997). Van Wagner (1996) concluded that the high discharge associated with heavy rainfall could account for a significant source of mortality in post-metamorphic Foothill Yellow-legged Frogs as well as eggs and tadpoles; he observed two adult females and several juveniles swept downstream with fatal injuries post-flooding. Severe flooding, specifically two 500-year flood events in early 1969 in Evey Canyon (Los Angeles County), resulted in massive riparian habitat destruction (Sweet 1983). Prior to the floods, Foothill Yellow-legged Frogs were widespread and common, but only four subsequent sightings were documented between 1970 and 1974 and none since (Sweet 1983, Adams 2017b). Sweet (1983) speculates that because Foothill Yellow-legged Frogs overwinter in the streambed in that area, the floods may have reduced the population's abundance below an extinction threshold. Four other herpetologists interviewed about Foothill Yellow-legged Frog extirpations in southern California listed severe flooding as a likely cause (Adams et al. 2017b).

As mentioned above, landslides are a frequent consequence of post-fire rainstorms and can result in lasting impacts to stream morphology, water quality, and Foothill Yellow-legged Frog populations. On the other hand, Olson and Davis (2009) suggest that periodic landslides can have beneficial effects by transporting woody debris into the stream that can increase habitat complexity and by replacing sediments that are typically washed downstream over time. Whether a landslide is detrimental or beneficial is likely heavily influenced by amount of precipitation and the underlying system. As previously described, too little precipitation could lead to prolonged loss of habitat through failure to transport material downstream, and too much precipitation can result in large-scale habitat destruction and direct mortality.

Climate Change

Global climate change threatens biodiversity and may lead to increased frequency and severity of drought, wildfires, flooding, and landslides (Williams et al. 2008, Keely and Syphard 2016). Data show a consistent trend of warming temperatures in California and globally; 2014 was the warmest year on record, followed by 2015, 2017, and 2016 (OEHHA 2018). Climate model projections for annual temperature in California in the 21st century range from 1.5 to 4.5°C (2.7-8.1°F) greater than the 1961-1990 mean (Cayan et al. 2008). Precipitation change projections are less consistent than those for temperature, but recent studies indicate increasing variability in precipitation, and increasingly dry conditions in California resulting from increased evaporative water loss primarily due to rising temperatures (Cayan et al. 2005, Williams et al. 2015, OEHHA 2018). Precipitation variability and proportion of dry years were negatively associated with Foothill Yellow-legged Frog presence in a range-wide analysis (Lind 2005). In addition, low precipitation intensified the adverse effects of dams on the species (Ibid.).

California recently experienced the longest drought since the U.S. Drought Monitor began reporting in 2000 (NIDIS 2019). Until March 5, 2019, California experienced drought effects in at least a portion of the state for 376 consecutive weeks; the most intense period occurred during the week of October 28, 2014 when D4 (the most severe drought category) affected 58.4% of California's land area (Figure 23; NIDIS 2019). A recent modeling effort using data on historical droughts, including the Medieval megadrought between 1100 and 1300 CE, indicates the mean state of drought from 2050 to 2099 in California will likely exceed the Medieval-era drought, under both high and moderate greenhouse gas emissions models (Cook et al. 2015). The probability of a multidecadal (35 yr) drought occurring during the late 21st century is greater than 80% in all models used by Cook et al. (2015). If correct, this would represent a climatic shift that not only falls outside of contemporary variability in aridity but would also be unprecedented in the past millennium (Ibid.).

As a result of increasing temperatures, a decreasing proportion of precipitation falls as snow, resulting in more runoff from rainfall during the winter and a shallower snowpack that melts more rapidly (Stewart 2009). A combination of reduced seasonal snow accumulation and earlier streamflow timing significantly reduces surface water storage capacity and increases the risk for winter and spring floods, which may require additional and taller dams and result in alterations to hydroelectric power generation flow regimes (Cayan et al. 2005, Knowles et al. 2006, Stewart 2009). The reduction in snowmelt volume

is expected to impact the northern Sierra (Feather, Yuba, and American River watersheds) to a greater extent than the southern portion (Young et al. 2009). The earlier shift in peak snowmelt timing is predicted to exceed four to six weeks across the entire Sierra Nevada depending on the amount of warming that occurs this century (Ibid.). In addition, the snow water equivalent is predicted to significantly decline by 2070-2099 over the 1961-1990 average in the Trinity, Sacramento, and San Joaquin drainages from -32% to -79%, and effectively no snow is expected to fall below 1000 m (3280 ft) in the high emissions/sensitive model (Cayan et al. 2008).

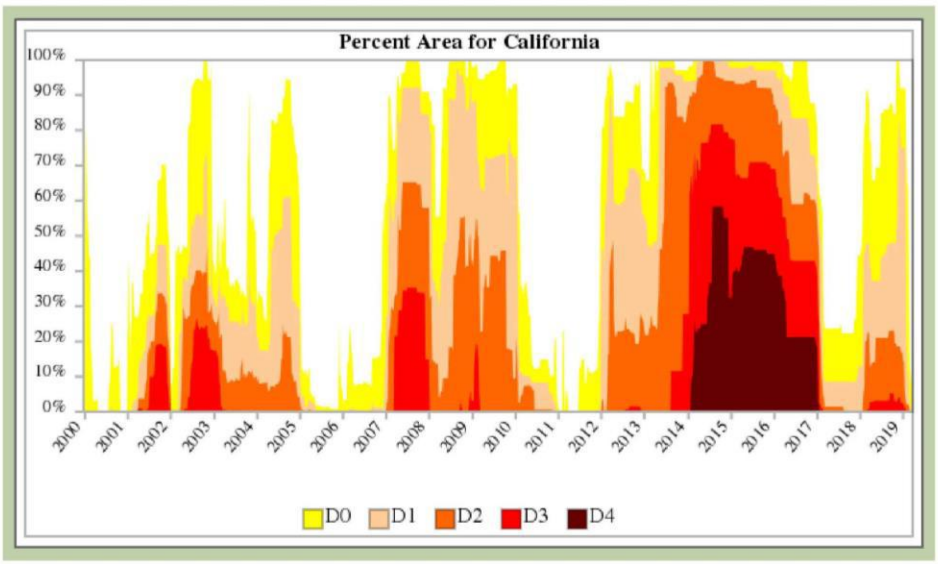


Figure 23. Palmer Hydrological Drought Indices 2000-present (NIDIS)

The earlier shift of snowmelt and lower water content will result in lower summer flows, which will intensify the competition for water among residential, agricultural, industrial, and environmental needs (Field et al. 1999, Cook et al. 2015). In unregulated systems, as long as water is present through late summer, an earlier hydrograph recession that triggers Foothill Yellow-legged Frog breeding could result in a longer time to grow larger prior to metamorphosis, which improves probability of survival (Yarnell et al. 2010, Kupferberg 2011b). However, if duration from peak to base flow shortens, it can result in increased sedimentation and reduced habitat complexity in addition to stranding (Yarnell et al. 2010).

Fire frequency relates to temperature, fuel loads, and fuel moisture (CCSP 2008). Therefore, increasing periods of drought combined with extreme heat and low humidity that stress or kill trees and other vegetation create ideal conditions for wildland fires (Ibid). Not surprisingly, the area burned by wildland fires over the western U.S. increased since 1950 but rose rapidly in the mid-1980s (Westerling et al. 2006, OEHHA 2018). As temperatures warmed and snow melted earlier, large-wildfire frequency and duration increased, and wildfire seasons lengthened (Westerling et al. 2006, OEHHA 2018).

In California, latitude inversely correlates with temperature and annual area burned, but the climate-fire relationship is substantially different across the state, and future wildfire regimes are difficult to predict (Keeley and Syphard 2016). For example, the relationship between spring and summer temperature and area burned in the Sierra Nevada is highly significant but not in southern California (Ibid.). Climate has a greater influence on fire regimes in mesic than arid environments, and the most influential climatological factor (e.g., precipitation, temperature, season, or their interactions) shifts over time (Ibid.). Nine of the 10 largest fires in California since 1932 have occurred in the past 20 years, 4 within the past 2 years (Figure 24; CAL FIRE 2019). However, it is possible this trend will not continue; climate- and wildfire-induced changes in vegetation could reduce wildfire severity in the future (Parks et al. 2016).

Wildfires themselves can accelerate the effects of climate change. Wildfires emit short-lived climate pollutants like black carbon (soot) and methane that are tens to thousands of times greater than carbon dioxide (the main focus of greenhouse gas reduction) in terms of warming effect and are responsible for 40% or more of global warming to date (CNRA 2016). Healthy forests can sequester large amounts of carbon from the atmosphere, but recently carbon emissions from wildfires have exceeded their uptake by vegetation in California (Ackerly et al. 2018).

With increased variability and changes in precipitation type, magnitude, and timing comes more variable and extreme stream flows (Mallakpour et al. 2018). Models for stream flow in California project higher high flows, lower low flows, wetter rainy seasons, and drier dry seasons (Ibid.). The projected water cycle extremes are related to strengthening El Niño and La Niña events, and both severe flooding and intense drought are predicted to increase by at least 50% by the end of the century (Yoon et al. 2015). These changes increase the likelihood of Foothill Yellow-legged Frog egg mass and tadpole scouring and stranding, even in unregulated rivers.

A species' vulnerability to climate change is a function of its sensitivity to climate change effects, its exposure to them, and its ability to adapt its behaviors to survive with them (Dawson et al. 2011). Myriad examples exist of species shifting their geographical distribution toward the poles and to higher elevations and changing their growth and reproduction with increases in temperature over time (Parmesan and Yohe 2003). However, in many places, fragmentation of suitable habitat by anthropogenic barriers (e.g., urbanization, agriculture, and reservoirs) limits a species' ability to shift its range (Pounds et al. 2007). The proportion of sites historically occupied by Foothill Yellow-legged Frogs that are now extirpated increases significantly on a north-to-south latitudinal gradient and at drier sites within California, suggesting climate change may contribute to the spatial pattern of the species' declines (Davidson et al. 2002).

Commented [MOU3]: Also Moritz et al. in Science for Yosemite..

An analysis of the climate change sensitivity of 195 species of plants and animals in northwestern North America revealed that, as a group, amphibians and reptiles were estimated to be the most sensitive (Case et al. 2015). Nevertheless, examples exist of amphibians adjusting their breeding behaviors (e.g., calling and migrating to breeding sites) to occur earlier in the year as global warming increases (Beebee 1995, Gibbs and Breisch 2001). Because of the rapid change in temperature, Beebee (1995) posits these are examples of behavioral and physiological plasticity rather than natural selection. However, for

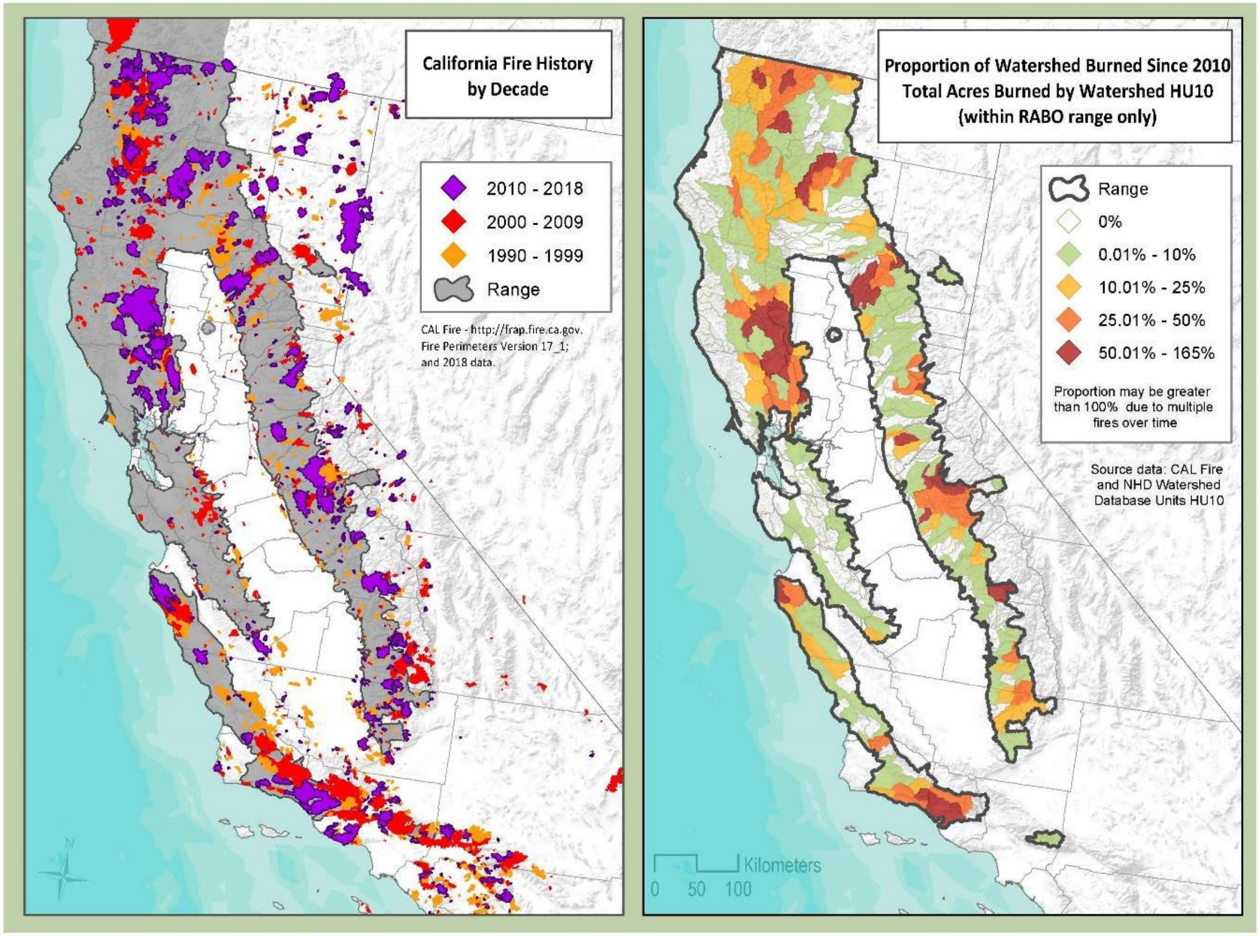


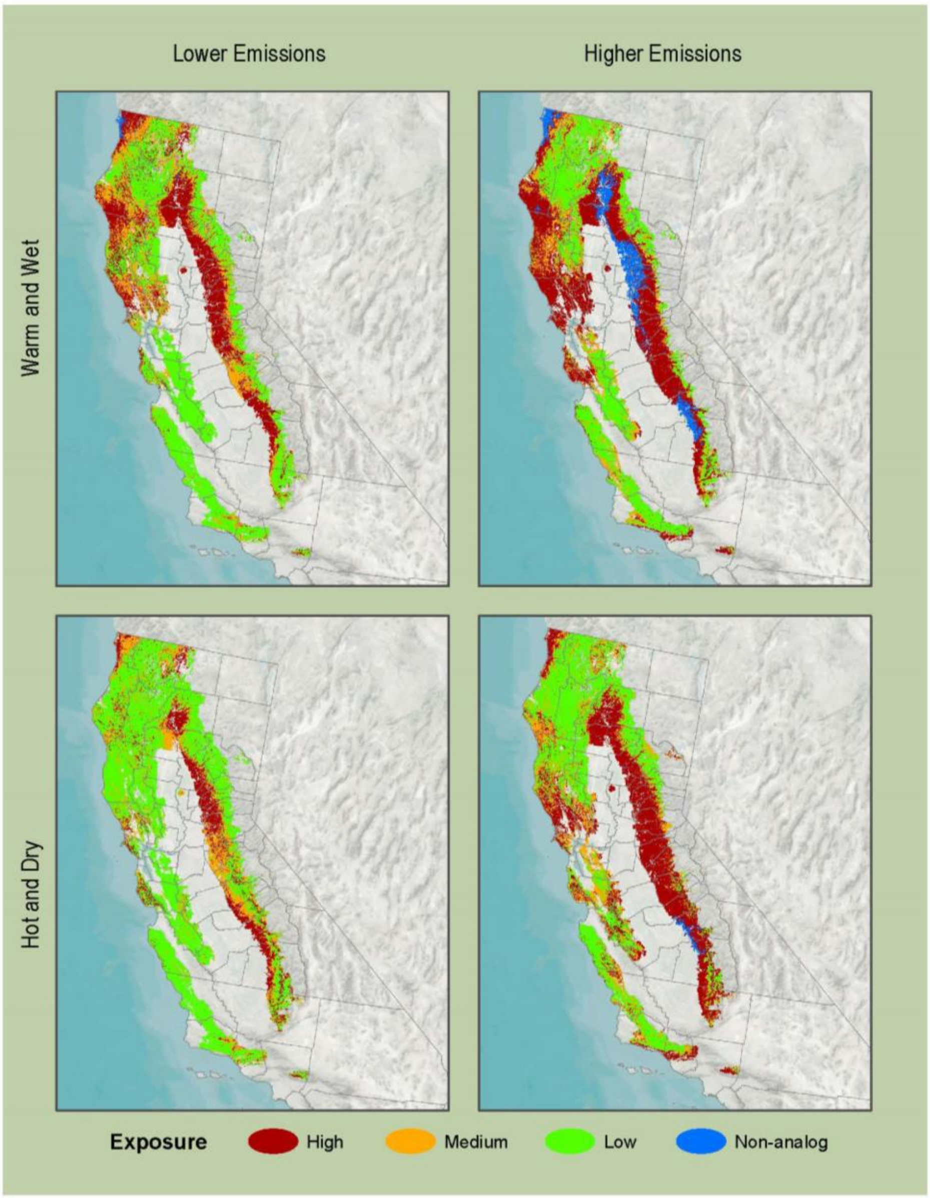
Figure 24. Fire history (1990-2018) and proportion of watershed burned (2010-2018) in California (CAL FIRE, NHD)

species with short generation times or in areas less affected by climate change, populations may be able to undergo evolutionary adaptation to the changing local environmental conditions (Hoffman and Sgrò 2011).

As previously described in the Seasonal Activity and Movements section, Foothill Yellow-legged Frog breeding is closely tied to water temperature, flow, and stage, and the species already adjusts its timing of oviposition by as much as a month in the same location during different water years, so the species may have enough inherent flexibility to reduce their vulnerability. The species appears fairly resilient to drought, fire, and flooding, at least in some circumstances. For example, after the 2012-2016 drought, the Loma Fire in late 2016, and severe winter flooding and landslides in 2016 and 2017, Foothill Yellow-legged Frog adults and metamorphs, as well as aquatic insects and rainbow trout, were abundant throughout Upper Llagas Creek in fall of 2017, and the substrate consisted of generally clean gravels and cobbles with only a slight silt coating in some pools (J. Smith pers. comm. 2017). The frogs and fish likely took refuge in a spring-fed pool, and the heavy rains scoured the fine sediments that eroded downstream (Ibid.). These refugia from the effects of climate change reduce the species' exposure, thereby reducing their vulnerability (Case et al. 2015).

Climate change models that evaluate the Foothill Yellow-legged Frog's susceptibility from a species and habitat perspective yield mixed results. An investigation into the possible effects of climate on California's native amphibians and reptiles used ecological niche models, future climate scenarios, and general circulation models to predict species-specific climatic suitability in 2050 (Wright et al. 2013). The results suggested approximately 90-100% of localities currently occupied by Foothill Yellow-legged Frogs are expected to remain climatically suitable in that time, and the proportion of currently suitable localities predicted to change ranges from -20% to 20% (Ibid.). However, a second study performed by the same research team using a subset of these models found that 66.4% of currently occupied cells will experience reduced environmental suitability in 2050 (Warren et al. 2014). This analysis included 90 species of native California mammals, birds, reptiles, and amphibians. For context, over half of the taxa were predicted to experience > 80% reductions, a consistent pattern reflected across taxonomic groups (Ibid.).

A third analysis investigated the long-term risk of climate change by modeling the relative environmental stress a vegetative community would undergo in 2099 given different climate and greenhouse gas emission scenarios (Thorne et al. 2016). This model does not incorporate any Foothill Yellow-legged Frog-specific data; it strictly projects climatic stress levels vegetative communities will experience within the species' range boundaries (Ibid.). Unsurprisingly, higher emissions scenarios resulted in a greater proportion of habitat undergoing climatic stress (Figure 25). Perhaps counterintuitively, the warm and wet scenario resulted in a greater amount of stress than the hot and dry scenario. When high emissions and warm and wet changes are combined, a much greater proportion of the vegetation communities will experience "non-analog" conditions, those outside of the range of conditions currently known in California (Ibid.).



Source - model extracts from -Thorne, J.H. et al. (2016) A climate change vulnerability assessment of California's terrestrial vegetation. CDFW.

Figure 25. Vegetative community exposure to climate change in 2099 based on Thorne et al. (2016).

Habitat Restoration and Species Surveys

Potential conflicts between managing riverine habitat below dams for both cold-water adapted salmonids and Foothill Yellow-legged Frogs was discussed previously. In addition to problems with temperatures and pulse flows, some stream restoration projects aimed at physically creating or improving salmonid habitat can also adversely affect the species. For example, boulder deflectors were placed in Hurdygurdy Creek (Del Norte County) to create juvenile steelhead rearing habitat; deflectors change broad, shallow, low-velocity reaches into narrower, deeper, faster reaches preferred by the fish (Fuller and Lind 1992). Foothill Yellow-legged Frogs were documented using the restoration reach as breeding habitat annually prior to placement of the boulders, but no breeding was detected in the following three years, suggesting this project eliminated the conditions the frogs require (Ibid.). In addition, a fish ladder to facilitate salmonid migration above the Alameda Creek Diversion Dam was recently constructed on a Foothill Yellow-legged Frog lek site, and the frogs may become trapped in the ladder (M. Grefsrud pers. comm. 2019). Use of rotenone to eradicate non-native fish as part of a habitat restoration project is rare, but if it is applied in streams occupied by Foothill Yellow-legged Frogs, it can kill tadpoles but is unlikely to impact post-metamorphic frogs (Fontenot et al. 1994). Metamorphosing tadpoles may be able to stay close enough to the surface to breathe air and survive but may display lethargy and experience increased susceptibility to predation (Ibid.).

Commonly when riparian vegetation is removed, regulatory agencies require a greater amount to be planted as mitigation to offset the temporal loss of habitat. This practice can have adverse impacts on Foothill Yellow-legged Frogs by reducing habitat suitability. Foothill Yellow-legged Frogs have been observed moving into areas where trees were recently removed, and they are known to avoid heavily shaded areas (Welsh and Hodgson 2011, M. Grefsrud pers. comm. 2019).

Biologists conducting surveys in Foothill Yellow-legged Frog habitat can trample egg masses or larvae if they are not careful. One method for sampling fish is electroshocking, which runs a current through the water that stuns the fish temporarily allowing them to be captured. Post-metamorphic frogs are unlikely to be killed by electroshocking; however, at high frequencies (60 Hz), they may experience some difficulty with muscle coordination for a few days (Allen and Riley 2012). This could increase their risk of predation. At 30 Hz, there were no differences between frogs that were shocked and controls (Ibid.). Tadpoles are more similar to fish in tail muscle and spinal structure and are at higher risk of injuries; however, researchers who reported observing stunned tadpoles noted they appeared to recover completely within several seconds (Ibid.). Adverse effects to Foothill Yellow-legged Frogs from electrofishing may only happen at frequencies higher than those typically used for fish sampling (Ibid.)

Small Population Sizes

Small populations are at greater risk of extirpation, primarily through the disproportionately greater impact of demographic, environmental, and genetic stochasticity on them compared to large populations, so any of the threats previously discussed will likely have an even greater adverse impact on small populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). This risk of extinction from genetic stochasticity is amplified when connectivity between the small populations, and thus gene flow,

is impeded (Fahrig and Merriam 1985, Taylor et al. 1993, Lande and Shannon 1996, Palstra and Ruzzante 2008). Genetic diversity provides capacity to evolve in response to environmental changes, and the "rescue effect" of gene flow is important in minimizing probability of local extinction (Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). However, the rescue effect is diminished in conditions of high local environmental stochasticity of recruitment or survival (Eriksson et al. 2014). In addition, populations living near their physiological limits and lacking adaptive capacity may not be able to evolve in response to rapid changes (Hoffmann and Sgrò 2011). Furthermore, while pathogens or parasites rarely result in host extinction, they can increase its likelihood in small populations by driving the host populations below a critically low threshold beneath which demographic stochasticity can lead to extinction, even if they possess the requisite genetic diversity to adapt to a changed environment (Gomulkiewicz and Holt 1995, Adams et al. 2017b).

A Foothill Yellow-legged Frog PVA revealed that, even with no dam effects considered (e.g., slower growth and increased egg and tadpole mortality), populations with the starting average density of adult females in regulated rivers (4.6/km [2.9/mi]) were four times more likely to go extinct within 30 years than those with the starting average density of adult females from unregulated rivers (32/km [120/mi]) (Kupferberg et al. 2009c). When the density of females in sparse populations was used (2.1/km [1.3/mi], the 30-year risk of extinction increased 13-fold (Ibid.). With dam effects, a number of the risk factors above contribute to the additional probability of local extinction such as living near their lower thermal tolerance and reduced recruitment and survival from scouring and stranding flows, poor food quality, and increased predation and competition (Kupferberg 1997a; Hoffmann and Sgrò 2011; Kupferberg et al. 2011a,b; Kupferberg et al. 2012; Eriksson et al. 2014). These factors act synergistically, contributing in part to the small size, high divergence, and low genetic diversity exhibited by many Foothill Yellow-legged Frog populations located in highly regulated watersheds (Kupferberg et al. 2012, Peek 2018).

EXISTING MANAGEMENT

Land Ownership within the California Range

Using the Department's Foothill Yellow-legged Frog range boundary and the California Protected Areas Database (CPAD), a GIS dataset of lands that are owned in fee title and protected for open space purposes by over 1,000 public agencies or non-profit organizations, the total area of the species' range in California comprises 13,620,447 ha (33,656,857 ac) (CPAD 2019, CWHR 2019). Approximately 37% is owned by federal agencies, 80% of which (4,071,178 ha [10,060,100 ac]) is managed by the Forest Service (Figure 26). Department of Fish and Wildlife-managed lands, State Parks, and other State agency-managed lands constitute around 2.6% of the range. The remainder of the range includes < 1% Tribal lands, 2.3% other conserved lands (e.g., local and regional parks), and 57% private and government-managed lands that are not protected for open space purposes. It is important to note that even if included in the CPAD, a property's management does not necessarily benefit Foothill Yellow-legged Frogs, but in some cases changes in management to conserve the species may be easier to undertake than on private lands or public lands not classified as conserved.

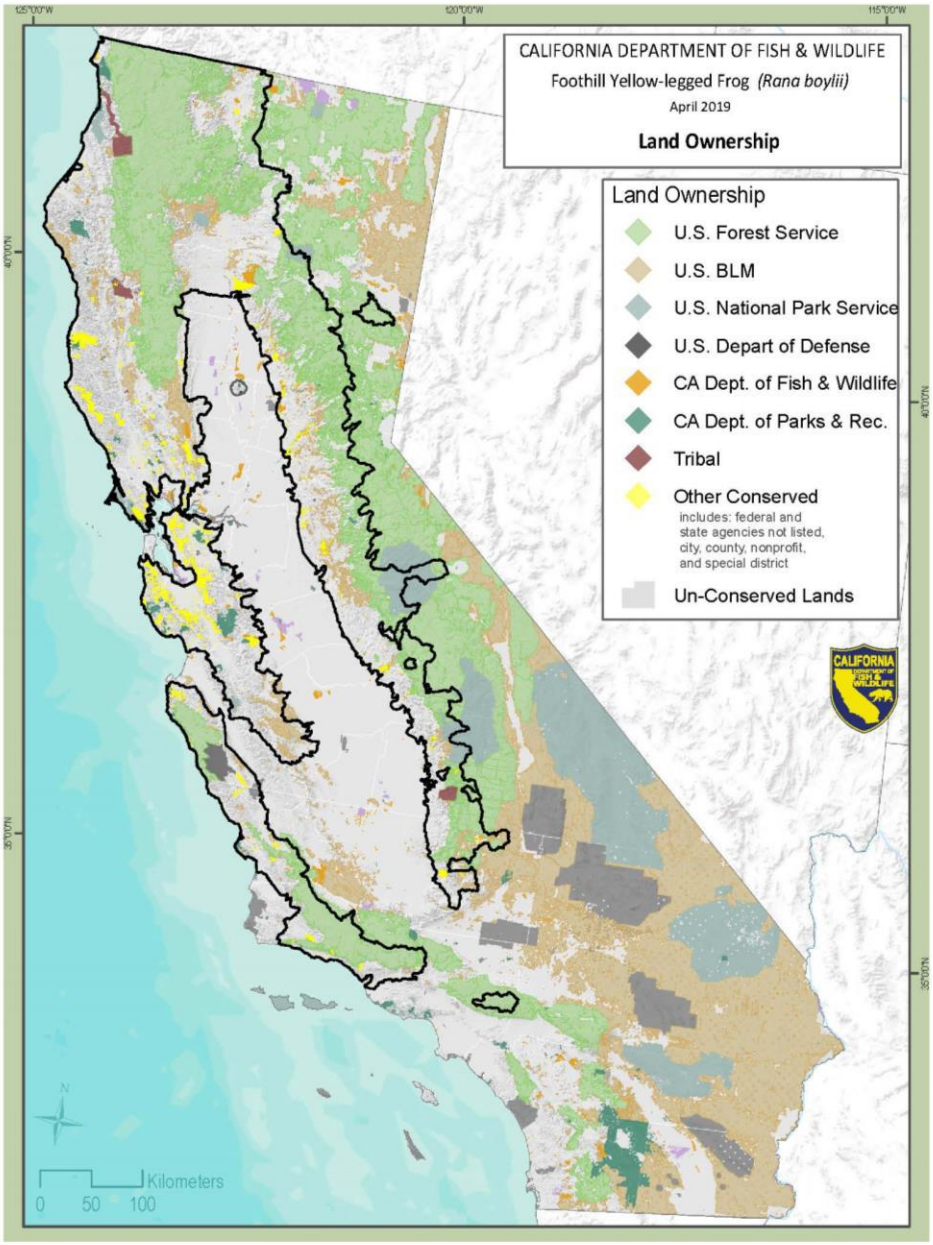


Figure 26. Conserved, Tribal, and other lands (BLM, CMD, CPAD, CWHR, DOD)

Statewide Laws

The laws and regulations governing land management within the Foothill Yellow-legged Frog's range vary by ownership. Several state and federal environmental laws apply to activities undertaken in California that may provide some level of protection for Foothill Yellow-legged Frogs and their habitat. The following is not an exhaustive list.

National Environmental Policy Act and California Environmental Quality Act

Most federal land management actions must undergo National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. § 4321, et seq.) analysis. NEPA requires federal agencies to document, consider alternatives, and disclose to the public the impacts of major federal actions and decisions that may significantly impact the environment. As a BLM and Forest Service Sensitive Species, impacts to Foothill Yellow-legged ~~Legged~~ Frogs are considered during NEPA analysis; however, the law has no requirement to minimize or mitigate adverse effects.

The California Environmental Quality Act (CEQA) is similar to NEPA; it requires state and local agencies to identify, analyze, and consider alternatives, and to publicly disclose environmental impacts from projects over which they have discretionary authority (Pub. Resources Code § 21000 et seq.). CEQA differs substantially from NEPA in requiring mitigation for significant adverse effects to a less than significant level unless overriding considerations are documented. CEQA requires an agency find projects that? may have a significant effect on the environment if they have the potential to substantially reduce the habitat, decrease the number, or restrict the range of any rare, threatened, or endangered species (Cal. Code Regs., tit. 14, §§ 15065(a)(1), 15380.). CEQA establishes a duty for public agencies to avoid or minimize such significant effects where feasible (Cal. Code regs., tit. 14, § 15021). Impacts to Foothill Yellow-legged Frogs, as an SSC, should be identified, evaluated, disclosed, and mitigated or justified under the Biological Resources section of an environmental document prepared pursuant to CEQA. However, a lead agency is not required to make a mandatory finding of significance conclusion unless it determines on a project-specific basis that the species meets the CEQA criteria for rare, threatened, or endangered.

Clean Water Act and Porter-Cologne Water Quality Control Act

The Clean Water Act originated in 1948 as the Federal Water Pollution Control Act of 1948. It was heavily amended in 1972 and became known as the Clean Water Act (CWA). The purpose of the CWA was to establish regulations for the discharge of pollutants into waters of the United States and establish quality standards for surface waters. Section 404 of the CWA forbids the discharge of dredged or fill material into waters and wetlands without a permit from the ACOE. The CWA also requires an alternatives analysis, and the ACOE is directed to issue their permit for the least environmentally damaging practicable alternative. The definition of waters of the United States has changed substantially over time based on Supreme Court decisions and agency rule changes.

The Porter-Cologne Water Quality Act was established by the State in 1969 and is similar to the CWA in that it establishes water quality standards and regulates discharge of pollutants into state waters, but it

also administers water rights which regulate water diversions and extractions. The SWRCB and nine Regional Water Boards share responsibility for implementation and enforcement of Porter-Cologne as well as the CWA's National Pollutant Discharge Elimination System permitting.

Federal and California Wild and Scenic Rivers Acts

In 1968, the U.S. Congress passed the federal Wild and Scenic Rivers Act (WSRA) (16 U.S.C. § 1271, et seq.) which created the National Wild and Scenic River System. The WSRA requires the federal government to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The WSRA prohibits the federal government from building, licensing, funding or otherwise aiding in the building of dams or other project works on rivers or segments of designated rivers. The WSRA does not give the federal government control of private property including development along protected rivers.

California's Wild and Scenic Rivers Act was enacted in 1972 so rivers that "possess extraordinary scenic, recreational, fishery, or wildlife values shall be preserved in their free-flowing state, together with their immediate environments, for the benefit and enjoyment of the people of the state." (Pub. Res. Code, § 5093.50). Designated waterways are codified in Public Resources Code sections 5093.50-5093.70. In 1981, most of California's designated Wild and Scenic Rivers were adopted into the federal system. Currently in California, 3,218 km (1,999.6 mi) of 23 rivers are protected by the WSRA, most of which are located in the northwest. Foothill Yellow-legged Frogs have been observed in 11 of the 17 designated rivers within their range (CNDDB 2019).

Lake and Streambed Alteration Agreements

Fish and Game Code Section 1602 requires entities to notify the Department of activities that "divert or obstruct the natural flow of, or substantially change or use any material from the bed, channel, or bank of any river, stream, or lake, or deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake." If the activity may substantially adversely affect an existing fish and wildlife resource, the Department may enter into a lake or streambed alteration agreement with the entity that includes reasonable measures necessary to protect the fish or wildlife resource (Fish & G. Code, §1602, subd. (a)(4)(B)). A lake or stream alteration agreement does not authorize take of species listed as candidates, threatened, or endangered under CESA (see Protection Afforded by Listing for CESA compliance requirements).

Medicinal and Adult-Use Cannabis Regulation and Safety Act

The commercial cannabis cultivation industry is unique in that any entity applying for an annual cannabis cultivation license from California Department of Food and Agriculture (CDFA) must include "a copy of any final lake or streambed alteration agreement…or written verification from the California Department of Fish and Wildlife that a lake or streambed alteration agreement is not required" with their license application (Cal. Code Regs., tit. 3, § 8102, subd. (v)). The SWRCB also enforces the laws related to waste discharge and water diversions associated with cannabis cultivation (Cal. Code Regs., tit. 3, § 8102, subd. (p)).

Forest Practice Act

The Forest Practice Act was originally enacted in 1973 to ensure that logging in California is undertaken in a manner that will also preserve and protect the State's fish, wildlife, forests, and streams. This law and the regulations adopted by the California Board of Forestry and Fire Protection (BOF) pursuant to it are collectively referred to as the Forest Practice Rules. The Forest Practice Rules implement the provisions of the Forest Practice Act in a manner consistent with other laws, including CEQA, Porter-Cologne, CESA, and the Timberland Productivity Act of 1982. The California Department of Forestry and Fire Protection (CAL FIRE) enforces these laws and regulations governing logging on private land.

Federal Power Act

The Federal Power Act and its major amendments are implemented and enforced by FERC and require licenses for dams operated to generate hydroelectric power. One of the major amendments required that these licenses "shall include conditions for the protection, mitigation and enhancement of fish and wildlife including related spawning grounds and habitat" (ECPA 1986). Hydropower licenses granted by FERC are usually valid for 30-50 years. If a licensee wants to renew their license, it must file a Notice of Intent and a pre-application document five years before the license expires to provide time for public scoping, any potentially new studies necessary to analyze project impacts and alternatives, and preparation of environmental documents. The applicant must officially apply for the new license at least two years before the current license expires.

As a federal agency, FERC must comply with federal environmental laws prior to issuing a new license or relicensing an existing hydropower project, which includes NEPA and ESA. As a result of environmental compliance or settlement agreements formed during the relicensing process, some operations have been modified and habitat restored to protect fish and wildlife. For example, the Lewiston Dam relicensing resulted in establishment of the Trinity River Restoration Program, which takes an ecosystem-approach to studying dam effects and protecting and restoring fish and wildlife populations downstream of the dam (Snover and Adams 2016). Similarly, relicensing of the Rock Creek-Cresta Project on the North Fork Feather River resulted in establishment of a multi-stakeholder Ecological Resources Committee (ERC). As a result of the ERC's studies and recommendations, pulse flows for whitewater boating were suspended for several years following declines of Foothill Yellow-legged Frogs, and the ERC is currently working toward augmenting the population in an attempt to increase abundance to a viable level.

Administrative and Regional Plans

Forest Plans

NORTHWEST FOREST PLAN

In 1994, BLM and the Forest Service adopted the Northwest Forest Plan to guide the management of over 97,000 km^2 (37,500 mi^2) of federal lands in portions of northwestern California, Oregon, and Washington. The Northwest Forest Plan created an extensive network of forest reserves including

Riparian Reserves. Riparian Reserves apply to all land designations to protect riparian dependent resources. With the exception of silvicultural activities consistent with Aquatic Conservation Strategy objectives, timber harvest is not permitted within Riparian Reserves, which can vary in width from 30 to 91 m (100-300 ft) on either side of streams, depending on the classification of the stream or waterbody (USFS and BLM 1994). Fuel treatment and fire suppression strategies and practices implemented within these areas are designed to minimize disturbance.

Sierra Nevada Forest Plan

Land and Resource Management Plans for forests in the Sierra Nevada were changed in 2001 by the Sierra Nevada Forest Plan Amendment and subsequently adjusted via a supplemental Environmental Impact Statement and Record of Decision in 2004, referred to as the Sierra Nevada Framework (USFS 2004). This established an Aquatic Management Strategy with Goals including maintenance and restoration of habitat to support viable populations of riparian-dependent species; spatial and temporal connectivity for aquatic and riparian species within and between watersheds to provide physically, chemically, and biologically unobstructed movement for their survival, migration, and reproduction; instream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats; the physical structure and condition of streambanks and shorelines to minimize erosion and sustain desired habitat diversity; and prevention of new introductions of invasive species and reduction of invasive species impacts that adversely affect the viability of native species. The Sierra Nevada Framework also includes Riparian Conservation Objectives and associated standards and guidelines specific to aquatic-dependent species, including the Foothill Yellow-legged Frog.

Resource Management Plans

Sequoia, Kings Canyon, and Yosemite National Parks fall within the historical range of the Foothill Yellow-legged Frog, but the species has been extirpated from these areas. The guiding principles for managing biological resources on National Park Service lands include maintenance of animal populations native to park ecosystems (Hayes et al. 2016). They also commit the agency to work with other land managers on regional scientific and planning efforts and maintenance or reintroduction of native species to the parks including conserving Foothill Yellow-legged Frogs in the Sierra Nevada (USDI NPS 1999 as cited in Hayes et al. 2016). A Sequoia and Kings Canyon National Parks Resource Management Plan does not include specific management goals for Foothill Yellow-legged Frogs, but it does include a discussion of the factors leading to the species' decline and measures to restore the integrity of aquatic ecosystems (Ibid.). The Yosemite National Park Resource Management Plan includes a goal of restoring Foothill Yellow-legged Frogs to the Upper Tuolumne River below Hetch Hetchy Reservoir (USDI NPS 2003 as cited in Hayes et al. 2016).

FERC Licenses

Dozens of hydropower dams have been relicensed in California since 1999, and several are in the process of relicensing (FERC 2019). In addition to following the Federal Power Act and other applicable federal laws, Porter-Cologne Water Quality Act requires non-federal dam operators to obtain a Water Quality Certification (WQC) from the SWRCB. Before it can issue the WQC, the SWRCB must consult with

the Department regarding the needs of fish and wildlife. Consequently, SWRCB includes conditions in the WQC that seek to minimize adverse effects to native species, and Foothill Yellow-legged Frogs have received some special considerations due to their sensitivity to dam operations during these licensing processes. As discussed above, the typical outcome is formation of an ERC-type group to implement the environmental compliance requirements and recommend changes to flow management to reduce impacts. Foothill Yellow-legged Frog-specific requirements fall into three general categories: data collection, modified flow regimes, and standard best management practices.

Data Collection

When little is known about the impacts of different flows and temperatures on Foothill Yellow-legged Frog occupancy and breeding success, data are collected and analyzed to inform recommendations for future modifications to operations such as temperature trigger thresholds. These surveys include locating egg masses and tadpoles, monitoring temperatures and flows, and recording their fate (e.g., successful development and metamorphosis, displacement, desiccation) during different flow operations and different water years. Examples of licenses with these conditions include the Lassen Lodge Project (FERC 2018), Rock Creek-Cresta Project (FERC 2009a), and El Dorado Project (EID 2007).

Modified Flow Regimes

When enough data exist to understand the effect of different operations on Foothill Yellow-legged Frog occupancy and success, license conditions may include required minimum seasonal instream flows, specific thermal regimes, gradual ramping rates to reduce the likelihood of early life stage scour or stranding, or freshet releases (winter/spring flooding simulation) to maintain riparian processes, and cancellation or prohibition of recreational pulse flows during the breeding season. Examples of licenses with these conditions include the Poe Hydroelectric Project (SWRCB 2017), Upper American Project (FERC 2014), and Pit 3, 4, 5 Project (FERC 2007b).

Best Management Practices

Efforts to reduce the impacts from maintenance activities and indirect operations include selective herbicide and pesticide application, aquatic invasive species monitoring and control, erosion control, and riparian buffers. Examples of licenses with these conditions include the South Feather Project (SWRCB 2018), Spring Gap-Stanislaus Project (FERC 2009b), and Chili Bar Project (FERC 2007a).

Habitat Conservation Plans and Natural Community Conservation Plans

Non-federal entities can obtain authorization for take of federally threatened and endangered species incidental to otherwise lawful activities through development and implementation of a Habitat Conservation Plan (HCP) pursuant to Section 10 of the ESA. The take authorization can extend to species not currently listed under ESA but which may become listed as threatened or endangered over the term of the HCP, which is often 25-75 years. California's companion law, the Natural Community Conservation Planning Act of 1991, takes a broader approach than either CESA or ESA. A Natural Community Conservation Plan (NCCP) identifies and provides for the protection of plants, animals, and their

habitats, while allowing compatible and appropriate economic activity. There are currently four HCPs that include Foothill Yellow-legged Frogs as a covered species, two of which are also NCCPs.

Humboldt Redwood (formerly Pacific Lumber) Company

The Humboldt Redwood Company (HRC) HCP covers 85,672 ha (211,700 ac) of private Coast Redwood and Douglas-fir forest in Humboldt County (HRC 2015). It is a 50-year HCP/incidental take permit (ITP) that was executed in 1999, revised in 2015 as part of its adaptive management strategy, and expires on March 1, 2049. The HCP includes an Amphibian and Reptile Conservation Plan and an Aquatics Conservation Plan with measures designed to sustain viable populations of Foothill Yellow-legged Frogs and other covered aquatic herpetofauna. These conservation measures include prohibiting or limiting tree harvest within Riparian Management Zones (RMZ), controlling sediment by maintaining roads and hillsides, restricting controlled burns to spring and fall in areas outside of the RMZ, conducting effectiveness monitoring throughout the life of the HCP, and use the data collected to adapt monitoring and management plans accordingly.

Watershed assessment surveys include observations of Foothill Yellow-legged Frogs and have documented their widespread distribution on HRC lands with a pattern of fewer near the coast in the fog belt and more inland (S. Chinnici pers. comm. 2017). The watersheds within the property are largely unaffected by dam-altered flow regimes or non-native species, so aside from the operations described under Timber Harvest above that are minimized to the extent feasible, the focus on suitable temperatures and denser canopy cover for salmonids may reduce habitat suitability for Foothill Yellow-legged Frogs over time (Ibid.).

San Joaquin County Multi-Species Habitat Conservation and Open Space Plan

The San Joaquin County Multi-Species Habitat Conservation and Open Space Plan (SJMSCP) is a 50-year HCP/ITP that was signed by the USFWS on November 14, 2000 (San Joaquin County 2000). The SJMSCP covers almost all of San Joaquin County except federal lands, a few select projects, and some properties with certain land uses, roughly 364,000 ha (900,000 ac). At the time of execution, approximately 70 ha (172 ac) of habitat within the SJMSCP area in the southwest portion of the county were considered occupied by Foothill Yellow-legged Frogs with another 1,815 ha (4,484 ac) classified as potential habitat, but it appears the species had been considered extirpated before then (Jennings and Hayes 1994, San Joaquin County 2000, Lind 2005). The HCP estimates around 8% of the combined modeled habitat would be converted to other uses over the permit term, but the establishment of riparian preserves with buffers around Corral Hollow Creek, where the species occurred historically, was expected to offset those impacts (San Joaquin County 2000, SJCOG 2018). However, the HCP did not require surveys to determine if Foothill Yellow-legged Frogs are benefiting (M. Grefsrud pers. comm. 2019).

East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan

The East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan (ECCC HCP/NCCP) is a multi-jurisdictional 30-year plan adopted in 2007 that covers over 70,423 ha (174,018 ac) in eastern Contra Costa County (Jones & Stokes 2006). The Foothill Yellow-legged Frog appears to be

extirpated from the ECCC HCP/NCCP area (CNDDB 2019). Nevertheless, suitable habitat was mapped, and impacts were estimated at well under 1% of both breeding and migratory habitat (Jones & Stokes 2006). One of the HCP/NCCP's objectives is acquiring high-quality Foothill Yellow-legged Frog habitat that has been identified along Marsh Creek (Ibid.). In 2017, the Viera North Peak 65 ha (160 ac) property was acquired that possesses suitable habitat for Foothill Yellow-legged Frogs (ECCCHC 2018).

Santa Clara Valley Habitat Plan

The Santa Clara Valley Habitat Plan (SCVHP) is a 50-year HCP/NCCP covering over 210,237 ha (519,506 ac) in Santa Clara County (ICF 2012). As previously mentioned, Foothill Yellow-legged Frogs appear to have been extirpated from lower elevation sites, particularly below reservoirs in this area. Approximately 17% of modeled Foothill Yellow-legged Frog habitat, measured linearly along streams, was already permanently preserved, and the SCVHP seeks to increase that to 32%. The maximum allowable habitat loss is 11 km (7 mi) permanent loss and 3 km (2 mi) temporary loss, while 167 km (104 mi) of modeled habitat is slated for protection. By mid-2018, 8% of impact area had been accrued and 3% of habitat protected (SCVHA 2019).

Green Diamond Aquatic Habitat Conservation Plan

Green Diamond Resources Company has an Aquatic Habitat Conservation Plan (AHCP) covering 161,875 ha (400,000 ac) of their land that is focused on cold-water adapted species, but many of the conservation measures are expected to benefit Foothill Yellow-legged Frogs as well (K. Hamm pers. comm. 2017). Examples include slope stability and road management measures to reduce stream sedimentation from erosion and landslides, and limiting water drafting during low flow periods with screens over the pumps to avoid entraining animals (Ibid.). Although creating more open canopy areas and warmer water temperatures is not the goal of the AHCP, the areas that are suitable for Foothill Yellow-legged Frog breeding are likely to remain that way because they are wide channels that receive sufficient sunlight (Ibid.).

SUMMARY OF LISTING FACTORS

CESA's implementing regulations identify key factors relevant to the Department's analyses and the Fish and Game Commission's decision on whether to list a species as threatened or endangered. A species will be listed as endangered or threatened if the Commission determines that the species' continued existence is in serious danger or is threatened by any one or any combination of the following factors: (1) present or threatened modification or destruction of its habitat; (2) overexploitation; (3) predation; (4) competition; (5) disease; or (6) other natural occurrences or human-related activities (Cal. Code Regs., tit. 14, § 670.1, subd. (i).

This section provides summaries of information from the foregoing sections of this status review, arranged under each of the factors to be considered by the Commission in determining whether listing is warranted.

Present or Threatened Modification or Destruction of Habitat

Most of the factors affecting ability to survive and reproduce listed above involve destruction or degradation of Foothill Yellow-legged Frog habitat. The most widespread, and potentially most significant, threats are associated with dams and their flow regimes, particularly in areas where they are concentrated and occur in a series along a river. Dams and the way they are operated can have up- and downstream impacts to Foothill Yellow-legged Frogs. They can result in confusing natural breeding cues, scouring and stranding of egg masses and tadpoles, reducing quality and quantity of breeding and rearing habitat, reducing tadpole growth rate, impeding gene flow among populations, and establishing and spreading non-native species (Hayes et al. 2016). These impacts appear to be most severe when the dam is operated for the generation of hydropower utilizing hydropeaking and pulse flows (Kupferberg et al. 2009c, Peek 2018). Foothill Yellow-legged Frog abundance below dams is an average of five times lower than in unregulated rivers (Kupferberg et al. 2012). The number, height, and distance upstream of dams in a watershed influenced whether Foothill Yellow-legged Frogs still occurred at sites where they had been present in 1975 in California (Ibid.). Water diversions for agricultural, industrial, and municipal uses also reduce the availability and quality of Foothill Yellow-legged Frog habitat. Dams are concentrated in the Bay Area, Sierra Nevada, and southern California (Figure 17), while hydropower plants are densest in the northern and central Sierra Nevada (Figure 18).

With predicted increases in the human population, ambitious renewable energy targets, higher temperatures, and more extreme and variable precipitation falling increasingly ~~more~~ as rain rather than snow, the need for more and taller dams and water diversions for hydroelectric power generation, flood control, and water storage and delivery is not expected to abate in the future. California voters approved Proposition 1, the Water Quality, Supply and Infrastructure Improvement Act of 2014, which dedicated $2.7 billion to water storage projects (PPIC 2018). In 2018, the California Water Commission approved funding for four new dams in California: expansion of Pacheco Reservoir (Santa Clara County), expansion of Los Vaqueros Reservoir (Contra Costa County), Temperance Flat Dam (new construction) on the San Joaquin River (Fresno County), and the off-stream Sites Reservoir (new construction) diverting the Sacramento River (Colusa County) (CWC 2019). No historical records of Foothill Yellow-legged Frogs from the Los Vaqueros or Sites Reservoir areas exist in the CNDDB, and one historical (1950) collection is documented from the Pacheco Reservoir area (CNDDB 2019). However, the proposed Temperance Flat Dam site is downstream of one of the only known extant populations of Foothill Yellow-legged Frogs in the East/Southern Sierra clade (Ibid.).

The other widespread threat to Foothill Yellow-legged Frog habitat is climate change, although the severity of its impacts is somewhat uncertain. While drought, wildland fires, floods, and landslides are natural and ostensibly necessary disturbance events for preservation of native biodiversity, climate change is expected to result in increased frequency and severity of these events in ways that may exceed species' abilities to adapt (Williams et al. 2008, Hoffmann and Sgrò 2011, Keely and Syphard 2016). These changes can lead to increased competition, predation, and disease transmission as species become concentrated in areas that remain wet into the late summer (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Loss of riparian vegetation from wildland fires can result in increased stream temperatures or concentrations of nutrients and trace heavy metals that inhibit growth and survival

(Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Stream sedimentation from landslides following fire or excessive precipitation can destroy or degrade breeding and rearing habitat (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). At least some models predict unprecedented dryness in the latter half of the century (Cook et al. 2015). The effects of climate change will be realized across the Foothill Yellow-legged Frog's range, and their severity will likely differ in ways that are difficult to predict. However, the impacts from extended droughts will likely be greatest in the areas that are naturally more arid, the lower elevations and latitudes of southern California and the foothills surrounding the Central Valley (Figure 21).

While most future urbanization is predicted to occur in areas outside of the Foothill Yellow-legged Frog's range, it has already contributed to the loss and fragmentation of Foothill Yellow-legged Frog habitat in California. In addition, the increased predation, wildland fires, introduced species, road mortality, disease transmission, air and water pollution, and disturbance from recreation that can accompany urbanization expand its impact far beyond its physical footprint (Davidson et al. 2002, Syphard et al. 2007, Cook et al. 2012, Bar-Massada et al. 2014). Within the Foothill Yellow-legged Frog's historical range, these effects appear most significant and extensive in terms of population extirpations in southern California and the San Francisco Bay Area.

Several other activities have the potential to destroy or degrade Foothill Yellow-legged Frog habitat, but they are less common across the range. They also tend to have relatively small areas of impact, although they can be significant in those areas, particularly if populations are already small and declining. These include impacts from mining, cannabis cultivation, vineyard expansion, overgrazing, timber harvest, recreation, and some stream habitat restoration projects (Harvey and Lisle 1998, Belsky et al. 1999, Merelender 2000, Pilliod et al. 2003, Bauer et al. 2015, Kupferberg and Furey 2015).

Overexploitation

Foothill Yellow-legged Frogs are not threatened by overexploitation. There is no known pet trade for Foothill Yellow-legged Frogs (Lind 2005). During the massive frog harvest that accompanied the Gold Rush, some Foothill Yellow-legged Frogs were collected, but because they are relatively small and have irritating skin secretions, there was much less of a market for them (Jennings and Hayes 1985). Within these secretions is a peptide with antimicrobial activity that is particularly potent against *Candida albicans*, a human pathogen that has been developing resistance to traditional antifungal agents (Conlon et al. 2003). However, the peptide's therapeutic potential is limited by its strong hemolytic activity, so further studies will focus on synthesizing analogs that can be used as antifungals, and collection of Foothill Yellow-legged Frogs for lab cultures is unlikely (Ibid.).

Like all native California amphibians, collection of Foothill Yellow-legged Frogs is unlawful without a permit from the Department. They may only be collected for scientific, educational, or propagation reasons through a Scientific Collecting Permit (Fish & G. Code § 1002 et seq.). The Department has the discretion to limit or condition the number of individuals collected or handled to ensure no significant adverse effects. Incidental harm from authorized activities on other aquatic species can be avoided or minimized by the inclusion of special terms and conditions in permits.

Predation

Predation is a likely contributor to Foothill Yellow-legged Frog population declines where the habitat is degraded by one or many other risk factors (Hayes and Jennings 1986). Predation by native garter snakes can be locally substantial; however, it may only have an appreciable population-level impact if the availability of escape refugia is diminished. For example, when streams dry and only pools remain, Foothill Yellow-legged Frogs are more vulnerable to predation by native and non-native species because they are concentrated in a small area with little cover.

Several studies have demonstrated the synergistic impacts of predators and other stressors. Foothill Yellow-legged Frogs, primarily as demonstrated through studies on tadpoles, are more susceptible to predation when exposed to some agrochemicals, cold water, high velocities, excess sedimentation, and even the presence of other species of predators (Harvey and Lisle 1998, Adams et al. 2003, Olson and Davis 2009, Kupferberg et al. 2011b, Kerby and Sih 2015, Catenazzi and Kupferberg 2018). Foothill Yellow-legged Frog tadpoles appear to be naïve to chemical cues from some non-native predators; they have not evolved those species-specific predator avoidance behaviors (Paoletti et al. 2011). Furthermore, early life stages are often more sensitive to environmental stressors, making them more vulnerable to predation, and Foothill Yellow-legged Frog population dynamics are highly sensitive to egg and tadpole mortality (Kats and Ferrer, 2003, Kupferberg et al. 2009c). Predation pressure is likely positively associated with proximity to anthropogenic changes in the environment, so in more remote or pristine places, it probably does not have a serious population-level impact.

Competition

Intra- and interspecific competition in Foothill Yellow-legged Frogs has been documented. Intraspecific male-to-male competition for females has been reported (Rombough and Hayes 2007). Observations include physical aggression and a non-random mating pattern in which larger males were more often engaged in breeding (Rombough and Hayes 2007, Wheeler and Welsh 2008). A behavior resembling clutch-piracy, where a satellite male attempts to fertilize already laid eggs, has also been documented (Rombough and Hayes 2007). These acts of competition play a role in population genetics, but they likely do not result in serious physical injury or mortality. Intraspecific competition among Foothill Yellow-legged Frog tadpoles was negligible (Kupferberg 1997a).

Interspecific competition appears to have a greater possibility of resulting in adverse impacts. Kupferberg (1997a) did not observe a significant change in tadpole mortality for Foothill Yellow-legged Frogs raised with Pacific Treefrogs compared to single-species controls. However, when reared together, Foothill Yellow-legged Frog tadpoles lost mass, while Pacific Treefrog tadpoles increased mass (Kerby and Sih 2015). As described previously under Introduced Species, Foothill Yellow-legged Frog tadpoles experienced significantly higher mortality and smaller size at metamorphosis when raised with bullfrog tadpoles (Kupferberg 1997a). The mechanism of these declines appeared to be exploitative competition, as opposed to interference, through the reduction of available algal resources from bullfrog tadpole grazing in the shared enclosures (Ibid.).

The degree to which competition threatens Foothill Yellow-legged Frogs likely depends on the number and density of non-native species in the area rather than intraspecific competition, and co-occurrence of Foothill Yellow-legged Frog and bullfrog tadpoles may be somewhat rare since the latter tends to breed in lentic (still water) environments (M. van Hattem pers. comm. 2019). Interspecific competition with other native species may have some minor adverse consequences on fitness.

Disease

Currently, the only disease known to pose a serious risk to Foothill Yellow-legged Frogs is Bd. Until 2017, the only published studies on the impact of Bd on Foothill Yellow-legged Frogs suggested it could reduce growth and body condition but was not lethal (Davidson et al. 2007, Lowe 2009, Adams et al. 2017b). However, two recent mass mortality events caused by chytridiomycosis proved they are susceptible to lethal effects, at least under certain conditions like drought-related concentration and presence of bullfrogs (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Some evidence indicates disease may have played a principal role in the disappearance of the species from southern California (Adams et al. 2017b). Bd is likely present in the environment~~al~~ throughout the Foothill Yellow-legged Frog's range, and with bullfrogs and treefrogs acting as carriers, it will remain a threat to the species; however, given the dynamics of the two recent die-offs in the San Francisco Bay area, the probability of future outbreaks may be greater in areas where the species is under additional stressors like drought and introduced species (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Therefore, as with predation, Foothill Yellow-legged Frogs are less likely to experience the adverse impacts of diseases in more remote areas with fewer anthropogenic changes to the environment.

Other Natural Events or Human-Related Activities

Agrochemicals, particularly organophosphates that act as endocrine disruptors, can travel substantial distances from the area of application through atmospheric drift and have been implicated in the disappearance and declines of many species of amphibians in California including Foothill Yellow-legged Frogs (LeNoir et al. 1999, Davidson 2004, Lind 2005, Olson and Davis 2009). Foothill Yellow-legged Frogs appear to be significantly more sensitive to the adverse impacts of some pesticides than other native species (Sparling and Fellers 2009, Kerby and Sih 2015). These include smaller body size, slower development rate, increased time to metamorphosis, immunosuppression, and greater vulnerability to predation and malformations (Kiesecker 2002, Hayes et al. 2006, Sparling and Fellers 2009, Kerby and Sih 2015). Some of the most dramatic declines experienced by ranids in California occurred in the Sierra Nevada east of the San Joaquin Valley where over half of the state's total pesticide usage occurs (Sparling et al. 2001).

Many Foothill Yellow-legged Frog populations are small, isolated from other populations, and possess low genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). Genetic diversity is important in providing a population the capacity to evolve in response to environmental changes, and connectivity among populations is important for gene exchange and in minimizing probability of local extinction (Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). Small populations are at much greater risk of extirpation primarily through the disproportionate impact of demographic, environmental, and genetic stochasticity than robust populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). Based on a Foothill Yellow-legged Frog PVA, populations in regulated rivers face a 4- to 13-fold greater extinction risk in 30 years than populations in unregulated rivers due to smaller population sizes (Kupferberg et al. 2009c). The threat posed by small population sizes is significant and the general pattern shows increases in severity from north to south; however, many sites, primarily in the northern Sierra Nevada, in watersheds with large hydropower projects are also at high risk.

PROTECTION AFFORDED BY LISTING

It is the policy of the State to conserve, protect, restore and enhance any endangered or threatened species and its habitat (Fish & G. Code, § 2052). The conservation, protection, and enhancement of listed species and their habitat is of statewide concern (Fish & G. Code, § 2051(c)). CESA defines "take" as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill (Fish & G. Code, § 86). The Fish and Game Code provides the Department with related authority to authorize "take" of species listed as threatened or endangered under certain circumstances (see, e.g., Fish & G. Code, §§ 2081, 2081.1, 2086, & 2835).

If the Foothill Yellow-legged Frog is listed under CESA, impacts of take caused by activities authorized through incidental take permits must be minimized and fully mitigated according to state standards (Fish & G. Code, § 2081, subd. (b)). These standards typically include protection of land in perpetuity with an easement, development and implementation of a species-specific adaptive management plan, and funding through an endowment to pay for long-term monitoring and maintenance to ensure the mitigation land meets performance criteria. Obtaining an incidental take permit is voluntary. The Department cannot force compliance; however, any person violating the take prohibition may be criminally and civilly liable under state law.

Additional protection of Foothill Yellow-legged Frogs following listing would be expected to occur through state and local agency environmental review under CEQA. CEQA requires affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on rare, threatened, and endangered species. In common practice, potential impacts to listed species are examined more closely in CEQA documents than potential impacts to unlisted species. Where significant impacts are identified under CEQA, the Department expects project-specific avoidance, minimization, and mitigation measures to benefit the species. State listing, in this respect, and consultation with the Department during state and local agency environmental review under CEQA, would be expected to benefit the Foothill Yellow-legged Frog in terms of reducing impacts from individual projects, which might otherwise occur absent listing.

For some species, CESA listing may prompt increased interagency coordination and the likelihood that state and federal land and resource management agencies will allocate funds toward protection and recovery actions. In the case of the Foothill Yellow-legged Frog, some multi-agency efforts exist, often associated with FERC license requirements, to improve habitat conditions and augment declining populations. The USFWS is leading an effort to develop regional Foothill Yellow-legged Frog conservation strategies, and CESA listing may result in increased priority for limited conservation funds.

LISTING RECOMMENDATION

CESA directs the Department to prepare this report regarding the status of the Foothill Yellow-legged Frog in California based upon the best scientific information available (Fish & G. Code, § 2074.6). CESA also directs the Department based on its analysis to indicate in the status report whether the petitioned action (i.e., listing as threatened) is warranted (Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

Under CESA, an endangered species is defined as "a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease" (Fish & G. Code, § 2062). A threatened species is defined as "a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA]" (Fish and G. Code, § 2067).

The Department includes and makes its recommendation in its status report as submitted to the Commission in an advisory capacity based on the best available science. In consideration of the scientific information contained herein, the Department has determined that listing the Foothill Yellow-legged Frog under CESA by genetic clade is the prudent approach due to the disparate degrees of imperilment among them. In areas of uncertainty, the Department recommends the higher protection status until clade boundaries can be better defined.

NORTHWEST/NORTH COAST: Not warranted at this time.

Clade-level Summary: This is the largest clade with the most robust populations (highest densities) and the greatest genetic diversity. This area is the least densely populated by humans; contains relatively few hydroelectric dams, particularly further north; and has the highest precipitation in the species' California range. The species is still known to occur in most, if not all, historically occupied watersheds; presumed extirpations are mainly concentrated in the southern portion of the clade around the heavily urbanized San Francisco Bay area. The proliferation of cannabis cultivation, particularly illicit grows in and around the Emerald Triangle, the apparent increase in severe wildland fires in the area, and potential climate change effects are cause for concern, so the species should remain a Priority 1 SSC here with continued monitoring for any change in its status.

WEST/CENTRAL COAST: Endangered.

Clade-level Summary: Foothill Yellow-legged Frogs appear to be extirpated from a relatively large proportion of historically occupied sites within this clade, particularly in the heavily urbanized northern portion around the San Francisco Bay. In the northern portion of the clade, nearly all the remaining populations (which may be fewer than a dozen) are located above dams, which line the mountains surrounding the Bay Area, and two are known to have undergone recent disease-associated die-offs. These higher elevation sites are more often intermittent or ephemeral streams than the lower in the watersheds. As a result, the more frequent and extreme droughts that have dried up large areas seem to have contributed to recent declines. Illegal cannabis cultivation, historical mining effects, overgrazing, and recreation likely contributed to declines and may continue to threaten remaining populations.

SOUTHWEST/SOUTH COAST: Endangered.

Clade-level Summary: The most extensive extirpations have occurred in this clade, and only two known extant populations remain. Both are small with apparently low genetic diversity, making them especially vulnerable to extirpation. This is also an area with a large human population, many dams, and naturally arid, fire-prone environments, particularly in the southern portion of the clade. Introduced species are widespread, and cannabis cultivation is rivaling the Emerald Triangle in some areas (e.g., Santa Barbara County). Introduced species, expanded recreation, disease, and flooding appear to have contributed to the widespread extirpations in southern California over 40 years ago.

FEATHER RIVER: Threatened.

Clade-level Summary: This is the smallest clade and has a high density of hydroelectric dams. It also recently experienced one of the largest, most catastrophic wildfires in California history. Despite these threats, Foothill Yellow-legged Frogs appear to continue to be relatively broadly distributed within the clade, although with all the dams in the area, most populations are likely disconnected. The area is more mesic and experienced less of a change in precipitation in the most recent drought than the clades south of it. The clade is remarkable genetically and morphologically as it is the only area where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs overlap and can hybridize. The genetic variation within the clade is greater than the other clades except for the Northwest/North Coast. Most of the area within the clade's boundaries is Forest Service-managed, and little urbanization pressure or known extirpations exist in this area. Recent FERC licenses in this area require Foothill Yellow-legged Frog specific conservation, which to date has included cancelling pulse flows, removing encroaching vegetation, and translocating egg masses and in situ head-starting to augment a population that had recently declined.

NORTHEAST/NORTHERN SIERRA: Threatened.

Clade-level Summary: The Northeast/Northern Sierra clade shares many of the same threats as the Feather River clade (e.g., relatively small area with many hydroelectric dams). The area is also more mesic and experienced less of a change in precipitation during the recent drought than more southern clades. However, this pattern may not continue as some models suggest loss of snowmelt will be greater in the northern Sierra Nevada, and one of the climate change exposure models suggests a comparatively large proportion of the lower elevations will experience climatic conditions not currently known from the area (i.e., non-analog) by the end of the century. Recent surveys suggest the area continues to support several populations of the species, some of which seem to remain robust, with a fairly widespread distribution. However, genetic analyses from several watersheds suggest many of these populations are isolated and diverging, particularly in regulated reaches with hydropeaking flows.

EAST/SOUTHERN SIERRA: Endangered.

Clade-level Summary: Like the Southwest/South Coast clade, widespread extirpations in this area were observed as early as the 1970s. Dams and introduced species were credited as causal factors in these declines in distribution and abundance, and mining and disease may also have contributed. This area is relatively arid, and drought effects appear greater here than in northern areas that exhibit both more precipitation and a smaller difference between drought years and the historical average. There is a relatively high number of hydroelectric power generating dams in series along the major rivers in this clade and at least one new proposed dam near one of the remaining populations. This area is also the most heavily impacted by agrochemicals from the San Joaquin Valley.

MANAGEMENT RECOMMENDATIONS

The Department has evaluated existing management recommendations and available literature applicable to the management and conservation of the Foothill Yellow-legged Frog to arrive at the following recommendations. These recommendations, which represent the best available scientific information, are largely derived ~~the~~ from the Foothill Yellow-legged Frog Conservation Assessment, the California Energy Commission's Public Interest Energy Research Reports, the Recovery Plans of West Coast Salmon and Steelhead, and the California Amphibian and Reptile Species of Special Concern (Kupferberg et al. 2009b,c; 2011a; NMFS 2012, 2013, 2014, 2016; Hayes et al. 2016, Thomson et al. 2016).

Conservation Strategies

Maintain current distribution and genetic diversity by protecting existing Foothill Yellow-legged Frog populations and their habitats and providing opportunities for genetic exchange. Increase abundance to viable levels in populations at risk of extirpation due to small sizes, when appropriate, through in situ or ex situ captive rearing and/or translocations. Use habitat suitability and hydrodynamic habitat models to identify historically occupied sites that may currently support Foothill Yellow-legged Frogs, or they could with minor habitat improvements or modified management. Re-establish extirpated populations in suitable habitat through captive propagation, rearing, and/or translocations. Prioritize areas in the southern portions of the species' range where extirpations and loss of diversity have been the most severe.

If establishing reserves, prioritize areas containing high genetic variation in Foothill Yellow-legged Frogs (and among various native species) and climatic gradients where selection varies over small geographical area because environmental heterogeneity can provide a means of maintaining phenotypic variability which increases the adaptive capacity of populations as conditions change. These reserves should provide connectivity to other occupied areas to facilitate gene flow and allow for ongoing selection to fire, drought, thermal stresses, and changing species interactions.

Research and Monitoring

Attempt to rediscover potentially remnant populations in areas where they are considered extirpated, prioritizing the southern portions of the species' range. Collect environmental DNA in addition to conducting visual encounter surveys to improve detectability. Concurrently assess presence of threats and habitat suitability to determine if future reintroductions may be possible. Collect genetic samples from any Foothill Yellow-legged Frogs captured for use in landscape genomics analyses and possible future translocation or captive propagation efforts. Attempt to better clarify clade boundaries where there is uncertainty. Study whether small populations are at risk of inbreeding depression, whether genetic rescue should be attempted, and if so, whether that results in hybrid vigor or outbreeding depression.

Continue to evaluate how water operations affect Foothill Yellow-legged Frog population demographics. Establish more long-term monitoring programs in regulated and unregulated (reference) rivers across the species' range but particularly in areas like the Sierra Nevada where most large hydropower dams in the species' range are concentrated. Assess whether the timing of pulse flows influences population dynamics, particularly whether early releases have a disproportionately large adverse effect by eliminating the reproductive success of the largest, most fecund females, who appear to breed earlier in the season. Investigate survival rates in poorly-understood life stages, such as tadpoles, young of the year, and juveniles. Determine the extent to which pulse flows contribute to displacement and mortality of post-metamorphic life stages.

Collect habitat variables that correlate with healthy populations to develop more site-specific habitat suitability and hydrodynamic models. Study the potential synergistic effect of increased flow velocity and decreased temperature on tadpole fitness. Examine the relationship between changes in flow, breeding and rearing habitat connectivity, and scouring and stranding to develop site-specific benign ramping rates. Incorporate these data and demographic data into future PVAs for use in establishing frog-friendly flow regimes in future FERC relicensing or license amendment efforts and habitat restoration projects. Ensure long-term funding for post-license or restoration monitoring to evaluate attainment of expected results and for use in adapting management strategies accordingly.

Evaluate the distribution of other threats such as cannabis cultivation, vineyard expansion, livestock grazing, mining, timber harvest, and urbanization and roads in the Foothill Yellow-legged Frog's range. Study the short- and long-term effects of wildland fires and fire management strategies. Assess the extent to which these potential threats pose a risk to Foothill Yellow-legged Frog persistence in both regulated and unregulated systems.

Investigate how reach-level or short-distance habitat suitability and hydrodynamic models can be extrapolated to a watershed level. Study habitat connectivity needs such as the proximity of breeding sites and other suitable habitats along a waterway necessary to maintain gene flow and functioning meta-population dynamics.

Habitat Restoration and Watershed Management

Remove or update physical barriers like dams and poorly constructed culverts and bridges to improve connectivity and natural stream processes. Remove anthropogenic features that support introduced predators and competitors such as abandoned mine tailing ponds that support bullfrog breeding. Conduct active eradication and management efforts to decrease the abundance of bullfrogs, non-native fish, and crayfish (where they are non-native). In managed rivers, manipulate stream flows to negatively affect non-native species not adapted to a winter flood/summer drought flow regime.

Adopt a multi-species approach to channel restoration projects and managed flow regimes (thermal, velocity, timing) and mimic the natural hydrograph to the greatest extent possible. When this is impractical or infeasible, focus on minimizing adverse impacts by gradually ramping discharge up and down, creating and maintaining gently sloping and sun-lit gravel bars and warm calm edgewater habitats for tadpole rearing, and mixing hypolimnetic water (from the lower colder stratum in a reservoir) with warmer surface water before release if necessary to ensure appropriate thermal conditions for successful metamorphosis. Promote restoration and maintenance of habitat heterogeneity (different depths, velocities, substrates, etc.) and connectivity to support all life stages and gene flow. Avoid damaging Foothill Yellow-legged Frog breeding habitat when restoring habitat for other focal species like anadromous salmonids.

Regulatory Considerations and Best Management Practices

Develop range-wide minimum summer baseflow requirements that protect Foothill Yellow-legged Frogs and their habitat with appropriate provisions to address regional differences using new more ecologically-meaningful approaches such as modified percent-of-flow strategies for watersheds (e.g., Mierau et al. 2018). Limit water diversions during the dry season and construction of new dams by focusing on off-stream water storage strategies.

Ensure and improve protection of riparian systems. Require maintenance of appropriate riparian buffers and canopy coverage (i.e., partly shaded) around occupied habitat or habitat that has been identified for potential future reintroductions. Restrict instream work to dry periods where possible. Prohibit fording in and around breeding habitat. Avoid working near streams after the first major rains in the fall when Foothill Yellow-legged Frogs may be moving upslope toward tributaries and overwintering sites. Use a 3 mm (0.125 in) mesh screen on water diversion pumps and limit the rate and amount of water diverted such that depth and flow remain sufficient to support Foothill Yellow-legged Frogs of all life stages occupying the immediate area and downstream. Install exclusion fencing where appropriate, and if Foothill Yellow-legged Frog relocation is required, conduct it early in the season because moving egg masses is easier than moving tadpoles.

Reduce habitat degradation from sedimentation, pesticides, herbicides, and other non-point source waste discharges from adjacent land uses including along tributaries of rivers and streams. Limit mining to parts of rivers not used for oviposition, such as deeper pools or reaches with few tributaries, and at times of year when frogs are more common in tributaries (i.e., fall and winter). Manage recreational activities in or adjacent to Foothill Yellow-legged Frog habitat (e.g., OHV and hiking trails, camp sites, boating ingress/egress, flows, and speeds) in a way that minimizes adverse impacts. Siting cannabis grows in areas with better access to roads, gentler slopes, and ample water resources could significantly reduce threats to the environment. Determine which, when, and where agrochemicals should be restricted to reduce harm to Foothill Yellow-legged Frogs and other species. Ensure all new road crossings and upgrades to existing crossings (bridges, culverts, fills, and other crossings) accommodate at least 100-year flood flows and associated bedload and debris.

Partnerships and Coordination

Establish collaborative partnerships with agencies, universities, and non-governmental organizations working on salmon and steelhead recovery and stream restoration. Anadromous salmonids share many of the same threats as Foothill Yellow-legged Frogs, and recovery actions such as barrier removal, restoration of natural sediment transport processes, reduction in pollution, and eradication of non-native predators would benefit frogs as well. Ensure Integrated Regional Water Management Plans and fisheries restoration programs take Foothill Yellow-legged Frog conservation into consideration during design, implementation, and maintenance.

Encourage local governments to place conditions on new developments to minimize negative impacts on riparian systems. Promote and implement initiatives and programs that improve water conservation use efficiency, reduce greenhouse gas emissions, promote sustainable agriculture and smart urban growth, and protect and restore riparian ecosystems. Shift reliance from on-stream storage to off-stream storage, resolve frost protection issues (water withdrawals), and ensure necessary flows for all life stages in all water years.

Establish a Department-coordinated staff and citizen scientist program to systematically monitor occupied stream reaches across the species' range.

Education and Enforcement

Support programs to provide educational outreach and local involvement in restoration and watershed stewardship, such as Project Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land and water use on Foothill Yellow-legged Frog survival.

Provide additional funding for increased law enforcement to reduce ecologically harmful stream alterations and water pollution and to ensure adequate protection for Foothill Yellow-legged Frogs at pumps and diversions. Identify and address illegal water diverters and out-of-compliance diverters, seasons of diversion, off-stream reservoirs, well pumping, and bypass flows to protect Foothill Yellow-legged Frogs. Prosecute violators accordingly.

ECONOMIC CONSIDERATIONS

The Department is charged in an advisory capacity in the present context to provide a written report and a related recommendation to the Commission based on the best scientific information available regarding the status of Foothill Yellow-legged Frog in California. The Department is not required to prepare an analysis of economic impacts (See Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

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Patterson, Laura@Wildlife

From: Ryan Peek <rapeek@ucdavis.edu>
Sent: Tuesday, June 18, 2019 12:52 AM
To: Patterson, Laura@Wildlife
Subject: Re: Peer Review Request: Foothill Yellow-legged Frog Status Review
Attachments: DRAFT FYLF Status Review-RAP.docx

Hi Laura,
Attached is my review of the draft FYLF status report. I'm sending this now because I leave tomorrow at 6am for about 9 days on the Yampa/Green River, so will be completely out of contact. If you have questions/concerns, I can follow up then. Overall, this is a really amazing compendium of all the research/knowledge about RABO, so kudos to you for all your hard work! It shows...this was simultaneously really cool to read (because after all this time I still really am fascinated by this species and always interested in learning more), and very depressing. I hope folks recognize just how dire things look for this species across much of the range. Most of my comments are pretty minor (hopefully) and I added an updated figure and a few citations you may want to check out or add.

I'll touch base when I get back.

Adios,
Ryan

On Tue, May 21, 2019 at 1:56 PM Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov> wrote:

> Good afternoon, Dr. Peek,
>
> Thanks for your patience. We had a couple of loose ends to tie up. Please see the attached letter and draft status review. If you have any questions or concerns with the timeline, please let me know.
>
> Will you please respond to this email to confirm you received it?
>
> Thanks again,
>
> Laura
>
> **From:** Ryan Peek <rapeek@ucdavis.edu>
> **Sent:** Thursday, April 25, 2019 5:05 PM
> **To:** Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov>
> **Subject:** Re: Peer Review Request: Foothill Yellow-legged Frog Status Review

Hi Laura,

I would be willing to review the draft status review, and I have no financial or other conflicts of interest.

Thanks very much,

Adios,
Ryan

On Thu, Apr 25, 2019 at 9:04 AM Patterson, Laura@Wildlife <Laura.Patterson@wildlife.ca.gov> wrote:

> Dear Dr. Peek,
>
> The Fish and Game Commission (Commission) was petitioned to list the Foothill Yellow-legged Frog as threatened under the California Endangered Species Act (CESA) by the Center for Biological Diversity in December 2016. The California Department of Fish and Wildlife (Department) is tasked with writing a status review and providing a recommendation to the Commission on whether or not the best scientific information available supports the petitioner's position that listing is warranted. Part of the status review process is external peer review of the draft status review.
>
> I am contacting you as a Foothill Yellow-legged Frog subject matter expert to request your participation in the peer review process. The Department expects the draft will be ready on for distribution to peer reviewers on or around May 17th. We would ask that you focus your review on the scientific information available regarding the status of Foothill Yellow-legged Frogs in California. Your peer review of the science and analysis regarding each of the listing factors prescribed in CESA (i.e., present or threatened habitat modification, overexploitation, predation, competition, disease, and other natural occurrences or human-related activities that could affect the species) is particularly valuable. We request that comments be submitted on or before one month from the date of receipt (on or around June 17th).
>
> In addition, per the Department's Peer Review Policy (Department Bulletin 2017-03), I must ensure that you have no financial or other conflict of interest with the outcome or implications of the peer reviewed product.
>
> Please respond to whether you are willing and able to participate in this important part of the listing determination process by Friday May 3rd.
>
> Thank you for your consideration,
>
> Laura

Laura Patterson

Statewide Amphibian and Reptile Conservation Coordinator

California Department of Fish and Wildlife

Nongame Wildlife Program

1812 9th Street

Sacramento, CA 95811

Please Help Endangered Species at Tax Time

https://www.wildlife.ca.gov/Tax-Donation

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"When we try to pick out anything by itself, we find it hitched to everything else in the universe."
John Muir (My First Summer in the Sierra, 1911)

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STATE OF CALIFORNIA
NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION

A STATUS REVIEW OF THE **FOOTHILL YELLOW-LEGGED FROG** (*Rana boylii*) IN CALIFORNIA

CHARLTON H. BONHAM, DIRECTOR
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

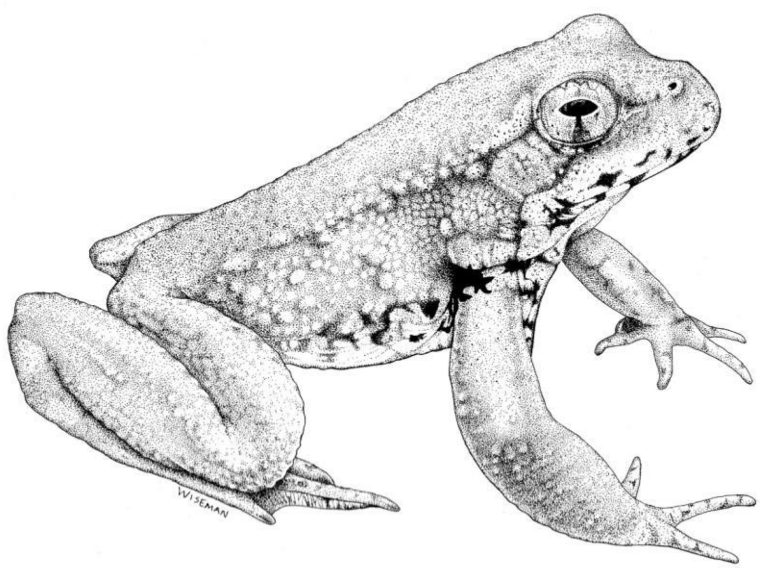
External Peer Review Draft

TABLE OF CONTENTS

LIST OF FIGURES

Commented [RAP1]: Pretty sure I made this figure in R, and this was part of the stuff Sarah and I did as part of the 2016 poster (Peek and Kupferberg). I don't care if it says Kupferberg and Peek or Peek and Kupferberg, but please add me to this figure when it's used.

LIST OF TABLES



ACKNOWLEDGMENTS

Laura Patterson prepared this report. Stephanie Hogan, Madeleine Wieland, and Margaret Mantor assisted with portions of the report, including the sections on Status and Trends in California and Existing Management. Kristi Cripe provided GIS analysis and figures. Review of a draft document was provided by the following California Department of Fish and Wildlife (Department) staff: Ryan Bourque, Marcia Grefsrud, and Mike van Hattem.

The Department is extremely grateful for the valuable comments provided on this report by the following peer reviewers: Dr. Sarah Kupferberg, Dr. Amy Lind, Dr. Jimmy McGuire, and Dr. Ryan Peek. The conclusions in this report are those of the Department and do not necessarily reflect those of the reviewers.

Cover photograph by Isaac Chellman, used with permission.

Illustration by Kevin Wiseman, used with permission.

EXECUTIVE SUMMARY

[To be completed after external peer review]

REGULATORY SETTING

Petition Evaluation Process

A petition to list the Foothill Yellow-legged Frog (*Rana boylii*) as threatened under the California Endangered Species Act (CESA) was submitted to the Fish and Game Commission (Commission) on December 14, 2016 by the Center for Biological Diversity. Commission staff transmitted the petition to the Department of Fish and Wildlife (Department) pursuant to Fish and Game Code section 2073 on December 22, 2016 and published a formal notice of receipt of the petition on January 20, 2017 (Cal. Reg. Notice Register 2017, No. 3-Z, p. 46). A petition to list or delist a species under CESA must include "information regarding the population trend, range, distribution, abundance, and life history of a species, the factors affecting the ability of the population to survive and reproduce, the degree and immediacy of the threat, the impact of existing management efforts, suggestions for future management, and the availability and sources of information. The petition shall also include information regarding the kind of habitat necessary for species survival, a detailed distribution map, and any other factors that the petitioner deems relevant" (Fish & G. Code, § 2072.3).

On April 17, 2017, the Department provided the Commission with its evaluation of the petition, "Evaluation of the Petition from the Center For Biological Diversity to List the Foothill Yellow-legged Frog (*Rana boylii*) as Threatened under the California Endangered Species Act," to assist the Commission in making a determination as to whether the petitioned action may be warranted based on the sufficiency of scientific information (Fish & G. Code, §§ 2073.5 & 2074.2; Cal. Code Regs., tit. 14, § 670.1, subds. (d) & (e)). Focusing on the information available to the Department relating to each of the relevant categories, the Department recommended to the Commission that the petition be accepted.

At its scheduled public meeting on June 21, 2017, in Smith River, California, the Commission considered the petition, the Department's petition evaluation and recommendation, and comments received. The Commission found that sufficient information existed to indicate the petitioned action may be warranted and accepted the petition for consideration. Upon publication of the Commission's notice of its findings, the Foothill Yellow-legged Frog was designated a candidate species on July 7, 2017 (Cal. Reg. Notice Register 2017, No. 27-Z, p. 986).

Status Review Overview

The Commission's action designating the Foothill Yellow-legged Frog as a candidate species triggered the Department's process for conducting a status review to inform the Commission's decision on whether listing the species is warranted. At its scheduled public meeting on June 21, 2018, in Sacramento, California, the Commission granted the Department a six-month extension to complete the status review and facilitate external peer review.

This status review report is not intended to be an exhaustive review of all published scientific literature relevant to the Foothill Yellow-legged Frog; rather, it is intended to summarize the key points from the best scientific information available relevant to the status of the species. This final report, based upon the best scientific information available to the Department, is informed by independent peer review of a draft report by scientists with expertise relevant to the Foothill Yellow-legged Frog. This review is intended to provide the Commission with the most current information on the Foothill Yellow-legged Frog and to serve as the basis for the Department's recommendation to the Commission on whether the petitioned action is warranted. The status review report also identifies habitat that may be essential to continued existence of the species and provides management recommendations for recovery of the species (Fish & G. Code, § 2074.6). Receipt of this report is to be placed on the agenda for the next available meeting of the Commission after delivery. At that time, the report will be made available to the public for a 30-day public comment period prior to the Commission taking any action on the petition.

Federal Endangered Species Act Review

The Foothill Yellow-legged Frog is currently under review for possible listing as threatened or endangered under the federal Endangered Species Act (ESA) in response to a July 11, 2012 petition submitted by the Center for Biological Diversity. On July 1, 2015, the U.S. Fish and Wildlife Service (USFWS) published its 90-day finding that the petition presented substantial scientific or commercial information indicating that the petitioned action may be warranted and initiated a status review of the species (USFWS 2015). On March 16, 2016, the Center for Biological Diversity sued the USFWS to compel issuance of a 12-month finding on whether listing under the ESA is warranted. On August 30, 2016, the parties reached a stipulated settlement agreement that the USFWS shall publish its 12-month finding in the Federal Register on or before September 30, 2020 (*Center for Biological Diversity v. S.M.R. Jewell* (D.D.C. Aug. 30, 2016, No. 16-CV-00503)).

BIOLOGY AND ECOLOGY

Species Description and Life History

> *"In its life-history* boylii *exhibits several striking specializations which are in all probability related to the requirements of life of a stream-dwelling species"* – Tracy I. Storer, 1925

The Foothill Yellow-legged Frog is a small- to medium-sized frog; adults range from 38 to 81 mm (1.5-3.2 in) snout to urostyle length (SUL) with females attaining a larger size than males and males possessing paired internal vocal sacs (Zweifel 1955, Nussbaum et al. 1983, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs are typically gray, brown, olive, or reddish with brown-black flecking and mottling, which generally matches the substrate of the stream in which they reside (Nussbaum et al. 1983, Stebbins and McGinnis 2012). They often have a pale triangle between the eyes and snout and broad dark bars on the hind legs (Zweifel 1955, Stebbins and McGinnis 2012). Foothill Yellow-legged Frogs have a relatively squat body and granular skin, giving them a rough appearance similar to a toad, and fully webbed feet with slightly expanded toe tips (Nussbaum et al. 1983). The tympanum is also rough

and relatively small compared to congeners at around one-half the diameter of the eye (Zweifel 1955). The dorsolateral folds (glandular ridges extending from the eye area to the rump) in Foothill Yellow-legged Frogs are indistinct compared to other western North American ranids (Stebbins and McGinnis 2012). Ventrally, the abdomen is white with variable amounts of dark mottling on the chest and throat, which are unique enough to be used to identify individuals (Marlow et al. 2016). As their name suggests, the underside of their hind limbs and lower abdomen are often yellow; however, individuals with orange and red have been observed within the range of the California Red-legged Frog (*Rana draytonii*), making hindlimb coloration a poor diagnostic characteristic for this species (Jennings and Hayes 2005).

Adult females likely lay one clutch of eggs per year and may breed every year (Storer 1925, Wheeler et al. 2006). Foothill Yellow-legged Frog egg masses resemble a compact cluster of grapes approximately 45 to 90 mm (1.8-3.5 in) in diameter length-wise and contain anywhere from around 100 to over 3,000 eggs (Kupferberg et al. 2009c, Hayes et al. 2016). The individual embryos are dark brown to black with a lighter area at the vegetative pole and surrounded by three jelly envelopes that range in diameter from approximately 3.9 to 6.0 mm (0.15-0.25 in) (Storer 1925, Zweifel 1955, Hayes et al. 2016).

Foothill Yellow-legged Frog tadpoles hatch out around 7.5 mm (0.3 in) long and are a dark brown or black (Storer 1925, Zweifel 1955). They grow rapidly to 37 to 56 mm (1.5-2.2 in) and turn olive with a coarse brown mottling above and an opaque silvery color below (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012). Their eyes are positioned dorsally when viewed from above (i.e., within the outline of the head), and their mouths are large, downward-oriented, and suction-like with several tooth rows (Storer 1925, Zweifel 1955, Stebbins and McGinnis 2012, Hayes et al. 2016). Foothill Yellow-legged Frogs metamorphose at around 14-17 mm (0.55-0.67 in) SUL (Fellers 2005). Sexual maturity is attained at around 30-40 mm (1.2-1.6 in) SUL and 1 year for males and around 40-50 mm (1.6-2.0 in) SUL and 3 years for females, although in some populations this has been accelerated by a year (Zweifel 1955, Kupferberg et al. 2009c, Breedveld and Ellis 2018). During the breeding season, males can be distinguished from females by the presence of nuptial pads (swollen darkened thumb bases that aid in holding females during amplexus) and calling, which frequently occurs underwater but sometimes from the surface (MacTague and Northen 1993, Stebbins 2003, Silver 2017).

The reported lifespan of Foothill Yellow-legged Frogs varies widely by study. Storer (1925) and Van Wagner (1996) estimated a maximum age of 2 years for both sexes and the vast majority of the population. Breedveld and Ellis (2018) calculated the typical lifespan of males at 3-4 years and 5-6 years for females. Bourque (2008), using skeletochronology, found an individual over 7 years old and a mean age of 4.7 and 3.6 years for males and females, respectively. Drennan et al. (2015) estimated maximum age at 13 years for both sexes in a Sierra Nevada population and 12 for males and 11 for females in a Coast Range population.

Range and Distribution

Foothill Yellow-legged Frogs historically ranged from the Willamette River drainage in Oregon west of the Sierra-Cascade crest to at least the San Gabriel River drainage in Los Angeles County, California (Figure 1; Zweifel 1955, Stebbins 2003). In addition, a disjunct population was reported from 2,040 m

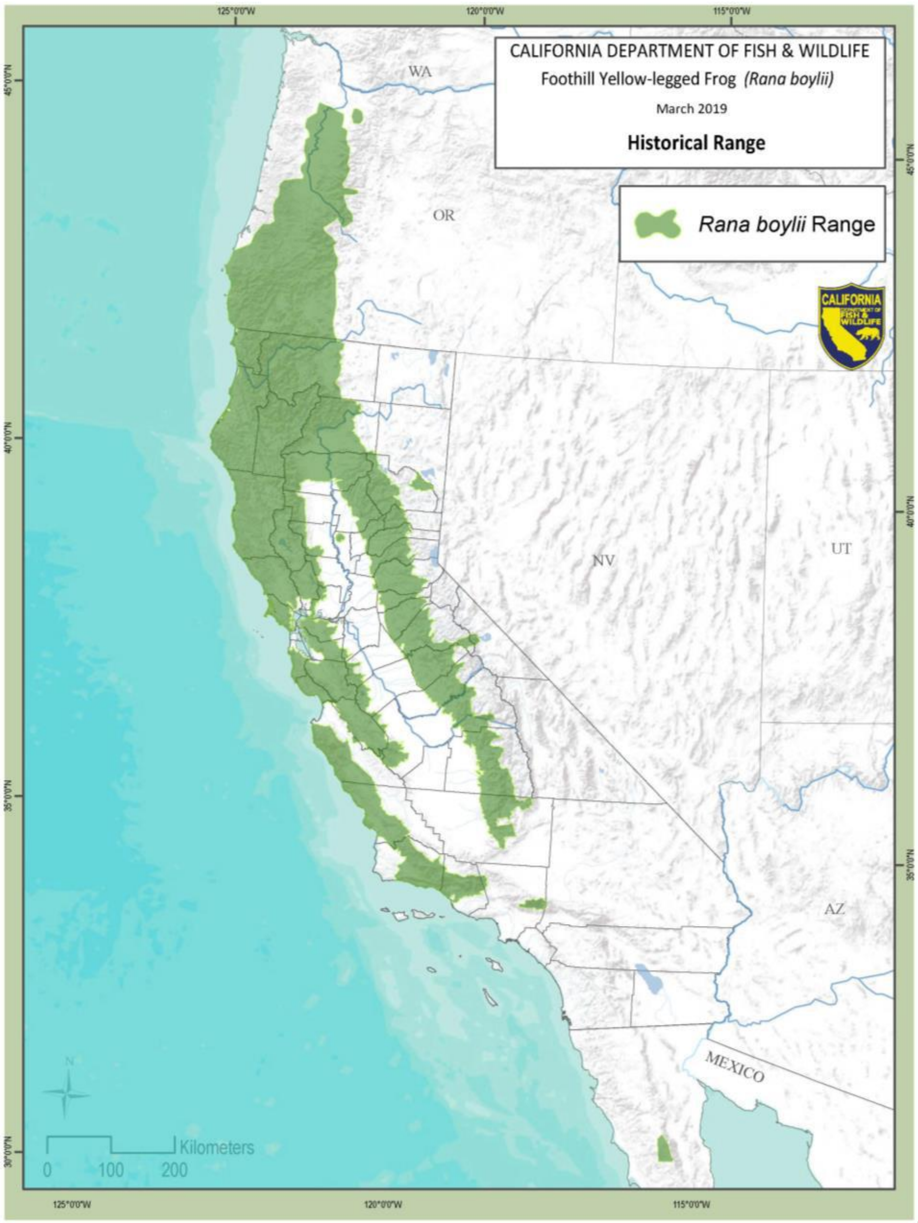


Figure 1. Foothill Yellow-legged Frog historical range (adapted from CWHR, Loomis [1965], Nussbaum et al. [1983])

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(6,700 ft) in the Sierra San Pedro Mártir, Baja California Norte, México (Loomis 1965). In California, the species occupies foothill and mountain streams in the Klamath, Cascade, Sutter Buttes, Coast, Sierra Nevada, and Transverse ranges from sea level to 1,940 m (6,400 ft), but generally below 1,525 m (5,000 ft) (Hemphill 1952, Nussbaum et al. 1983, Stebbins 2003, Olson et al. 2016). Zweifel (1955) considered Foothill Yellow-legged Frogs to be present and abundant throughout their range where streams possessed suitable habitat.

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Taxonomy and Phylogeny

Foothill Yellow-legged Frogs belong to the family Ranidae (true frogs), which inhabits every continent except Antarctica and contains more than 700 species (Stebbins 2003). The species was first described by Baird (1854) as *Rana boylii*. After substantial taxonomic uncertainty with respect to its relationship to other ranids (frogs in the family Ranidae) and several name changes over the next century, the Foothill Yellow-legged Frog (*R. boylii* with no subspecific epithet) was eventually recognized as a distinct species again by Zweifel (1955, 1968). The phylogenetic relationships among the western North American *Rana* spp. have been revised several times and are still not entirely resolved (Thomson et al. 2016). The Foothill Yellow-legged Frog was previously thought to be most closely related to the higher elevation Mountain Yellow-legged Frog (*R. muscosa*) (Zweifel 1955; Green 1986a,b). However, genetic analyses undertaken by Macey et al. (2001) and Hillis and Wilcox (2005) suggest they are more closely related to Oregon Spotted Frogs (*R. pretiosa*) and Columbia Spotted Frogs (*R. luteiventris*), respectively.

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Yuan, Z.-Y., Zhou, W.-W., Chen, X., Poyarkov, N. A., Jr, Chen, H.-M., Jang-Liaw, N.-H., … Che, J. (2016). Spatiotemporal diversification of the true frogs (Genus Rana): A historical framework for a widely studied group of model organisms. *Systematic Biology*, *65*(5), 824–842. https://doi.org/10.1093/sysbio/syw055

Population Structure and Genetic Diversity

Foothill Yellow-legged Frog populations exhibit varying levels of partitioning and genetic diversity at different spatial scales. At the coarse landscape level across the species' extant range, McCartney-Melstad et al. (2018) recovered five deeply divergent, geographically cohesive, genetic clades (Figure 2), while Peek (2018) recovered six (Figure 3). Genetic divergence is the process of speciation; it is a measure of the number of mutations accumulated by populations over time from a shared ancestor. This accumulation of genetic differentiation between groups is what ~~that~~ differentiates one population from another population ~~them from the other populations~~ in a species. When genetic divergence among ~~clades~~ groups with common ancestors (clades) is large enough, it can be used as a tool to define new species or subspecies.

The geographic breaks among the five Foothill Yellow-legged Frog clades were similar between the studies, but Peek (2018) identified a separate deeply divergent genetic clade in the Feather River watershed that is distinct from the rest of the northern Sierra Nevada clade. The five clades the two studies shared include the following [Note: naming conventions follow McCartney-Melstad et al. (2018) and Peek (2018)]:

(1) Northwest/North Coast: north of San Francisco Bay in the Coast Ranges and east into Tehama County;
(2) Northeast/Northern Sierra: northern El Dorado County (North Fork American River watershed, includes Middle Fork American) and north in the Sierra Nevada to southern Plumas County (Upper Yuba River watershed);

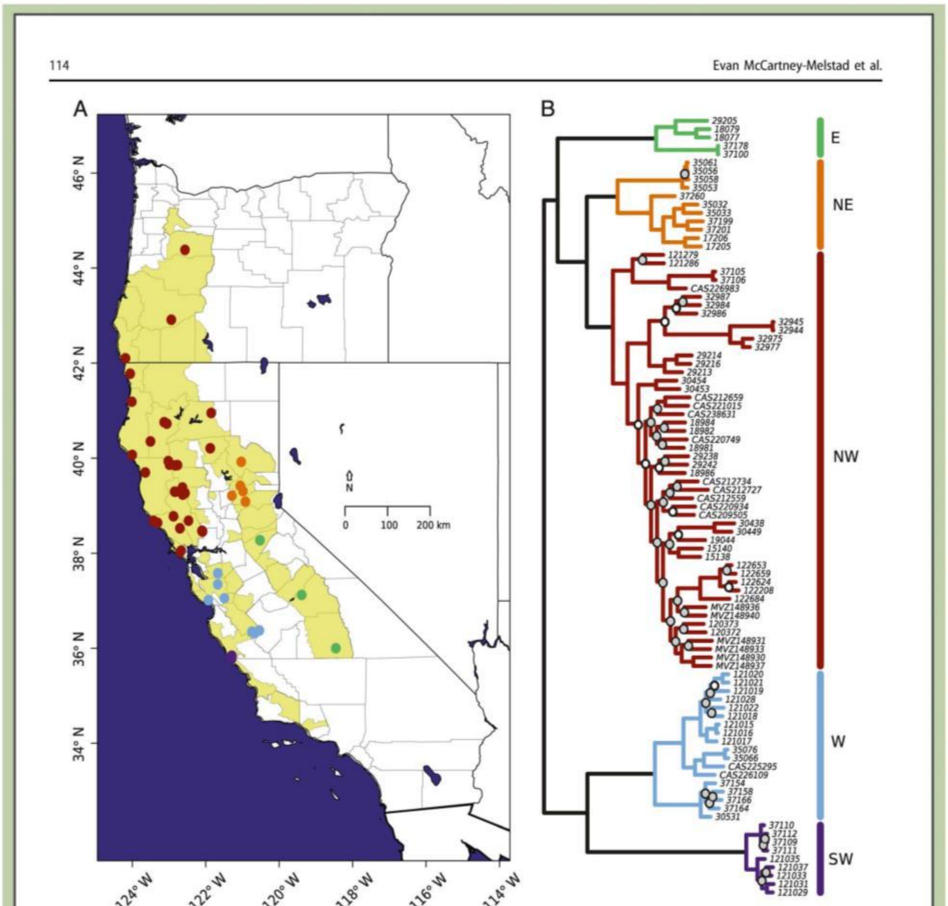

Fig. 1 a Map of *Rana boylii* sample localities. County outlines are shown within California and Oregon. Light yellow indicates the IUCN range map of *R. boylii*, excluding a small disjunct population at Sierra San Pedro Martir, Baja California, Mexico. Dots are colored by major grouping as determined in the **b** RAxML phylogeny, with midpoint rooting. Nodes without dots received >95% bootstrap support, those with white dots received <95% but greater than or equal to 75% bootstrap support, while nodes with gray dots received <75% bootstrap support

Figure 2. Foothill Yellow-legged Frog clades by McCartney-Melstad et al. (2018)

(3) East/Southern Sierra: El Dorado County (South Fork American River watershed) and south in the Sierra Nevada [no samples from Amador County were tested, but they would most likely fall within this clade because it is located between two other populations that occur within this clade];

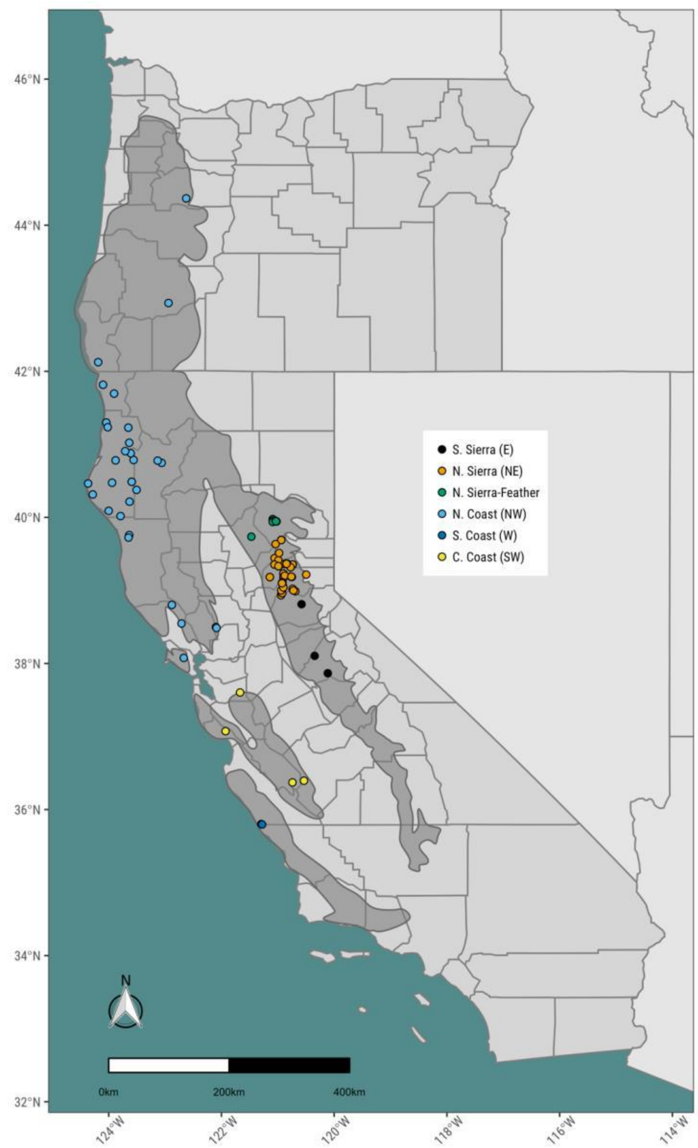

Figure 3. Foothill Yellow-legged Frog clades by Peek (2018)

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(4) West/Central Coast: south of San Francisco Bay in the Coast Ranges to San Benito and Monterey counties, presumably east of the San Andreas Fault/Salinas Valley;
(5) Southwest/South Coast presumably west of the San Andreas Fault/Salinas Valley in Monterey County and south in the Coast Ranges.

The Feather River clade is found primarily in Plumas and Butte counties (Peek 2018). Peek's analysis found that this clade is as distinct ~~as~~from the other Sierra Nevada clades as the Sierra Nevada populations are distinct from ~~the rest of the Sierra Nevada as a cohesive group and~~ all the coastal ~~populations~~ clades~~as one group~~, meaning it was found to be deeply divergent from the rest of the clades. McCartney-Melstad et al. (2018) also recognized the Feather River watershed as distinct from the rest of the northern Sierra but not as deeply divergent from the other clades as Peek. The Feather River watershed is also the only known location where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs (*R. sierrae*) co-occur and where two F1 hybrids (50% ancestry from each species) were found (Peek 2018). In addition, Peek's genetic data provided ~~Peek~~weak support for ~~'s modeling results only weakly supported~~ dividing the West/Central Coast and Southwest/South Coast groups into separate clades, but had fewer samples from these localities than McCartney-Melstad et al.

Previous work conducted by Lind et al. (2011) found a somewhat similar pattern, that populations on the periphery of the species' range are considerably genetically divergent from the rest of the range. Their results suggested that hydrologic regions and river basins were important landscape features that influenced the genetic structure of Foothill Yellow-legged Frog populations. However, using more modern genomic techniques, McCartney-Melstad et al. (2018) found nearly twice the variation among the five phylogenetic clades than among drainage basins, indicating other factors contributed to current population structure. They report that the depth of genetic divergence among Foothill Yellow-legged Frog clades exceeds that of any anuran (frog or toad) for which similar data are available and recommend using them as management units instead of the previously suggested watershed boundaries.

Levels of genetic diversity within the clades differed significantly. Genetic diversity provides populations with the evolutionary capacity to adapt to changing conditions ~~gives species the ability to adapt to changing conditions~~ (i.e., evolve), and its loss often signals extreme population ~~and range~~ reductions as well as potential inbreeding depression that can reduce survival and reproductive success (Lande and Shannon 1996, Hoffmann and Sgrò 2011, McCartney-Melstad et al. 2018). Loss of genetic diversity in Foothill Yellow-legged Frogs largely follows a north-to-south pattern, with the southern clades in particular (Southwest/South Coast and East/Southern Sierra) showing the greatest loss of nucleotide diversity ~~possessing the least amount~~ (McCartney-Melstad et al. 2018, Peek 2018). In addition, these study results demonstrate that Foothill Yellow-legged Frogs have lost genetic diversity over time across their entire range except for the large Northwest/North Coast clade, which appears to have undergone a relatively recent population expansion (McCartney-Melstad et al. 2018, Peek 2018).

At a watershed scale, Dever (2007) found that tributaries to rivers and streams are important for preserving genetic diversity, and populations separated by more than 10 km (6.2 mi) show signs of genetic isolation. In other words, even in the absence of anthropogenic barriers to dispersal (e.g., dams and reservoirs), individuals located more than 10 km (6.2 mi) are not typically considered part of a single interbreeding population (Olson and Davis 2009). Peek (~~2011~~2010, 2018) reported that at this finer-scale, population structure and genetic diversity appear to be more strongly influenced by river regulation type (i.e., dammed or undammed) than to geographic distance or watershed boundaries. In general, regulated (dammed) rivers had limited gene flow and higher genetic divergence among subpopulations compared with unregulated (undammed) rivers (Peek ~~2011~~2010, 2018). In addition, differences in river hydrologic~~water flow~~ regimes within regulated rivers affected genetic connectivity and diversity (Peek ~~2011~~2010, 2018). Subpopulations in hydropeaking reaches, in which pulsed flows are used for electricity generation or whitewater boating, exhibited significantly lower gene flow and genetic diversity than those in bypass reaches where water is diverted from upstream in the basin down to power generating facilities (Figure 4; Peek 2018). River regulation had a greater influence on genetic differentiation among sites than geographic distance in the Alameda Creek watershed as well (Stillwater Sciences 2012). Reduced connectivity among sites leads to lower gene flow and a loss of genetic diversity through genetic drift, which can diminish adaptability to changing environmental conditions (Palstra and Ruzzante 2008). Peek (2011) posits that given the *R. boylii* species group is estimated to be 8 million years old (Macey et al. 2001), the significant reductions in connectivity and genetic diversity over short evolutionary time periods in regulated rivers (often less than 50 years from the time of dam construction) is cause for concern, particularly when combined with small population sizes.

Habitat Associations and Use

> *"These frogs are so closely restricted to streams that it is unusual to find one at a greater distance from the water than it could cover in one or two leaps."* – Richard G. Zweifel, 1955

Foothill Yellow-legged Frogs inhabit rivers and streams ranging from primarily rain-fed (coastal populations) to primarily snow-influenced (most Sierra Nevada and Klamath-Cascade populations) from headwater streams to large rivers (Bury and Sisk 1997, Wheeler et al. 2014). Occupied rivers and streams flow through a variety of vegetation types including hardwood, conifer, and valley-foothill riparian forests; mixed chaparral; and wet meadows (Hayes et al. 2016). Because the species is so widespread and can be found in so many types of habitats, the vegetation community is likely less important in determining Foothill Yellow-legged Frog occupancy and abundance than the aquatic biotic and abiotic conditions in the specific river, stream, or reach (Zweifel 1955). The species is an obligate stream-breeder, which sets it apart from other western North American ranids (Wheeler et al. 2014). Foothill Yellow-legged Frog habitat is generally characterized as partly-shaded, shallow, perennial rivers and streams with a low gradient and rocky substrate that is at least cobble-sized (Zweifel 1955, Hayes and Jennings 1988). However, the use of intermittent and ephemeral streams by post-metamorphic Foothill Yellow-legged Frogs may not be all that uncommon in some parts of the species' range in California (R. Bourque pers. comm. 2019). The species has been reported from some atypical habitats as well, including ponds, isolated pools in intermittent streams, and meadows along the edge of streams that lack a rocky substrate (Fitch 1938, Zweifel 1955, J. Alvarez pers. comm. 2017, CDFW 2018a).

As stream-breeding poikilotherms (animals whose internal temperature varies with ambient temperature), appropriate flow velocity, temperature, and water availability are critically important to

Foothill Yellow-legged Frogs (Kupferberg 1996a, Van Wagner 1996, Wheeler et al. 2006, Lind et al. 2016). Habitat quality is also influenced by hydrologic regime (regulated vs. unregulated), substrate, presence of non-native predators and competitors, water depth, and availability of high-quality food and basking sites (Lind et al. 1996, Yarnell 2005, Wheeler et al. 2006, Catenazzi and Kupferberg 2017). Habitat suitability and use vary by life stage, sex, geographic location, watershed size, and season and

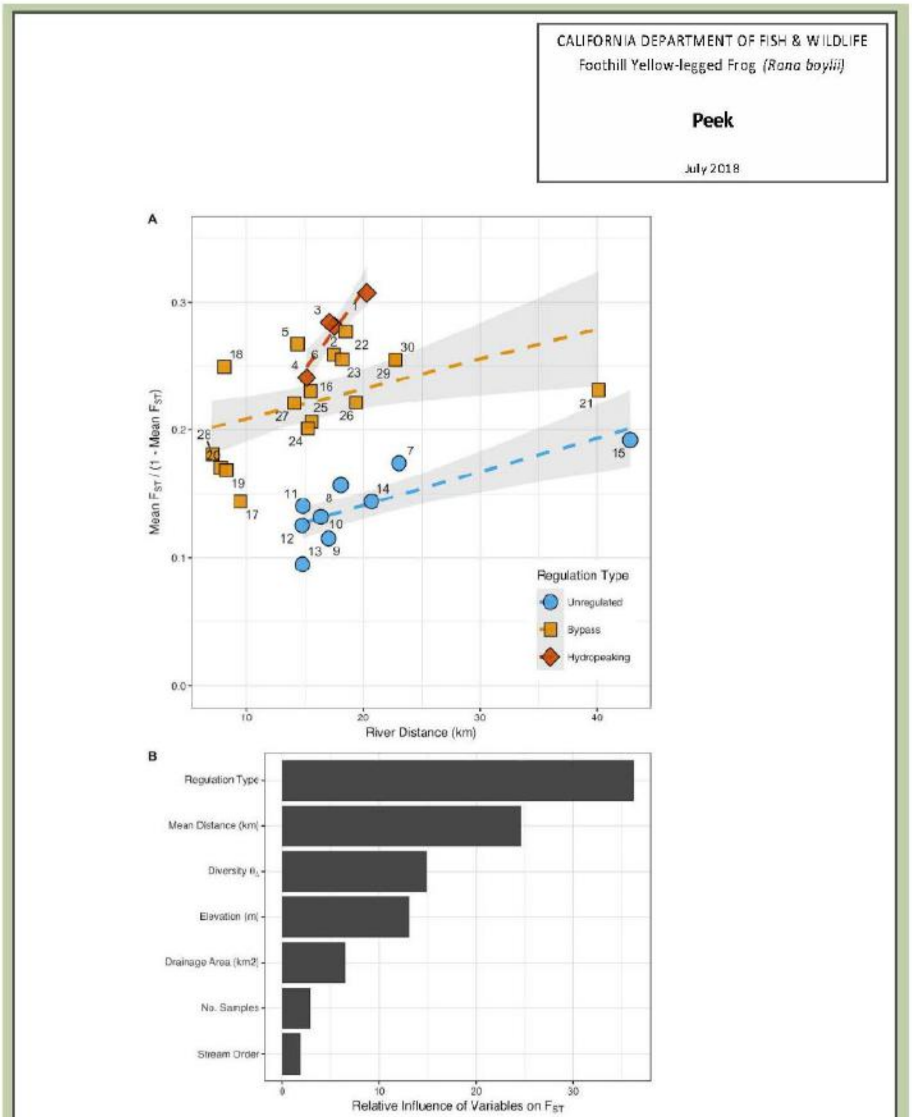

Figure 3. Relationship between river regulation and genetic differentiation in FYLF. A) Mean pairwise F_{ST} vs. mean river distance for each location; B) Relative influence of variables on F_{ST} from boosted regression tree models.

Figure 4. River regulation's relative influence on genetic differentiation from Peek (2018)

can generally be categorized as breeding and rearing habitat, nonbreeding active season habitat, and overwintering habitat (Van Wagner 1996, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011, Hayes et al. 2016, Catenazzi and Kupferberg 2017). Yarnell (2005) located higher densities of Foothill Yellow-legged Frogs in areas with greater habitat heterogeneity and suggested that they were selecting for sites that possessed the diversity of habitats necessary to support each life stage within a relatively short distance.

Breeding and Rearing Habitat

Suitable breeding habitat must be connected to suitable rearing habitat for metamorphosis to be successful. When this connectivity exists, as flows decline through the season, tadpoles can follow the receding shoreline into areas of high productivity and lower predation risk as opposed to becoming trapped in isolated pools with a high risk of overheating, desiccation, and predation (Kupferberg et al. 2009c).

Several studies on Foothill Yellow-legged Frog breeding habitat, carried out across the species' range in California, reported similar findings. Foothill Yellow-legged Frogs select oviposition (egg-laying) sites within a narrow range of depths, velocities, and substrates and exhibit fidelity to breeding sites that consistently possess suitable microhabitat characteristics over time (Kupferberg 1996a, Bondi et al. 2013, Lind et al. 2016). At a coarse-spatial scale, breeding sites in rivers and large streams are often located near the confluence of tributary streams in sunny, wide, shallow reaches (Kupferberg 1996a, Yarnell 2005, GANDA 2008, Peek 2010~~1~~). These areas are highly productive compared to cooler, deeper, closed-canopy sites (Catenazzi and Kupferberg 2013). At a fine-spatial scale, females prefer to lay eggs in low velocity areas dominated by cobble- and boulder-sized substrates, often associated with sparsely-vegetated point bars (Kupferberg 1996a, Lind et al. 1996, Van Wagner 1996, Bondi et al. 2013, Lind et al. 2016). They tend to select areas with less variable, more stable flows, and in areas with higher flows at the time of oviposition, they place their eggs on the downstream side of large cobblestones and boulders, which protects them from being washed away (Kupferberg 1996a, Wheeler et al. 2006).

Appropriate rearing temperatures are vital for successful metamorphosis. Tadpoles grow faster and larger in warmer water to a point (Zweifel 1955; Catenazzi and Kupferberg 2017, 2018). Zweifel (1955) conducted experiments on embryonic thermal tolerance and determined that the critical low was approximate 6°C (43°F), and the critical high was around 26°C (79°F). Welsh and Hodgson (2011) determined that best the single variable for predicting Foothill Yellow-legged Frog presence was temperature since none were observed below 13°C (55°F), but numbers increased significantly with increasing temperature. Catenazzi and Kupferberg (2013) measured tadpole thermal preference at 16.5-22.2°C (61.7-72.0°F), and the distribution of Foothill Yellow-legged Frog populations across a watershed was consistent within this temperature range. At temperatures below 16°C (61°F), tadpoles were absent under closed canopy and scarce even with an open canopy (Ibid.). Catenazzi and Kupferberg (2017) found regional differences in apparently suitable breeding temperatures. Inland populations from primarily snowmelt-fed systems with relatively cold water were relegated to reaches that are warmer on average during the warmest 30 days of the year than coastal populations in the chiefly rainfall-fed, and thus warmer, systems (17.6-24.2°C [63.7-75.6°F] vs. 15.7-22.0°C [60.3-71.6°F], respectively).

However, experiments on tadpole thermal preference demonstrated that individuals from different source populations selected similar rearing temperatures, which presumably optimized development (Ibid.). In regulated systems, where water released from dams is often colder than normal, suitable rearing temperatures downstream may be limited (Wheeler et al. 2014, Catenazzi and Kupferberg 2017).

Appropriate flow velocities are also critical for survival to metamorphosis. The velocity at which Foothill Yellow-legged Frog egg masses shear away from the substrate they are adhered to varies according to factors such as depth and degree to which the eggs are sheltered (Spring Rivers Ecological Sciences 2003). This critical velocity is expected to decrease as the egg mass ages due to the~~ir~~ reduced structural integrity of the protective jelly envelopes (Hayes et al. 2016). Short-duration increases in flow velocity may be tolerated if the egg masses are somewhat sheltered, but sustained high velocities increase the likelihood of detachment (Kupferberg 1996a, Spring Rivers Ecological Sciences 2003). Hatchlings and tadpoles about to undergo metamorphosis are relatively poor swimmers and require especially slow, stable flows during these stages of development (Kupferberg et al. 2011b). Tadpoles respond to increasing flows by swimming against the current to maintain position for a short period of time and eventually swimming to the bottom and seeking refuge in the rocky substrate's interstitial spaces (Ibid.). When tadpoles are exposed to repeated increases in velocities, their growth and development are delayed (Ibid.). Under experimental conditions, the critical velocity at which tadpoles were swept downstream ranged between 20 and 40 cm/s (0.66-1.31 ft/s); however, as they reach metamorphosis it decreases to as low as 10 cm/s (0.33 ft/s) (Ibid.).

Nonbreeding Active Season Habitat

Post-metamorphic Foothill Yellow-legged Frogs utilize a more diverse range of habitats and are much more dispersed during the nonbreeding active season than the breeding season. Microhabitat preferences appear to vary by location and season, but some patterns are common across the species' range. Foothill Yellow-legged Frogs tend to remain close to the water's edge (average < 3 m [10 ft]); select sunny areas with limited canopy cover; and are often associated with riffles and pools (Zweifel 1955, Hayes and Jennings 1988, Van Wagner 1996, Welsh et al. 2005, Haggarty 2006, Bourque 2008, Gonsolin 2010, Welsh and Hodgson 2011). Adequate water, food resources, cover from predators, ability to thermoregulate (e.g., presence of basking sites and cool refugia), and absence of non-native predators are important components of nonbreeding active season habitat (Hayes and Jennings 1988, Van Wagner 1996, Catenazzi and Kupferberg 2013).

Overwintering Habitat

Overwintering habitat varies depending on local conditions, but as with the rest of the year, Foothill Yellow-legged Frogs are most often found in or near water where they can forage and take cover from predators and high discharge events (Storer 1925, Zweifel 1955). In larger streams and rivers, Foothill Yellow-legged Frogs are often found along tributaries during the winter where the risk of being displaced by heavy flows is reduced (Kupferberg 1996a, Gonsolin 2010). Bourque (2008) found 36.4% of adult females used intermittent and ephemeral tributaries during the overwintering season. Van

Wagner (1996) located most overwintering frogs using pools with cover such as boulders, root wads, and woody debris. During high flow events, they moved to the stream's edge and took cover under vegetation like sedges (*Carex* sp.) or leaf litter (Ibid.). Rombough (2006) found most Foothill Yellow-legged Frogs under woody debris along the high-water line and often using seeps along the stream-edge, which provided them with moisture, a thermally stable environment, and prey.

Exceptions to the pattern of remaining near the stream's edge during winter have been reported. Cook et al. (2012) observed dozens of juvenile Foothill Yellow-legged Frogs traveling over land, as opposed to using riparian corridors. They were found using upland habitats with an average distance of 71.3 m (234 ft) from water (range: 16-331 m [52-1,086 ft]) (Ibid.). In another example, a single subadult that was found adjacent to a large wetland complex 830 m (2,723 ft) straight-line distance from the wetted edge of the Van Duzen River, although it is possible the wetland was connected to the river via a spillway or drainage that may have served as the movement corridor (CDFW 2018a, R. Bourque pers. comm. 2019).

Seasonal Activity and Movements

Because Foothill Yellow-legged Frogs occupy areas with relatively mild winter temperatures, they can be active year-round, although at low temperatures (< 7°C [44 °F], they become lethargic (Storer 1925, Zweifel 1955, Van Wagner 1996, Bourque 2008). They are active both day and night, and during the day adults are often observed basking on warm objects such as sun-heated rocks, although this is also when their detectability is highest (Fellers 2005, Wheeler et al. 2005). By contrast, Gonsolin (2010) tracked radio-telemetered Foothill Yellow-legged Frogs under substrate a third of the time and underwater a quarter of the time, although nearly all his detections of frogs without transmitters were basking.

Adult Foothill Yellow-legged Frogs migrate from their overwintering sites to breeding habitat in the spring, often from a tributary to its confluence with a larger stream or river. In areas where tributaries dry down, juveniles also make this downstream movement (Haggarty 2006). When the tributary itself is perennial and provides suitable breeding habitat, the frogs may not undertake these long-distance movements (Gonsolin 2010). Cues for adults to initiate this migration to breeding sites are somewhat enigmatic and vary by location, elevation, and amount of precipitation (S. Kupferberg and A. Lind pers. comm. 2017). They can also include day length, water temperature, and sex (GANDA 2008, Gonsolin 2010, Yarnell et al. 2010, Wheeler et al. 2018). Males initiate movements to breeding sites where they congregate in leks (areas of aggregation for courtship displays), and females arrive later and over a longer period (Wheeler and Welsh 2008, Gonsolin 2010). Most males utilize breeding sites associated with their overwintering tributaries, but some move substantial distances to other sites and may use more than one breeding site in the same season (Wheeler and Welsh 2006, GANDA 2008).

While the predictable hydrograph in California consists of wet winters with high flows and dry summers with low flows, the timing and quantity of seasonal discharge can vary significantly from year to year. The timing of oviposition can influence offspring growth and survival. Early breeders risk scouring of egg masses from their substrate by late spring storms in wet years or desiccation if waters recede rapidly, but when they successfully hatch, tadpoles benefit from a longer growing season, which can enable them to metamorphose at a larger size and increase their likelihood of survival (Railsback et al. 2016).

Later breeders are less likely to have their eggs scoured away or desiccated because flows are generally more stable, but they have fewer mate choices, and their tadpoles have a shorter growing period before metamorphosis, reducing their chance of survival (Ibid.). Some evidence indicates larger females, who coincidentally lay larger clutches, breed earlier (Kupferberg et al. 2009c, Gonsolin 2010). Consequently, early season scouring or stranding of egg masses or tadpoles can disproportionately impact the population's reproductive output because later breeders produce fewer and smaller eggs per clutch (Kupferberg et al. 2009c, Gonsolin 2010).

Timing of oviposition is often a function of water temperature and flow, but it consistently occurs on the descending limb of the hydrograph which corresponds to high ~~high winter discharge~~spring discharge gradually receding toward low summer baseflow (Kupferberg 1996a, GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010, Yarnell et al. 2010). Under natural conditions, the timing coincides with intermittent tributaries drying down and increases in algal blooms that provide forage for tadpoles (Haggarty 2006, Power et al. 2008). At lower elevations, breeding can start in late March or early April, and at mid-elevations, breeding typically occurs in mid-May to mid-June (Gonsolin 2010, S. Kupferberg and A. Lind pers. comm. 2017). The time of year a population initiates breeding can vary by a month among water years, occurring later at deeper sites when colder water becomes warmer (Wheeler et al. 2018). In wetter years, delayed breeding into early July can occur in some colder snowmelt systems (S. Kupferberg and A. Lind pers. comm. 2017, GANDA 2018).

Commented [RAP7]: We seen as much as 2 months…early May to late June early July (2011 and 2015/16) in the NF American and Rubicon rivers. You can use me or Sarah Y. as a pers comm if you'd like…I'm working on that manuscript still… ☺

A population's period of oviposition can also vary from two weeks to three months, meaning they could be considered explosive breeders at some sites and prolonged breeders at others (Storer 1925, Zweifel 1955, Van Wagner 1996, Ashton et al. 1997, Wheeler and Welsh 2008). Water temperature typically warms to over 10°C (50°F) before breeding commences (GANDA 2008, Gonsolin 2010, Wheeler et al. 2018). Wheeler and Welsh (2008) observed Foothill Yellow-legged Frogs breeding when flows were below 0.6 m/s (2 ft/s), pausing during increased flows until they receded, and GANDA (2008) reported breeding initiated when flow decreased to less than 55% above baseflow.

Male Foothill Yellow-legged Frogs spend more time at breeding sites during the season than females, many of whom leave immediately after laying their eggs (GANDA 2008, Wheeler and Welsh 2008, Gonsolin 2010). Daily movements are usually short (< 0.3 m [1 ft]), but some individuals travel substantial distances: median 70.7 m/day (232 ft/day) in spring and 37.1 m/day (104 ft/day) in fall/winter, nearly always using streams as movement corridors (Van Wagner 1996, Bourque 2008, Gonsolin 2010). The maximum reported movement rate is 1,386 m/d (0.86 mi/day), and the longest seasonal (post-breeding) daily distance reported is 7.04 km (4.37 mi) by a female that traveled up a dry tributary and over a ridge before returning to and moving up the mainstem creek (Bourque 2008). Movements during the non-breeding season are typically in response to drying channels or during rain events (Bourque 2008, Gonsolin 2010, Cook et al. 2012).

Hatchling Foothill Yellow-legged Frog tadpoles~~s~~ tend to remain with what is left of the egg mass for several days before dispersing into the interstitial spaces in the substrate (Ashton et al. 1997). They often move downstream in areas of moderate flow and will follow the location of warm water in the channel throughout the day (Brattstrom 1962, Ashton et al. 1997, Kupferberg et al. 2011a). Tadpoles usually metamorphose in late August or early September (S. Kupferberg and A. Lind pers. comm. 2017). Twitty et al. (1967) reported that newly metamorphosed Foothill Yellow-legged Frogs mostly migrated upstream, which may be an evolutionary mechanism to return to their natal site after being washed downstream (Ashton et al. 1997).

Home Range and Territoriality

Foothill Yellow-legged Frogs exhibit a lek-type mating system in which males aggregate at the breeding site and establish calling territories (Wheeler and Welsh 2008, Bondi et al. 2013). The species has a relatively large calling repertoire for western North American ranids with seven unique vocalizations recorded (Silver 2017). Some of these can be reasonably attributed to territory defense and mate attraction communications (MacTeague and Northen 1993, Silver 2017). Physical aggression among males during the breeding season has been reported (Rombough and Hayes 2007, Wheeler and Welsh 2008). In addition, Wheeler and Welsh (2008) observed a non-random mating pattern in which males engaged in amplexus with females were larger than males never seen in amplexus, suggesting either physical competition or female preference for larger individuals. Very little information has been published on Foothill Yellow-legged Frog home range size. Wheeler and Welsh (2008) studied males during a 17-day period during breeding season and classified some of them "site faithful" based on their movements and calculated their home ranges. Two-thirds of males tracked were site faithful, and their mean home range size was 0.58 m^2 (SE = 0.10 m^2; 6.24 ft^2 [SE = 1.08 ft^2]) (Ibid.). In contrast, perhaps because the study took place over a longer time period, Bourque (2008) reported approximately half of the males he tracked during the spring were mobile, and the other half were sedentary. The median distances traveled along the creek (a proxy for home range size since they rarely leave the riparian corridor) for mobile and sedentary males were 149 m (489 ft) and 5.5 m (18 ft), respectively.

Diet and Predators

Foothill Yellow-legged Frog diet varies by life stage and likely body size. Tadpoles graze on periphyton (algae growing on submerged surfaces) scraped from rocks and vegetation and grow faster, and to a larger size, when it contains a greater proportion of epiphytic diatoms with nitrogen-fixing endosymbionts (*Epithemia* spp.), which are high in protein and fat (Kupferberg 1997b, Fellers 2005, Hayes et al. 2016, Catennazi and Kupferberg 2017). Tadpoles may also forage on necrotic tissue from dead bivalves and other tadpoles, or more likely the algae growing on them (Ashton et al. 1997, Hayes et al. 2016). Post-metamorphic Foothill Yellow-legged Frogs primarily feed on a wide variety of terrestrial arthropods but also some aquatic invertebrates (Fitch 1936, Van Wagner 1996, Haggarty 2006). Most of their diet consists of insects and arachnids (Van Wagner 1996, Haggarty 2006, Hothem et al. 2009). Haggarty (2006) did not identify any preferred taxonomic groups, but she noted larger Foothill Yellow-legged Frogs consumed a greater proportion of large prey items compared to smaller individuals, suggesting the species may be gape-limited generalist predators. Hothem et al. (2009) found mammal hair and bones in a Foothill Yellow-legged Frog. Adult Foothill Yellow-legged Frogs, like many other ranids, also cannibalize conspecifics (Wiseman and Bettaso 2007). In the fall when young-of-year are abundant, they may provide an important source of nutrition for adults prior to overwintering (Ibid.).

Foothill Yellow-legged Frogs are preyed upon by several native and introduced species, including each other as described above. Some predators target specific life stages, while others may consume multiple stages. Several species of gartersnakes (genus *Thamnophis*) are the primary and most widespread group of native predators on Foothill Yellow-legged Frogs tadpoles through adults is (Fitch 1941, Fox 1952, Zweifel 1955, Lind and Welsh 1994, Ashton et al. 1997, Wiseman and Bettaso 2007, Gonsolin 2010). Table 1 lists other known and suspected predators of Foothill Yellow-legged Frogs.

Table 1. Confirmed and potential Foothill Yellow-legged Frog predators in California in addition to gartersnakes (*Thamnophis* spp.)

Common Name	Scientific Name	Classification	Native	Prey Life Stage(s)	Sources
Caddisfly (larva)	*Dicosmoecus gilvipes*	Insect	Yes	Embryos (eggs)	Rombough and Hayes 2005
Dragonfly (nymph)	*Aeshna walker*	Insect	Yes	Larvae	Catenazzi and Kupferberg 2018
Waterscorpion	*Ranatra brevicollis*	Insect	Yes	Larvae	Catenaazi and Kupferberg 2018
Signal Crayfish	*Pacifastacus leniusculus*	Crustacean	No	Embryos (eggs) and Larvae	Rombough and Hayes 2005; Wiseman et al. 2005
Speckled Dace	*Rhinichthys osculus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Reticulate Sculpin	*Cottus perplexus*	Fish	Yes	Larvae	Rombough and Hayes 2005
Sacramento Pike~~-~~m~~M~~innow	*Ptychocheilus grandis*	Fish	Yes*	Embryos (eggs) and Adults	Ashton and Nakamoto 2007
Sunfishes	Family Centrachidae	Fish	No	Larvae	Moyle (1973); Hayes and Jennings 1986
Catfishes	Family Ictaluridae	Fish	No	Larvae	Moyle (1973); Hayes and Jennings 1986
Rough-skinned Newt	*Taricha granulosa*	Amphibian	Yes	Embryos (eggs)	Evenden 1948
California Giant Salamander	*Dicamptodon ensatus*	Amphibian	Yes	Larvae	Fidenci 2006
American Bullfrog	*Rana catesbeiana*	Amphibian	No	Larvae to Adults	Crayon 1998; Hothem et al. 2009
California Red-legged Frog	*Rana draytonii*	Amphibian	Yes	Larvae to Adults	Gonsolin 2010
American Robin	*Turdus migratorius*	Bird	Yes	Larvae	Gonsolin 2010
Common Merganser	*Mergus merganser*	Bird	Yes	Larvae	Gonsolin 2010
American Dipper	*Cinclus mexicanus*	Bird	Yes	Larvae	Ashton et al. 1997
Mallard	*Anas platyrhynchos*	Bird	Yes	Adults	Rombough et al. 2005
Raccoon	*Procyon lotor*	Mammal	Yes	Larvae to Adults	Zweifel 1955; Ashton et al. 1997
River Otter	*Lontra canadensis*	Mammal	Yes	Adults	T. Rose pers. comm. 2014

* Introduced to the Eel River, location of documented predation; Foothill Yellow-legged Frogs are extirpated from most areas of historical range overlap

Commented [RAP8]: Do you have a copy of Susan Corum's thesis from Humboldt State? It's from 2003 and is about the effects of sac pikeminnow on FYLF in coastal streams…should probably add as citation here too.

Corum, S. D. (2003). *Effects of Sacramento Pikeminnow on Foothill Yellow-Legged Frogs in Coastal Streams* (August). Humboldt State University.

STATUS AND TRENDS IN CALIFORNIA

Administrative Status

Sensitive Species

The Foothill Yellow-legged Frog is listed as a Sensitive Species by the U.S. Bureau of Land Management (BLM) and U.S. Forest Service (Forest Service). These agencies define Sensitive Species as those species that require special management consideration to promote their conservation and reduce the likelihood and need for future listing under the ESA.

California Species of Special Concern

The Department's Species of Special Concern (SSC) designation is similar to the federal Sensitive Species designation. It is administrative, rather than regulatory in nature, and intended to focus attention on animals at conservation risk. The designation is used to stimulate needed research on poorly known species and to target the conservation and recovery of these animals before they meet the CESA criteria for listing as threatened or endangered (Thomson et al. 2016). The Foothill Yellow-legged Frog is listed as a Priority 1 (highest risk) SSC (Ibid.).

Trends in Distribution and Abundance

Range-wide in California

Range is the general geographical area in which an organism occurs. For purposes of CESA and this Status Review, the range is the species' California range (*Cal. Forestry Assn. v. Cal. Fish and Game Com.* (2007) 156 Cal.App.4th 1535, 1551). Systematic, focused, range-wide assessments of Foothill Yellow-legged Frog distribution and abundance are rare, both historically and contemporarily. A detailed account of what has been documented within the National Parks and National Forests in California can be found in Appendix 3 of the *Foothill Yellow-legged Frogs Conservation Assessment in California* (Hayes et al. 2016).

Most Foothill Yellow-legged Frog records are incidental observations made during stream surveys for ESA-listed salmonids and simply document presence at a particular date and location, although some include counts or estimates of abundance by life stage. This makes assessing trends in distribution and abundance difficult despite a relatively large number of observations compared to many other species tracked by the California Natural Diversity Database (CNDDB). The CNDDB contained 2,366 Foothill Yellow-legged Frog occurrences in its March 2019 edition, 500 of which are documented from the past 5 years.

A few wide-ranging survey efforts that included Foothill Yellow-legged Frogs exist. Reports from early naturalists suggest Foothill Yellow-legged Frogs were relatively common in the Coast Ranges as far south as central Monterey County, in eastern Tehama County, and in the foothills in and near Yosemite National Park (Grinnell and Storer 1924, Storer 1925, Grinnell et al. 1930, Martin 1940). In addition to

these areas, relatively large numbers of Foothill Yellow-legged Frogs (17-35 individuals) were collected at sites in the central and southern Sierra Nevada and the San Gabriel Mountains between 1911 and 1950 (Hayes et al. 2016). Widespread disappearances of Foothill Yellow-legged Frog populations were documented as early as the 1970s and 80s in southern California, the southern Coast Range, and the central and southern Sierra Nevada foothills (Moyle 1973, Sweet 1983).

Twenty-five years ago, the Department published the first edition of *Amphibians and Reptile Species of Special Concern in California* (Jennings and Hayes 1994). The authors revisited hundreds of localities that had historically been occupied by Foothill Yellow-legged Frogs between 1988 and 1991 and consulted local experts to determine presumed extant or extirpated status. Based on these survey results and stressors observed on the landscape, they considered Foothill Yellow-legged Frogs endangered in central and southern California south of the Salinas River in Monterey County. They considered the species threatened in the west slope drainages of the Cascade Mountains and Sierra Nevada east of the Central Valley, and they considered the remainder of the range to be of special concern (Ibid.).

Fellers (2005) and his field crews conducted surveys for Foothill Yellow-legged Frogs throughout California. They visited 804 sites across 40 counties with suitable habitat within the species' historical range. They detected at least one individual at 213 sites (26.5% of those surveyed) over 28 counties. They located Foothill Yellow-legged Frogs in approximately 40% of streams in the North Coast, 30% in the Cascade Mountains and south of San Francisco in the Coast Range, and 12% in the Sierra Nevada. Fellers estimated population abundance was 20 or more adults at only 14% of the sites where the species was found and noted the largest and most robust populations occurred along the North Coast. In addition, to determine status of Foothill Yellow-legged Frogs across the species' range and potential causes for declines, Lind (2005) used previously published status accounts, species expert and local biologist professional opinions, and field visits to historically occupied sites between 2000-2002. She determined that Foothill Yellow-legged Frogs had disappeared from 201 of 394 of the sites, representing just over 50%. The coarse-scale trend in California is one of greater population declines and extirpations of amphibians? Or just FYLF? in lower elevations and latitudes (Davidson et al. 2002).

Few site-specific population trend data are available from which to evaluate status. However, long-term monitoring efforts often use egg mass counts as a proxy to estimate adult breeding females. The results of these studies often reveal extreme interannual variability in number of egg masses laid (Ashton et al. 2010, S. Kupferberg and M. Power pers. comm. 2015, Peek and Kupferberg 2016). In a meta-analysis of egg mass count data collected across the species' range in California over the past 25 years, Peek and Kupferberg (2016) reported declines in two unregulated rivers and an increase in another. Their models did not detect any significant trends in abundance across different locations or regulation type (dammed or undammed); however, high interannual variability can render trend detection difficult. Interannual variability was substantially greater in regulated rivers vs. unregulated; the median coefficient of variation was 66.9% and 41.6%, respectively (Ibid.). The greater variability in regulated rivers decreases the probability of detecting significant declines, and coupled with low abundance, it can lead to populations dropping below a density necessary for persistence without detection, resulting in extirpation.

Regional differences in Foothill Yellow-legged Frog persistence across its range have been recognized for nearly 50 years (i.e., more extirpations documented in the south). Because of these differences and the recent availability of new landscape genomic data, more detailed descriptions of trends in Foothill Yellow-legged Frog population distribution and abundance in California are evaluated by clade below. Figure 5 depicts Foothill Yellow-legged Frog localities across all clades in California by the most recent confirmed sighting in the datasets available to the Department within a Public Lands Survey System (PLSS) section. "Transition Zones" are those areas where the exact clade boundaries are unknown due to a lack of samples. In addition, while not depicted as an area of uncertainty, no genetic samples have been tested south of the extant population in northern San Luis Obispo County, in the Sutter Buttes in Sutter County, or northeastern Plumas County. It is possible there were historically more clades than currently understood.

Caution should be exercised in comparing the following observation data across the species' range and across time since survey effort and reporting are not standardized. These data can be useful for making some general inferences about distribution, abundance, and trends. For instance, assuming the observation correctly identifies the species, the date on the record is the last time the species was confirmed to have occurred at that location. However, this only works in the affirmative. For example, at a site where the last time the species was seen was 75 years ago, the species may still persist there if no one has surveyed it since the original observation. CNDDB staff use information on land use conversion, follow-up visits, and biological reports to categorize an occurrence location as "extirpated" or "possibly extirpated".

Northwest/North Coast Clade

This clade extends from north of San Francisco Bay through the Coast Range and Klamath Mountains to the northern limit of the Foothill Yellow-legged Frog's range and east through the Cascade Range. It includes Del Norte, Siskiyou, Humboldt, Trinity, Shasta, Tehama, Mendocino, Glenn, Colusa, Lake, Sonoma, Napa, Yolo, Solano, and Marin counties. This clade covers the largest geographic area and contains the greatest amount of genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). In addition, it is the only clade with an increasing trend in genetic diversity (Peek 2018).

Early records note the comparatively high abundance of Foothill Yellow-legged Frogs in this area. Storer (1925) described Foothill Yellow-legged Frogs as very common in many of Coast Range streams north of San Francisco Bay, and Cope (1879,1883 as cited in Hayes et al. 2016) noted they were "rather abundant in the mountainous regions of northern California." In addition, relatively large collections occurred over short periods of time in this region in the late 1800s and the first half of the 20th century (Hayes et al. 2016). Nineteen were taken over two weeks in 1893 along Orrs Creek, a tributary to the Russian River, and 40 from near Willits (both in Mendocino County) in 1911; 112 were collected over three days at Skaggs Spring (Sonoma County) in 1911; 57 were taken in one day along Lagunitas Creek (Marin County) in 1928; and 50 were collected in one day near Denny (Trinity County) in 1955 (Ibid.).

A few long-term Foothill Yellow-legged Frog egg mass monitoring efforts undertaken within this clade's boundaries found densities vary significantly, often based on river regulation type, and documented

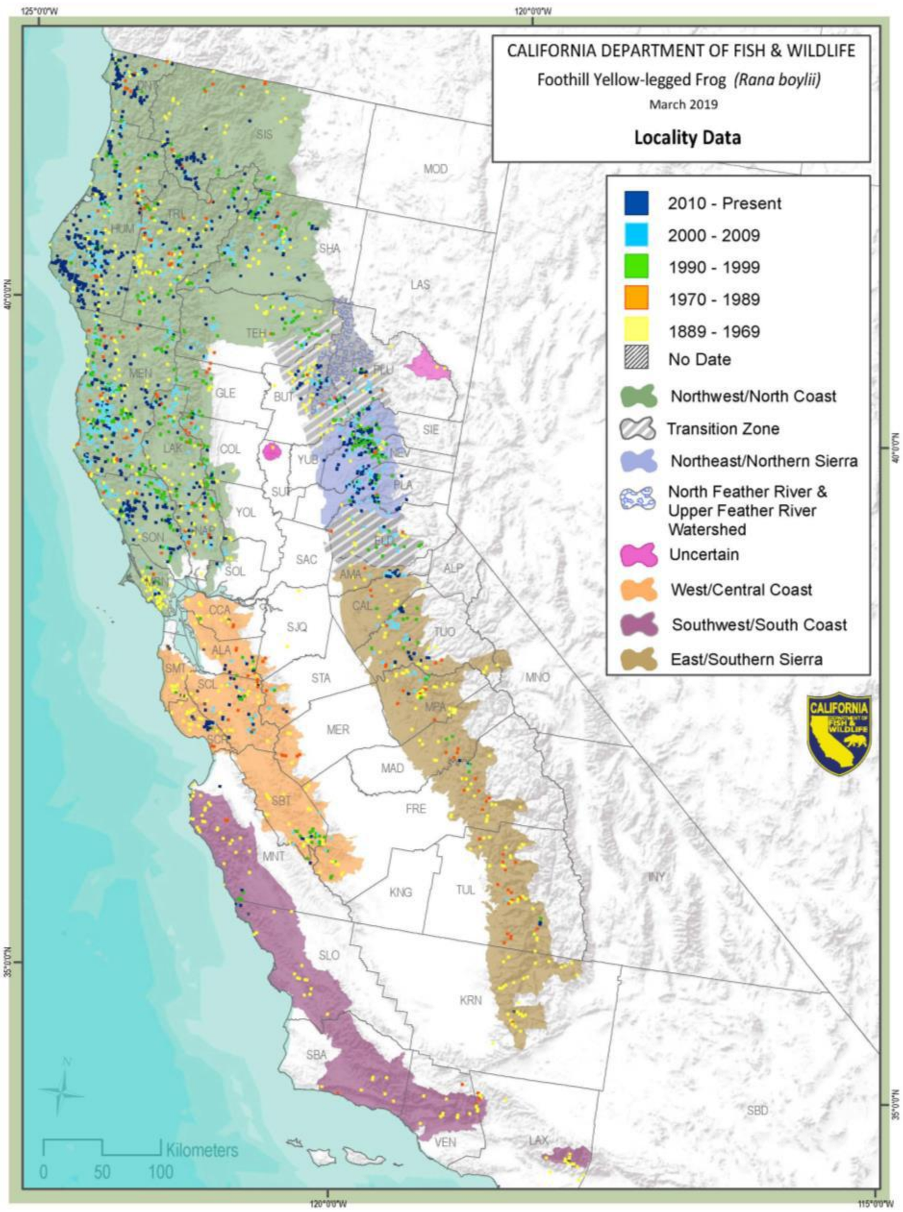

Figure 5. Foothill Yellow-legged Frog occurrence data from 1889-2019 overlaying the six clades by most recent sighting in a Public Lands Survey System section (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

several robust populations. The Green Diamond Resources Company has been monitoring a stretch of the Mad River near Blue Lake (Humboldt County) since 2008 (GDRC 2018). The greatest published density of Foothill Yellow-legged Frog egg masses was documented here in 2009 at 323.6 egg masses/km (520.7/mi) (Bourque and Bettaso 2011). However, in 2017, surveyors counted 625.1 egg masses/km (1,006/mi) along the same reach (GDRC 2018). At its lowest during this period, egg mass density was calculated at 71.54/km (115.1/mi) in 2010, although this count occurred after a flooding even that likely scoured over half of the egg masses laid that season (GDRC 2018, R. Bourque pers. comm. 2019). During a single day survey in 2017 along approximately 2 km (1.3 mi) of Redwood Creek in Redwood National Park (Humboldt County), 2,009 young and 126 adult Foothill Yellow-legged Frogs were found (D. Anderson pers. comm. 2017). Some reaches of the South Fork Eel River (Mendocino County) also support high densities of Foothill Yellow-legged Frogs. Kupferberg (pers. comm. 2018) recorded 206.9 and 106.2 egg masses/km (333 and 171/mi) along two stretches in 2016, and 201.7 and 117.5 egg masses/km (324 and 189/mi) in 2017. However, other reaches yielded counts as low as 6.1 and 8.4 egg masses/km (9.8 and 13.5/mi) (Ibid.). In the Angelo Reserve (an unregulated reach), the 24-year mean density was 109 egg masses/km (175.4/mi) (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015). In contrast, a 10-year mean density of egg masses below Lewiston Dam on the Trinity River (Trinity County) was 0.89/km (1.43/mi) (Ibid.).

Figure 6 depicts PLSS sections with positive sightings of Foothill Yellow-legged Frogs from the CNDDB, Biological Information Observation System datasets, and personal communications that are color coded by the most recent date of detection. Within this clade, Foothill Yellow-legged Frogs were observed in at least 343 areas in the past 5 years (CNDDB 2019). The species remains widespread within many watersheds, although most observations only verify presence, or fewer than ten individuals or egg masses are recorded (Ibid.). Documented extirpations are comparatively rare, but also likely undetected or under-reported, and nearly all occurred just north of the high-populated San Francisco Bay area (Figure 7; Ibid.).

West/Central Coast

This clade extends south from the San Francisco Bay through the Diablo Range and down the peninsula through the Santa Cruz and Gabilan Mountains in the Coast Range east of the Salinas Valley. It includes most of Contra Costa, Alameda, San Mateo, Santa Cruz, Santa Clara, and San Benito counties; western San Joaquin, Stanislaus, Merced, and Fresno counties; and a small portion of eastern Monterey County. Records of Foothill Yellow-legged Frogs occurring south of San Francisco Bay did not exist until specimens were collected in 1918 around what is now Pinnacles National Park in San Benito County, and little information exists on historical distribution and abundance within this clade (Storer 1923).

Within this clade, Foothill Yellow-legged Frogs were observed in at least 24 areas in the past five years (Figure 8; CNDDB 2019). Documented and possible extirpations are concentrated around the San Francisco Bay and sites at the southern portion of the clade's range, although these may not have been resurveyed since their original observations in the 1940s through 1960s, except for a site in Pinnacles National Park that was surveyed in 1994 (Figure 9; Ibid.). In addition, although not depicted,

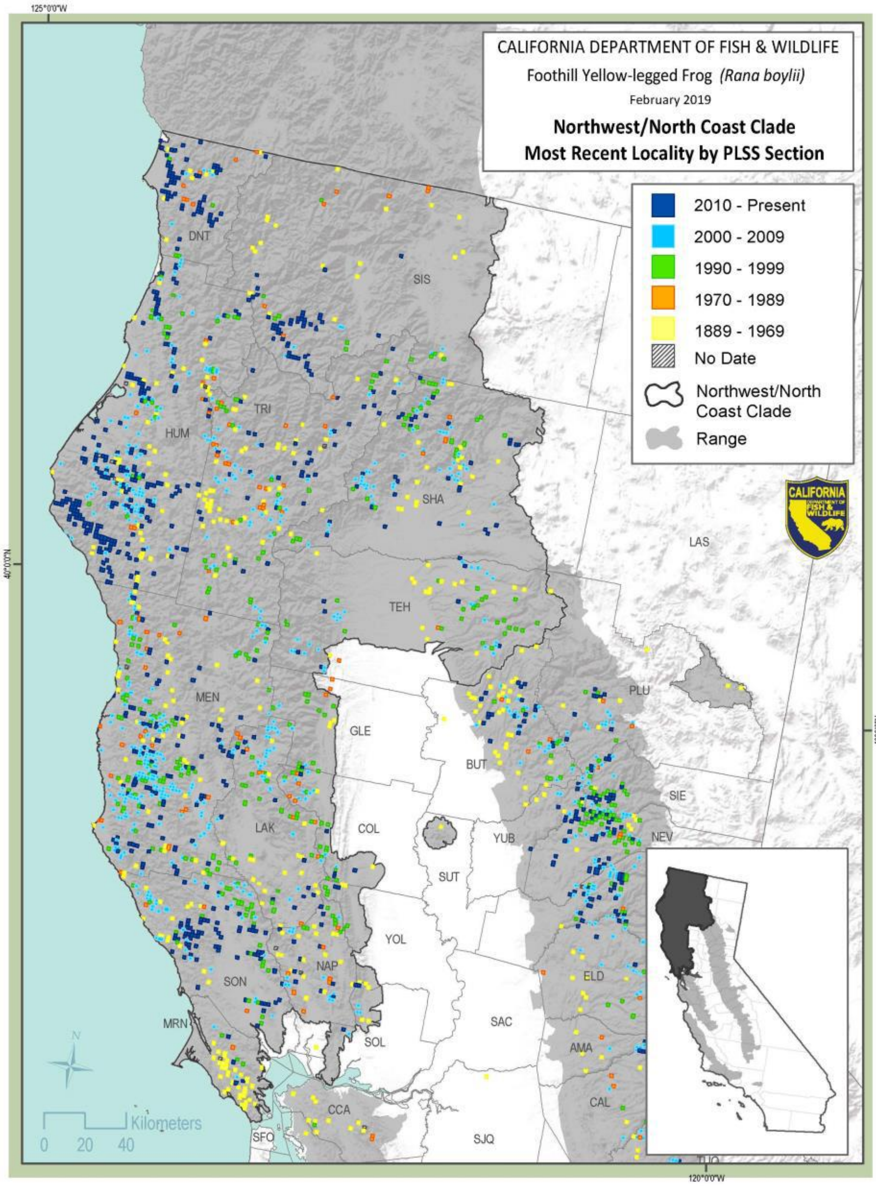

Figure 6. Close-up of Northwest/North Coast Foothill Yellow-legged Frog clade observations from 1889-2019 (ARSSC, BIOS, CDFW, CNDDB, HRC, MRC)

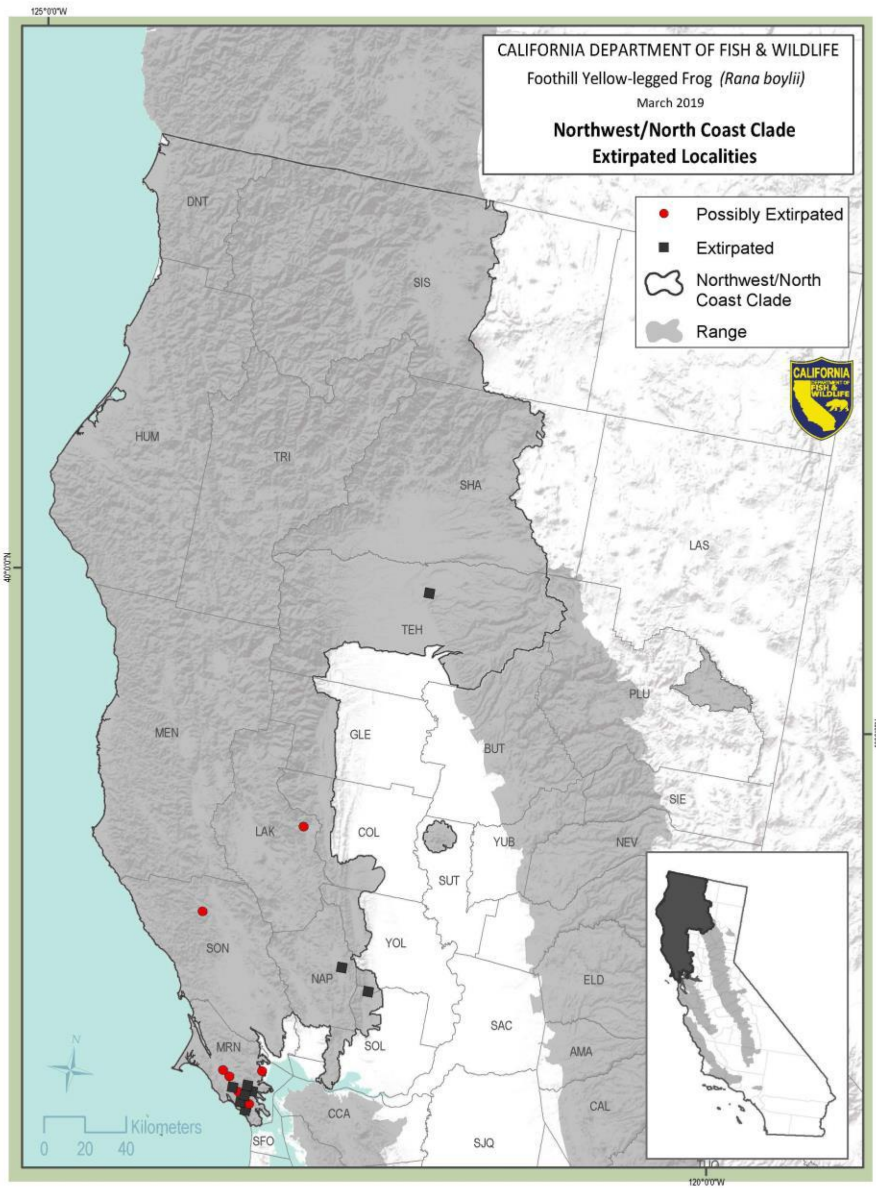

Figure 7. Possibly extirpated and extirpated Northwest/North Coast Foothill Yellow-legged Frog clade sites (CNDDB)

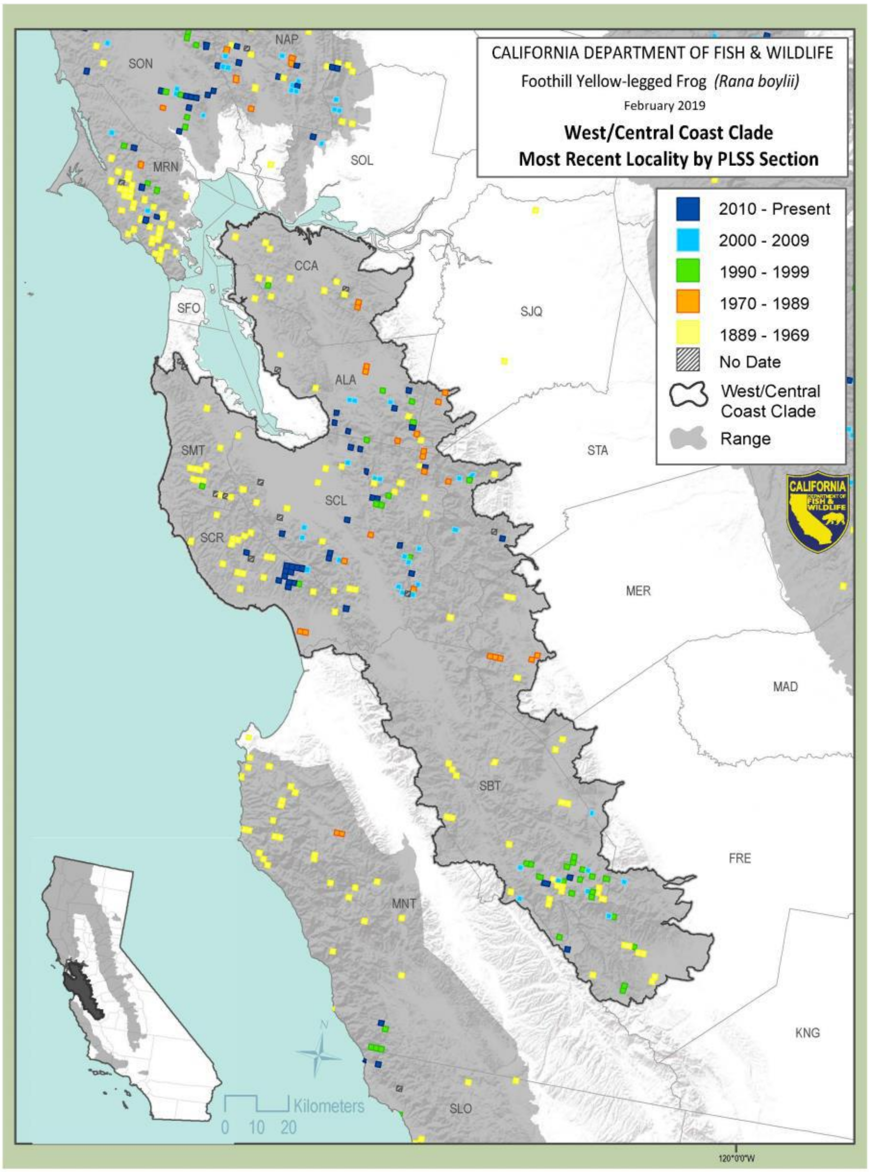

Figure 8. Close-up of West/Central Coast clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

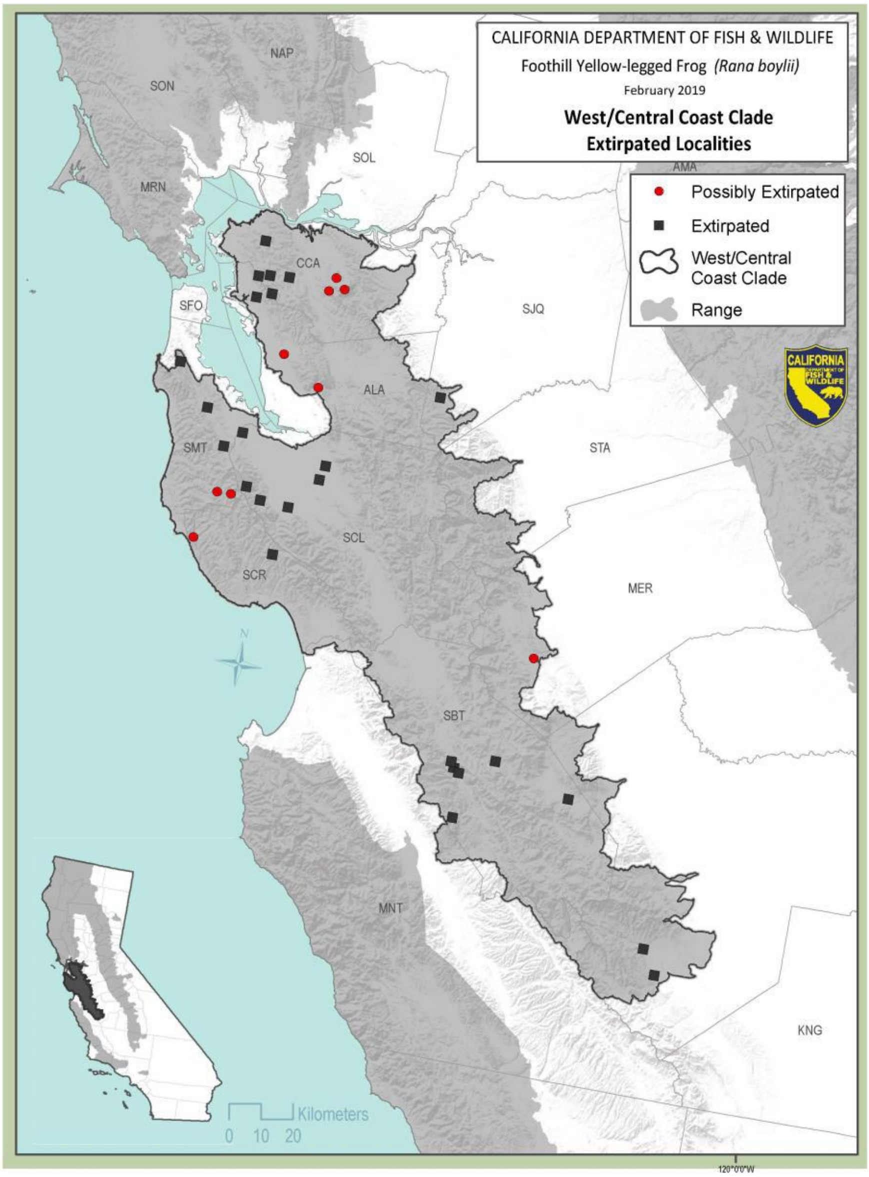

Figure 9. Possibly extirpated and extirpated West/Central Coast Foothill Yellow-legged Frog clade sites (CNDDB)

two populations on Arroyo Mocho and Arroyo Valle south of Livermore (Alameda County) are also likely extirpated (M. Grefsrud pers. comm. 2019).

The San Francisco Bay Area is heavily urbanized. Foothill Yellow-legged Frogs may be gone from Contra Costa County; eight of the nine CNDDB records from the county are museum specimens collected between 1891 and 1953, and the most recent observation was two adults in a plunge pool in an intermittent tributary to Moraga Creek in 1997. No recent (2010 or later) observations exist from San Mateo County (Ibid.). Historically occupied lower-elevation sites surrounding the San Francisco Bay and inland appear to be extirpated, but there are (or were) some moderately abundant breeding populations remaining at higher elevations in Arroyo Hondo (Alameda County), Alameda Creek (Alameda and Santa Clara counties), Coyote and Upper Llagas creeks (Santa Clara County), and Soquel Creek (Santa Cruz County) with some scattered smaller populations also persisting in these counties (J. Smith pers. comm. 2016, 2017; CNDDB 2019). The Alameda Creek and Coyote Creek populations recently underwent large-scale mortality events, so their numbers are likely substantially lower than what is currently reported in the CNDDB (Adams et al. 2017a, Kupferberg and Catenazzi 2019). In addition, the Arroyo Hondo population will lose approximately 1.6 km (1 mi) of prime breeding habitat (i.e., supported the highest density of egg masses on the creek) as the Calaveras Reservoir is refilled following its dam replacement project in 2019 (M. Grefsrud pers. comm. 2019). Foothill Yellow-legged Frogs may be extirpated from Corral Hollow Creek in San Joaquin County, but a single individual was observed five years ago further up the drainage in Alameda County within an Off-Highway Vehicle park (CNDDB 2019). Few recent sightings of Foothill Yellow-legged Frogs in the east-flowing creeks are documented. They may still be extant in the headwaters of Del Puerto Creek (western Stanislaus County), but the records further downstream indicate bullfrogs (known predators and disease reservoirs) are moving up the system (Ibid.). Several locations in southern San Benito, western Fresno, and eastern Monterey counties have relatively recent (2000 and later) detections (Ibid.). However, while many of these sites supported somewhat large populations in the 1990s, the more recent records report fewer than ten individuals (Ibid.). The exception is a Monterey County site where around 25 to 30 were observed in 2012 (Ibid.).

Southwest/South Coast

Widespread extirpations occurred decades ago, primarily in the 1960s and 1970s, in this area (Adams et al. 2017b). As a result, genetic samples were largely unavailable, and the boundaries are speculative. The clade is presumed to include the Coast Range from Monterey Bay south to the Transverse Range across to the San Gabriel Mountains. This clade includes portions of Monterey, San Luis Obispo, Santa Barbara, Ventura, and Los Angeles counties. Storer (1923) reported that Foothill Yellow-legged Frogs were collected for the first time in Monterey County in 1919 and that a specimen collected by Cope in 1889 in Santa Barbara and listed as *Rana temporaria pretiosa* may refer to the Foothill Yellow-legged Frog because as previously mentioned, the taxonomy of this species changed several times over the first century after it was named.

Foothill Yellow-legged Frogs had been widespread and fairly abundant in this area until the late 1960s (Figure 10) but were rapidly extirpated throughout the southern Coast Ranges and western Transverse

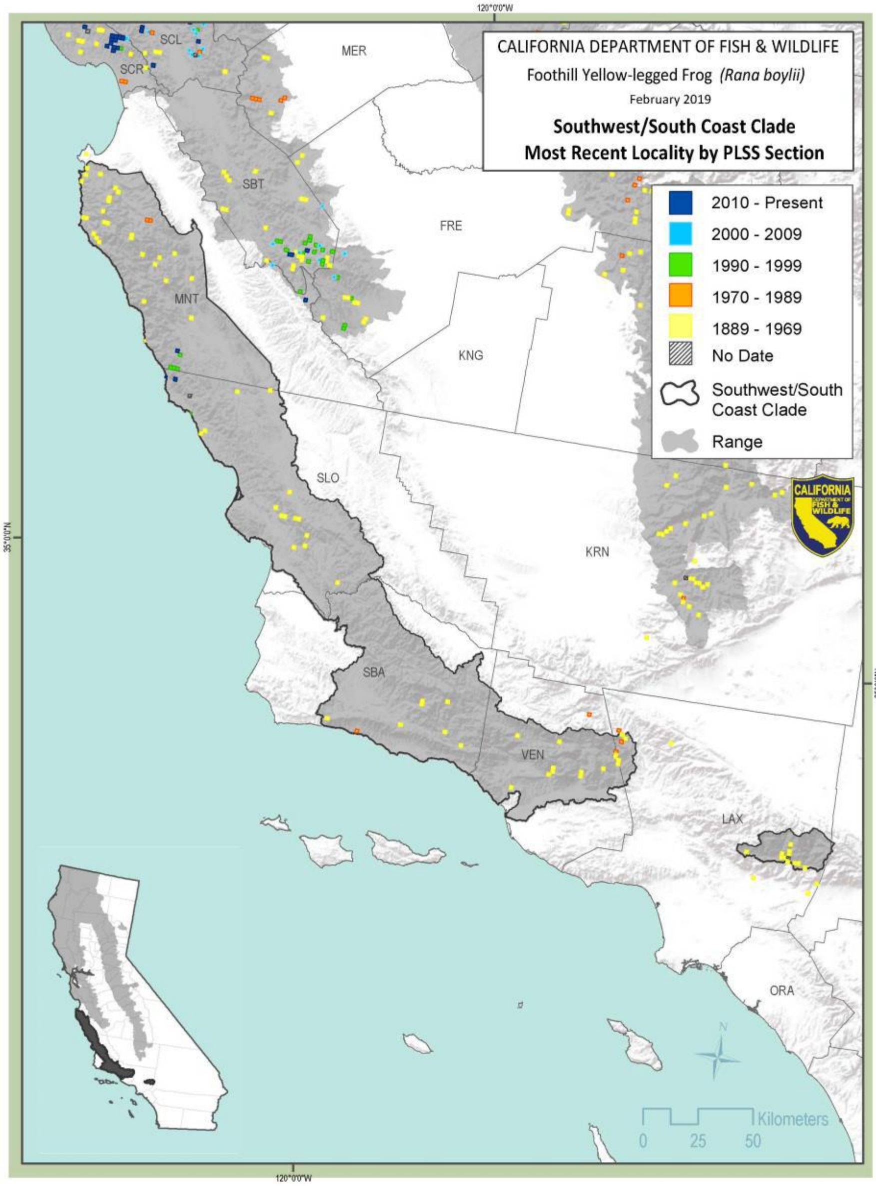

Figure 10. Close-up of Southwest/South Coast clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

Ranges by the mid-1970s (Figure 11; Sweet 1983, Adams et al. 2017b). Only two known extant populations exist from this clade, located near the border of Monterey and San Luis Obispo counties (S. Sweet pers. comm. 2017, McCartney-Melstad et al. 2018, Peek 2018, CNDDB 2019). They appear to be extremely small and rapidly losing genetic diversity, making them at high risk of extirpation (McCartney-Melstad et al. 2018, Peek 2018).

Northeast/Feather River and Northern Sierra

The exact clade boundaries in the Sierra Nevada are unclear and will require additional sampling and testing to define (Figure 12). The Northeast clade presumably encompasses the Feather River and Northern Sierra clades. The Feather River clade is located primarily in Plumas and Butte counties. The Northern Sierra clade roughly extends from the Feather River watershed south to the Middle Fork American River. It includes portions of El Dorado, Placer, Nevada, Sierra, and Plumas counties. It may also include portions of Amador, Butte, and eastern Tehama counties. No genetic samples were available to test in the Sutter Buttes or the disjunct population in northeastern Plumas County to determine which clades they belonged to before they were extirpated (Figure 13; Olson et al. 2016, CNDDB 2019).

In general, there is a paucity of historical Foothill Yellow-legged Frog data for west-slope Sierra Nevada streams, particularly in the lower elevations of the Sacramento Valley, and no quantitative abundance data exist prior to major changes in the landscape (i.e., mining, dams, and diversions) or the introduction of non-native species (Hayes et al. 2016). Foothill Yellow-legged Frogs have been collected frequently from the Plumas National Forest area in small numbers from the turn of the 20th century through the 1970s (Ibid.). Estimates of relative abundance are not clear from the records, but they suggest the species was somewhat widespread in this area.

More recently, Foothill Yellow-legged Frog populations in the Sierra Nevada have been the subject of a substantial number of surveys and focused research associated with recent and ongoing relicensing of hydroelectric power generating dams by the Federal Energy Regulatory Commission (FERC). Consequently, Foothill Yellow-legged Frogs have been observed in at least 30 areas in Plumas and Butte counties (roughly the Feather River clade) over the past five years (CNDDB 2019). As with the rest of the range, most records are observations of only a few individuals; however, many observations occurred over multiple years, and in some cases all life stages were observed over multiple years (Ibid). The populations appear to persist even with the small numbers reported. The only long-term consistent survey effort has been occurring on the North Fork Feather River along the Cresta and Poe reaches (GANDA 2018). The Cresta reach's subpopulation declined significantly in 2006 and never recovered despite modification of the flow regime to reduce egg mass and tadpole scouring and some habitat restoration (Ibid.). A pilot project to augment the Cresta reach's subpopulation through in situ captive rearing was initiated in 2017 (Dillingham et al. 2018). It resulted in the highest number of young-of-year Foothill Yellow-legged Frogs recorded during fall surveys since researchers started keeping count (Ibid.). The number of egg masses laid in the Poe reach varies substantially year-to-year from a low of 26 in 2001 to a high of 154 in 2015 and back down to 36 in 2017 (GANDA 2018).

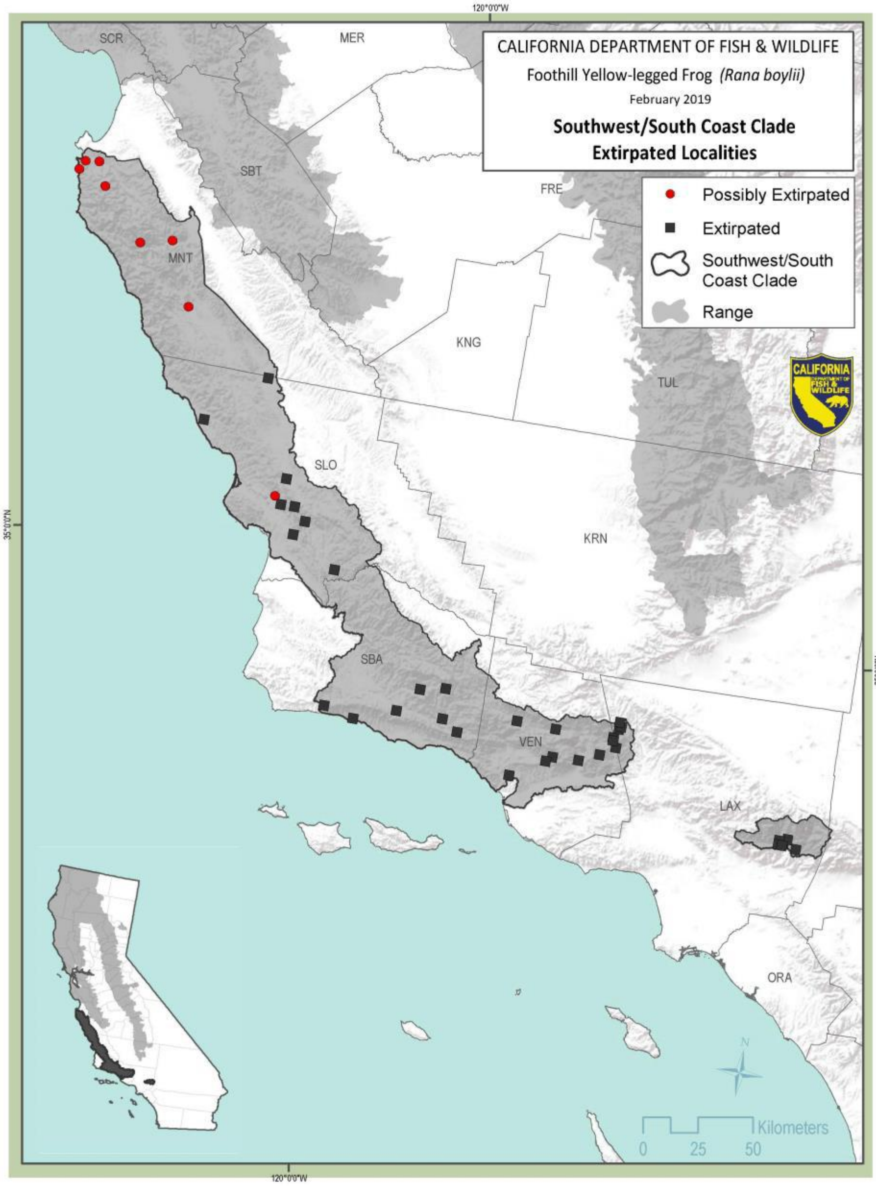

Figure 11. Possibly extirpated and extirpated Southwest/South Coast Foothill Yellow-legged Frog clade sites (CNDDB)

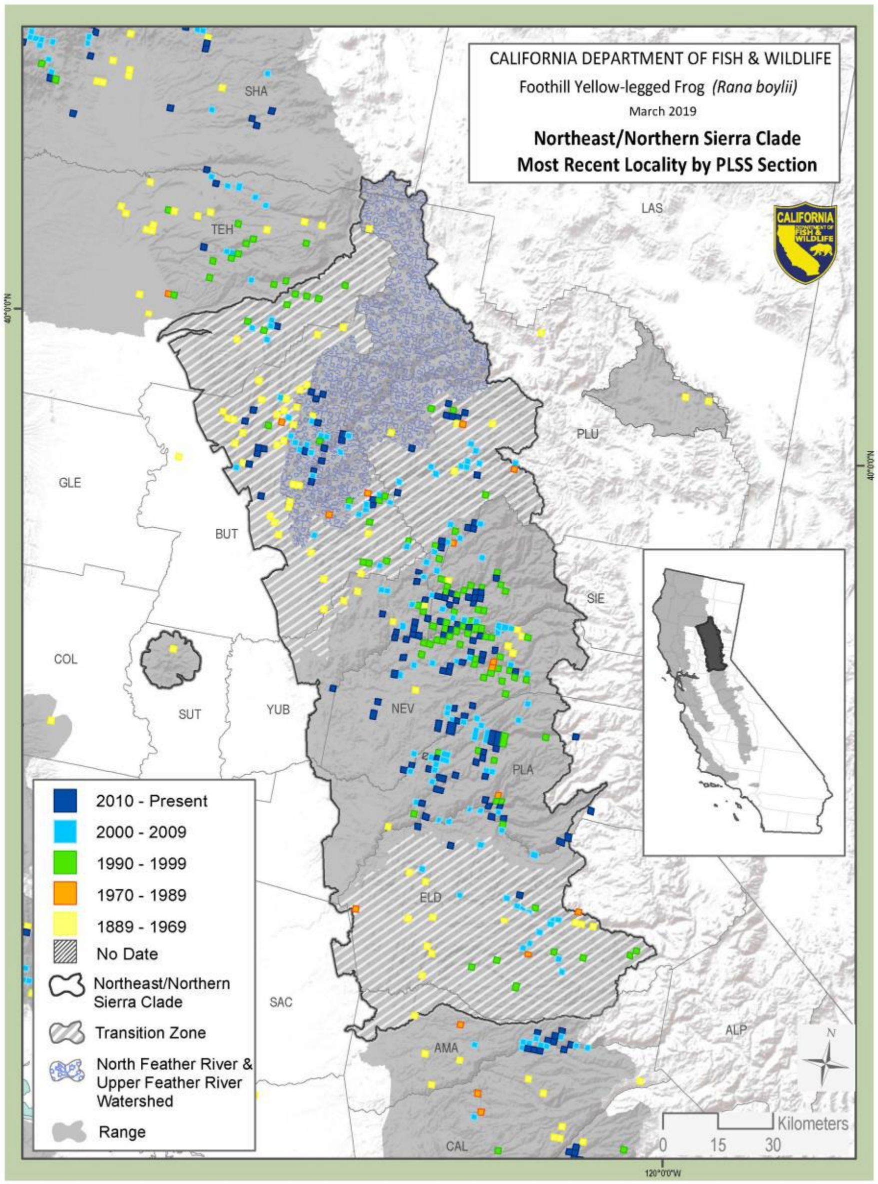

Figure 12. Close-up of Northeast/Feather River and Northern Sierra clades observations from 1889-2019 (ARSSC, BIOS, CNDDB)

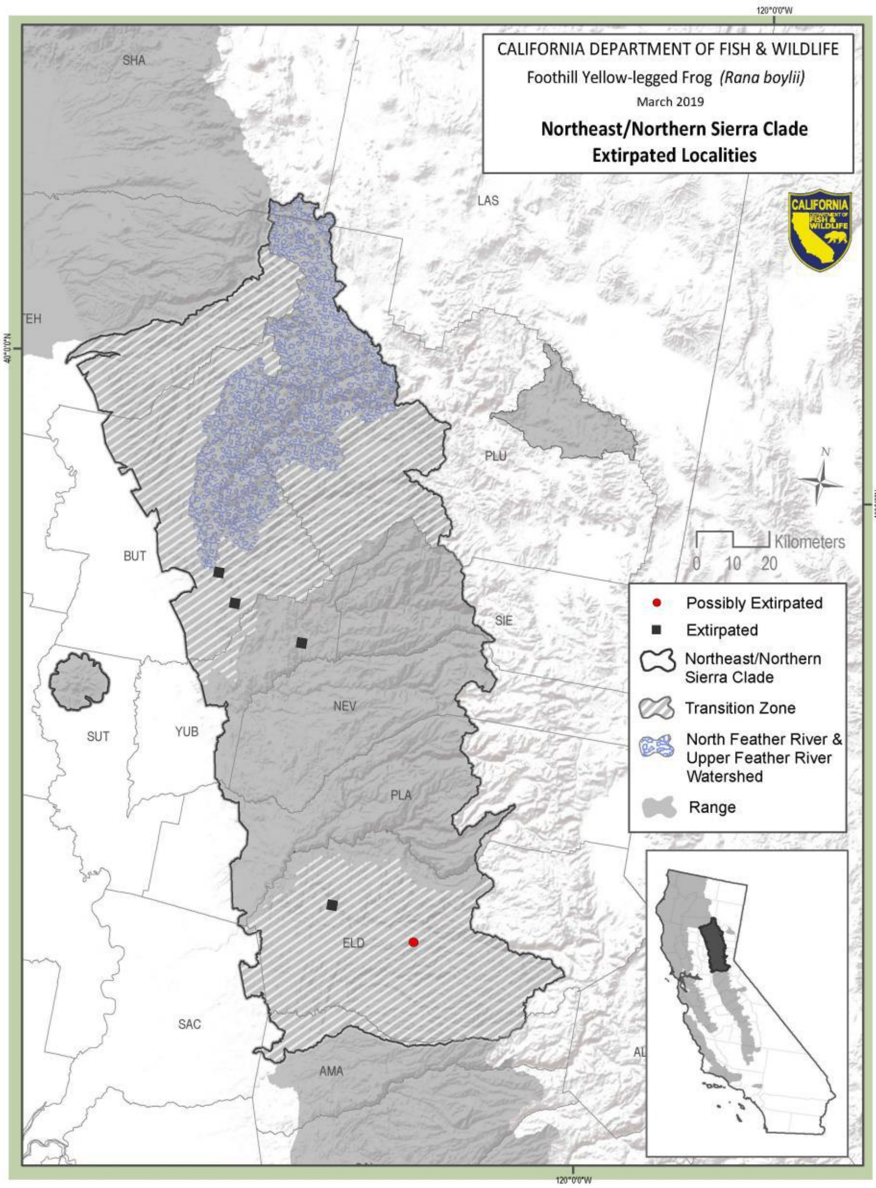

Figure 13. Possibly extirpated and extirpated Northeast/Feather River and Northern Sierra Foothill Yellow-legged Frog clades sites (CNDDB)

Foothill Yellow-legged Frogs have been observed in at least 71 areas in the past 5 years in the presumptive Northeast/Northern Sierra clade. The general pattern in this clade, and across the range ~~for that matter~~, is that unregulated rivers or reaches have more areas that are occupied more consistently and in larger numbers than regulated rivers or reaches (CNDDB 2019, S. Kupferberg pers. comm. 2019). Foothill Yellow-legged Frogs were rarely observed in the hydropeaking reach of the Middle Fork American River and were observed in low numbers in the bypass reach, but they were present and breeding in small tributary populations (PCWA 2008). Relatively robust populations appear to inhabit the North Fork American River and Lower Rubicon River (Gaos and Bogan 2001, PCWA 2008, Hogan and Zuber 2012, K. Kundargi pers. comm. 2014, S. Kupferberg pers. comm. 2019). Additional apparently sufficiently large and relatively stable populations occur on Clear Creek, South Fork Greenhorn Creek, and Shady Creek (Nevada County) and the North and Middle Yuba River (Sierra County), but the remaining observations are of small numbers in tributaries with minimal connectivity among them (CNDDB 2019, S. Kupferberg pers. comm. 2019).

East/Southern Sierra

The East/Southern Sierra clade is presumed to range from the South Fork American River watershed, the northernmost site where individuals from this clade were collected, south to where the Sierra Nevada meets the Tehachapi Mountains. It likely includes El Dorado, Amador, Calaveras, Tuolumne, Mariposa, Madera, Fresno, Tulare, and Kern counties (Figure 14; Peek 2018). The proportion of extirpated sites in this clade is second only to the Southwest/South Coast and follows the pattern of greater losses in the south (Figure 15). Like the southern coastal clade, the southern Sierra clade has low genetic variability and a trajectory of continued loss of diversity (Ibid.).

Historical collections of small numbers of Foothill Yellow-legged Frogs occurred in every major river system within this clade beginning as early as the turn of the 20th century, indicating widespread distribution but little information on abundance (Hayes et al. 2016). By the early 1970s, declines in Foothill Yellow-legged Frog populations from this area were already apparent; Moyle (1973) found them at 30 of 95 sites surveyed in 1970. Notably bullfrogs inhabited the other 65 sites formerly occupied by Foothill Yellow-legged Frogs, and they co-occurred at only 3 sites (Ibid.). In 1992, Drost and Fellers (1996) revisited the sites around Yosemite National Park (Tuolumne and Mariposa counties) that Grinnell and Storer (1924) surveyed in 1915 and 1919. Foothill Yellow-legged Frogs had disappeared from all seven historically occupied sites and were not found at any new sites surveyed surrounding the park (Ibid.). Resurveys of previously occupied sites on the Stanislaus (Tuolumne County), Sierra (Fresno County), and Sequoia (Tulare County) National Forests were also undertaken (Lind et al. 2003b). Foothill Yellow-legged Frogs were absent from the sites in Sierra and Sequoia National Forests, six at each forest; however, a new population was discovered in the Sierra and two in the Sequoia forests (Ibid.). These populations remain extant but are small and isolated (CNDDB 2019). Two of the six sites on the Stanislaus were still occupied, and 19 new populations were found with evidence of breeding at seven of them (Lind et al. 2003b). Twenty of the 24 populations extant at the time inhabited unregulated waterways (Ibid.). Most of the CNDDB (2019) records of Foothill Yellow-legged Frogs on the Stanislaus are at least a decade old and are represented by low numbers.

Commented [RAP9]: May want to clarify this a bit…sites or frogs? I'd split into a separate sentence specifying that frogs were absent from 6 sites in each forest…can't hurt to be explicit.

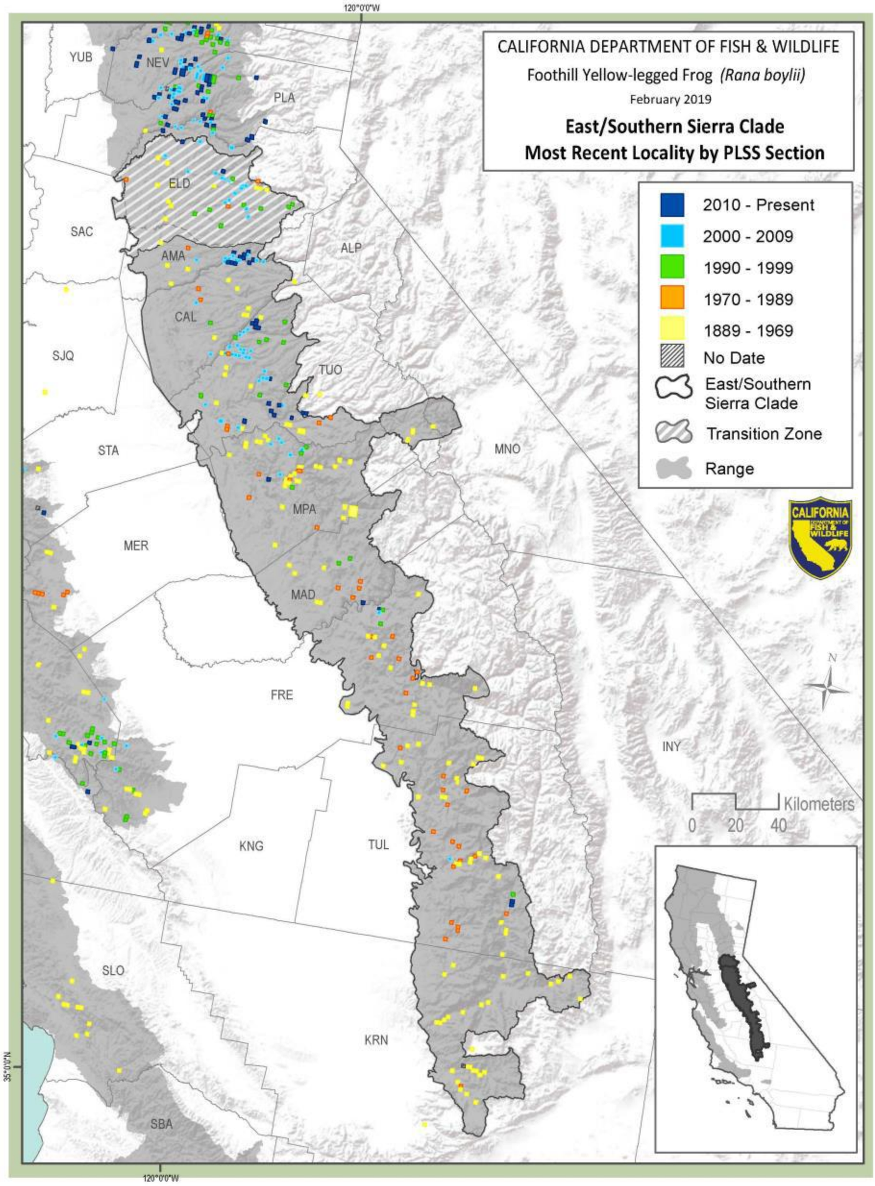

Figure 14. Close-up of East/Southern Sierra clade observations from 1889-2019 (ARSSC, BIOS, CNDDB)

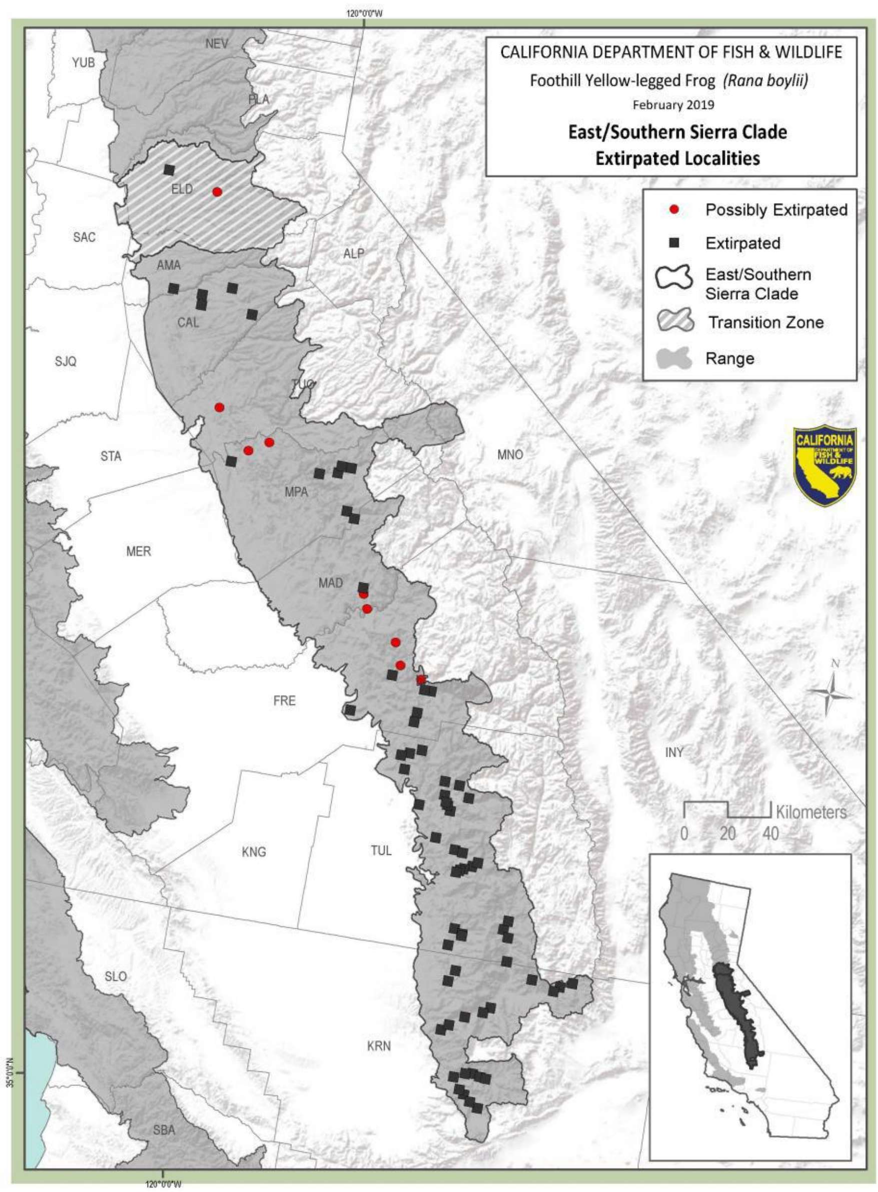

Figure 15. Possibly extirpated and extirpated East/Southern Sierra Foothill Yellow-legged Frog clade sites (CNDDB)

More recently, surveys for Foothill Yellow-legged Frogs were conducted along the South Fork American River as part of the El Dorado Hydroelectric Project's FERC license amphibian monitoring requirements (GANDA 2017). Between 2002 and 2016 counts of different life stages varied significantly by year but the trend for every life stage was a decline over that period (Ibid.). There appears to be a small population persisting along the North Fork Mokelumne River (Amador and Calaveras counties), but it was only productive during the 2012-2014 drought years (Ibid.). Small numbers have also been observed recently in several locations on private timberlands in Tuolumne County (CNDDB 2019).

FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE

"The fortunes of the boylii *population fluctuate with those of the stream"* - Tracy I. Storer, 1925

Several past and ongoing activities have changed the watersheds upon which Foothill Yellow-legged Frogs depend, and many interact with each other exacerbating their adverse impacts. With such an expansive range in California, the degree and severity of these impacts on the species often vary by location. To the extent feasible based on the best scientific information available, those differences are discussed below.

Dams, Diversions, and Water Operations

Foothill Yellow-legged Frogs evolved in a Mediterranean climate with predictable cool, wet winters and hot, dry summers, with their life cycle is adapted to these conditions. In California and other areas with a Mediterranean climate, human demands for water are at the highest when runoff and precipitation are lowest, and annual water supply varies significantly but always follows the general pattern of peak discharge declining to baseflow in the late spring or summer (Grantham et al. 2010). The Foothill Yellow-legged Frog's life cycle depends on this ~~discharge~~ flow pattern and the specific habitat conditions it produces (see the Breeding and Rearing Habitat section). Dams are ubiquitous, but not evenly distributed, in California. Figure 16 depicts the locations of dams under the jurisdiction of the Army Corps of Engineers (ACOE) and the California Department of Water Resources (DWR). Figure 17 depicts the number of surface diversions per PLSS section within the Foothill Yellow-legged Frog's range (eWRIMS 2019).

Dam operations frequently change the amount, ~~and~~ timing, and frequency of water availability; its temperature, depth, and velocity; and its sediment transport and channel morphology altering functions, which can result in dramatic consequences on the Foothill Yellow-legged Frog's ability to survive and successfully reproduce. Several studies comparing Foothill Yellow-legged Frog populations in regulated and unregulated reaches within the same watershed investigate potential dam-effects. These studies demonstrated that dams and their operations can result in several factors that contribute to population declines and possible extirpation. These factors include confusing breeding cues, scouring and stranding of egg masses and tadpoles, reduced quality and quantity of breeding and rearing habitat, reduced tadpole growth rate, barriers to gene flow, and establishment and spread of non-native species (Hayes et al. 2016). In addition, as previously discussed in the Population Structure and Genetic Diversity section, subpopulations of Foothill Yellow-legged Frogs on regulated rivers are more genetically isolated, and the

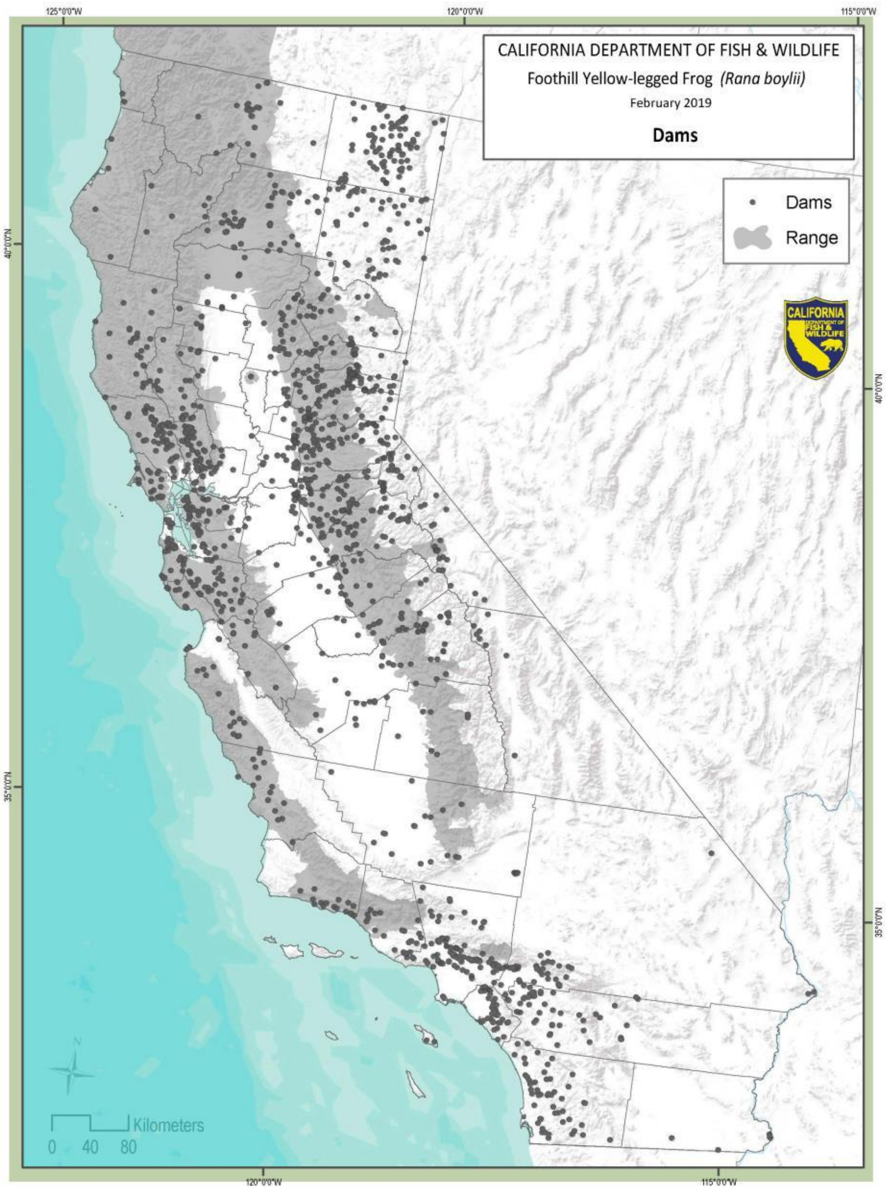

Figure 16. Locations of ACOE and DWR jurisdictional dams (DWR, FRS)

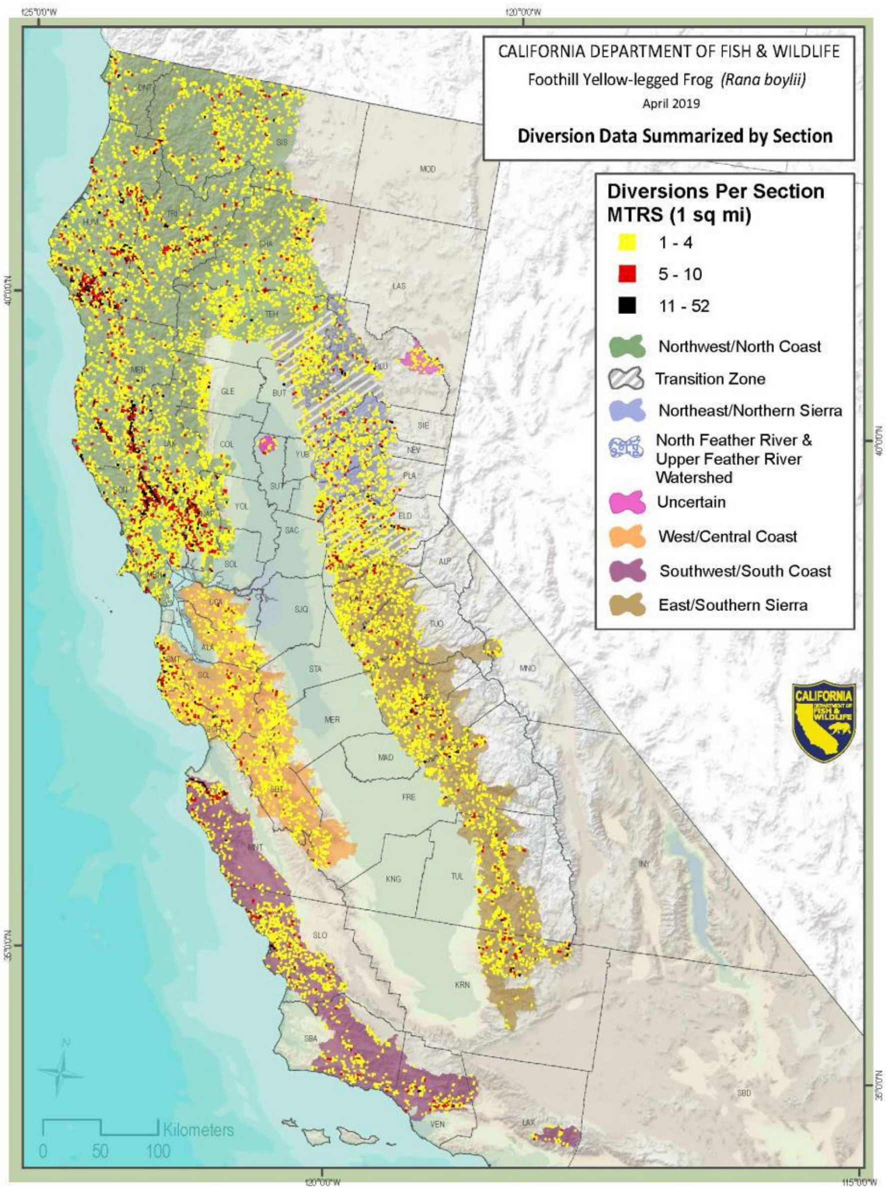

Figure 17. Number of surface water diversions per Public Lands Survey System section within the Foothill Yellow-legged Frog's range in California (eWRIMs)

type of water operations (hydropeaking vs. bypass flows) significantly affects the degree of connectivity and associated gene flow loss among them (Peek 2010~~1~~, 2018). Figure 18 depicts the locations of hydroelectric power plants.

As discussed in the Seasonal Activity and Movements section, cues for Foothill Yellow-legged Frogs to start breeding ~~appear~~ include~~to involve~~ water temperature and velocity, two features altered by dams. Dam operations typically result in reduced flows that are more stable over the course of a year than unimpaired conditions, and dam managers are frequently required to maintain thermally appropriate water temperatures and flows for cold-water-adapted salmonids (USFWS and Hoopa Valley Tribe 1999, Wheeler et al. 2014). For example, late-spring and summer water temperatures on the mainstem Trinity River below Lewiston Dam have been reported to be up to 10°C (20°F) cooler than average pre-dam temperatures, while average winter temperatures are slightly warmer (USFWS and Hoopa Valley Tribe 1999). As a result, Foothill Yellow-legged Frogs breed later on the mainstem Trinity River compared to six nearby tributaries, and some mainstem reaches may never attain the minimum required temperature for breeding (Wheeler et al. 2014, Snover and Adams 2016). In addition, annual discharges past Lewiston Dam have been 10-30% of pre-dam flows and do not mimic the natural hydrograph (Lind et al. 1996).

Aseasonal discharges from dams occur for several reasons including increased flow in late-spring and early summer to facilitate outmigration of salmonids, channel maintenance pulse flows, short-duration releases for recreational whitewater boating, rapid reductions after a spill (uncontrolled flows released down a spillway when reservoir capacity is exceeded) to retain water for power generation or water supply later in the year, peaking flows for hydroelectric power generation, and sustained releases to maintain the seismic integrity of the dam (Lind et al. 1996, Jackman et al. 2004, Kupferberg et al. 2011b, Kupferberg et al. 2012, Snover and Adams 2016). The results of a Foothill Yellow-legged Frog population viability analysis (PVA) suggest that the likelihood a population will persist is very sensitive to early life stage mortality; the 30-year probability of extinction increases significantly with high levels of egg or tadpole scouring or stranding (Kupferberg et al. 2009c). For instance, in 1991 and 1992, all egg masses laid before high flow releases to encourage outmigration of salmonids on the Trinity River were scoured away (Lind et al. 1996). According to the PVA, even a single annual pulse flow such as this or for recreational boating, can result in a three- to five-fold increase in the 30-year extinction risk based on amount of tadpole mortality experienced (Kupferberg et al. 2009c). Management after natural spills can also lead to substantial mortality. For example, in 2006, Foothill Yellow-legged Frogs on the North Fork Feather River bred during a prolonged spill, and the rapid recession below Cresta Dam that followed stranded and desiccated all the eggs laid (Kupferberg et al. 2009b). Rapid flows can also increase predation risk if tadpoles are forced to seek shelter under rocks where crayfish and other invertebrate predators are more common or if they are displaced into the water column where their risk of predation by fish is greater (Ibid.).

Commented [RAP10]: I think while this is true, it's also true that dams also artificially elevate flows over the course of the year (impaired summer baseflows are often much higher than natural flows), and they also can have much more aseasonal variability (i.e., hydropeaking). So here I'd rephrase/restructure this to focus more on the fact that flow regulation impairs natural patterns of flow variability and predictability/seasonality. You could mention the examples above or keep it broad…but I could see the "typically result in reduced flows that are more stable" comment as something that could be misconstrued or misused if taken by itself.

Commented [RAP11]: Many examples of baseflows as much higher than pre-dam, especially in the Sierras (NF Feather, MF American, Tuolumne, NF Mokelumne, SF American, etc.)

The overall reduction of flows and frequency of large winter floods below dams can produce extensive changes to Foothill Yellow-legged Frog habitat quality. They reduce the formation of river bars that are regularly used as breeding habitat, and they create deeper and steeper channels with less complexity and fewer warm, calm, shallow edgewater habitats for tadpole rearing (Lind et al. 1996, Wheeler and Welsh 2008, Kupferberg et al. 2011b, Wheeler et al. 2014). For example, 26 years after construction of

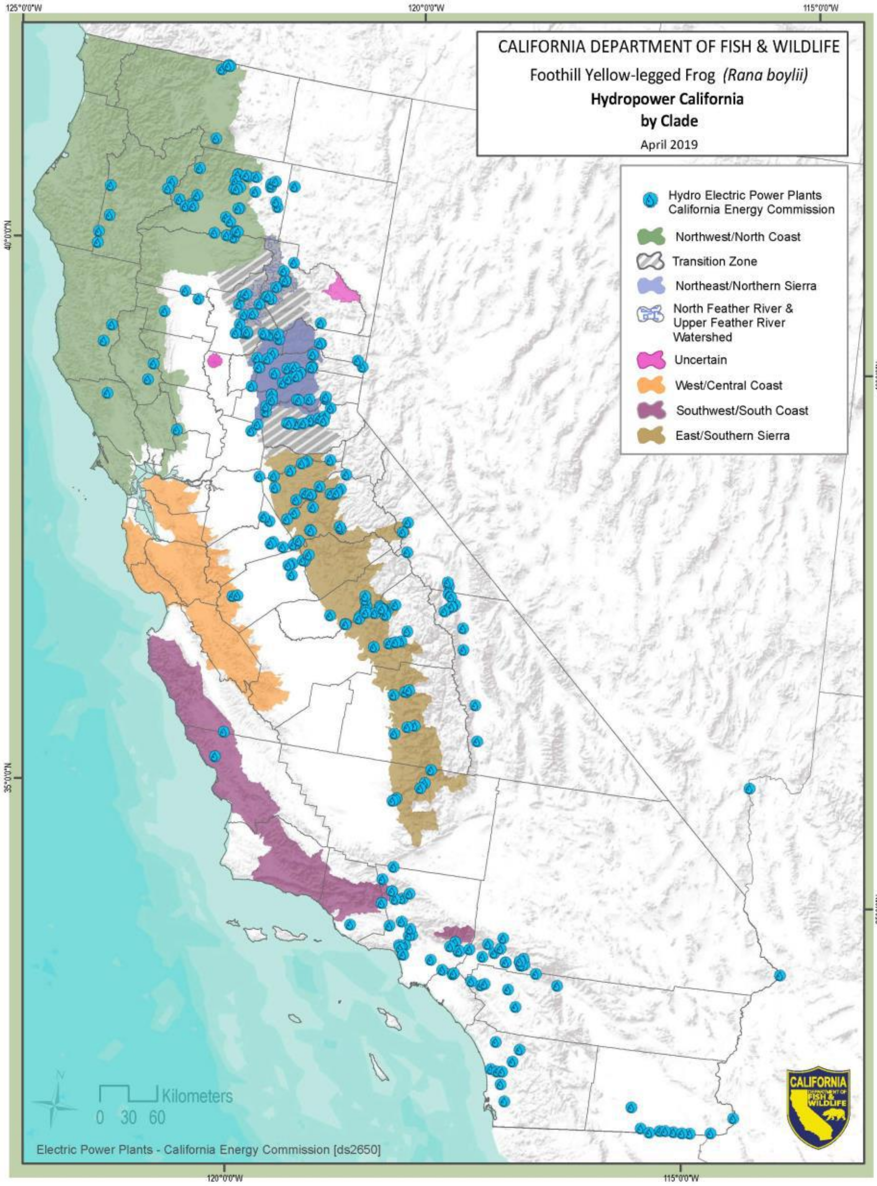

Figure 18. Locations of hydroelectric power generating dams (BIOS)

the Lewiston Dam on the Trinity River, habitat changes in a 63 km (39 mi) stretch from the dam downstream were evaluated (Lind et al. 1996). Riparian vegetation went from covering 30% of the riparian area pre-dam to 95% (Ibid.). Additionally, river bars made up 70% of the pre-dam riparian area compared to 4% post-dam, amounting to a 94% decrease in available Foothill Yellow-legged Frog breeding habitat (Ibid.).

Several features of riverine habitat below dams can decrease tadpole growth rate and other measures of fitness. As ectotherms, Foothill Yellow-legged Frogs require temperatures that support their metabolism, food conversion efficiency, growth, and development, and these temperatures may not be reached until late in the season, or not at all, when the water released is colder than their lower thermal limit (Kupferberg et al. 2011a, Catenazzi and Kupferberg 2013, Wheeler et al. 2014). Colder temperatures and higher flows reduce time spent feeding and efficiency at food assimilation, resulting in slower growth and development (Kupferberg et al. 2011a,b; Catenazzi and Kupferberg 2018). Large bed-scouring winter floods promote greater *Cladophora glomerate* blooms, the filamentous green alga that dominates primary producer biomass during the tadpole rearing season (Power et al. 2008, Kupferberg et al. 2011a). The period of most rapid tadpole growth often coincides with blooms of highly nutritious and more easily assimilated epiphytic diatoms, so reduced flows can have food-web impacts on tadpole growth and survival (Power et al. 2008, Kupferberg et al. 2011a, Catenazzi and Kupferberg 2018). In addition, colder temperatures and fluctuating summer flows, such as those released for hydroelectric power generation, can reduce the amount of algae available for grazing and can change the algal assemblage to one dominated by mucilaginous stalked diatoms like *Didymosphenia geminate* that have low nutritional value (Spring Rivers Ecological Sciences 2003, Kupferberg et al 2011a, Furey et al. 2014). Altered temperatures, flows, and food quality can contribute to slower growth and development, longer time to metamorphosis, smaller size at metamorphosis, and reduced body condition, which adversely impact fitness (Kupferberg et al. 2011b, Catenazzi and Kupferberg 2018).

As discussed in more detail in the Population Structure and Genetic Diversity section, both are strongly affected by river regulation (Peek 2010~~1~~, 2018; Stillwater Sciences 2012). Foothill Yellow-legged Frogs primarily use watercourses as movement corridors, so the reservoirs created behind dams are often uninhabitable and represent barriers to gene flow (Bourque 2008; Peek 2010~~1~~, 2018). This decreased connectivity can lead to loss of genetic diversity, ~~inducing~~ which can reduce a species' ability to adapt to changing conditions (Palstra and Ruzzante 2008).

Decreased winter discharge below dams facilitates establishment and expansion of invasive bullfrogs, whose tadpoles require overwintering and are not well-adapted to flooding events (Lind et al. 1996, Doubledee et al. 2003). Where they occur, bullfrogs tend to dominate areas more altered by dam operations than less impaired areas that support a higher proportion of native species (Moyle 1973, Fuller et al. 2011). In addition to downstream effects, ~~the~~ reservoirs ~~created~~ behind dams directly inundate and eliminate ~~destroy~~ lotic (flowing) Foothill Yellow-legged Frog habitat, typically do not retain natural riparian communities due to fluctuating water levels, are often managed for human activities not compatible with the species' needs, and act as a source of introduced species upstream and downstream (Brode and Bury 1984, PG&E 2018). Moyle and Randall (1998) identified characteristics of sites with low native biodiversity in the Sierra Nevada foothills; they were often drainages that had been

Commented [RAP12]: Could cite the 2013 CEC report that Sarah Yarnell & others did on spring recession characterization in reg/unreg rivers, we have figures/data showing algal abundance/biomass in the MF American and SF Yuba was extremely high and was driven by didymo growth. (https://www.energy.ca.gov/2014publications/CEC-500-2014-030/CEC-500-2014-030.pdf)
Yarnell, S. M., Peek, R. A., Rheinheimer, D. E., Lind, A. J., & Viers, J. H. (2013). *Management of the Spring Snowmelt Recession: An Integrated Analysis of Empirical, Hydrodynamic, and Hydropower Modeling Applications* (No. CEC-500-2014-030; Vol. CEC-500–2014–2030). California Energy Commission, PIER.

dammed and diverted in lower- to middle-elevations and dominated by introduced fishes and bullfrogs. Even small-scale operations can have significant effects. Some farming operations divert water during periods of high flows and store it in small impoundments for use during low flow-high ~~need~~ demand times; these ponds can serve as sources for introduced species like bullfrogs to spread into areas where the habitat would otherwise be unsuitable (Kupferberg 1996b).

The mechanisms described above result in the widespread pattern of greater Foothill Yellow-legged Frog density in unregulated rivers and in reaches far enough downstream of a dam to experience minimal effects from it (Lind et al. 1996, Kupferberg 1996a, Bobzien and DiDonato 2007, Peek 2010~~1~~). Abundance of Foothill Yellow-legged Frogs in unregulated rivers averages five times greater than population abundance downstream of large dams (Kupferberg et al. 2012). Figure 19 depicts a comprehensive collection of egg mass density data where at least four years of surveys have been undertaken, showing much lower abundance in regulated (S. Kupferberg pers. comm. 2019). In California, Foothill Yellow-legged Frog presence is associated with an absence of dams or with only small dams far upstream (Lind 2005, Kupferberg et al. 2012). Hydroelectric power generation from Sierra Nevada rivers accounts for nearly half its statewide production and about 9% of all electrical power used in California (Dettinger et al. 2018). Every major stream below 600 m (1968 ft) in the Sierra Nevada has at least one large reservoir (≥ 0.12 km^3 [100,000 ac-ft]), and many have multiple medium and small ones (Hayes et al. 2016). Because of this, Catenazzi and Kupferberg (2017) posit that the dam-effect on Foothill Yellow-legged Frog populations is likely greater in the Sierra Nevada than the Coast Range because dams are more often constructed in a series along a river in the former and spaced close enough together such that suitable breeding temperatures may never occur in the intervening reaches.

Commented [RAP13]: In case I miss one, all these should be 2010, when I finished my MS. Not sure if the library date shows 2011, but the MS was signed, sealed and delivered in Aug 2010. ☺

Pathogens and Parasites

Perhaps the most widely recognized amphibian disease is chytridiomycosis, which is caused by the fungal pathogen *Batrachochytrium dendroabatidis* (Bd). Implicated in the decline of over 500 amphibian species, including 90 presumed extinctions, it represents the greatest recorded loss of biodiversity attributable to a disease (Scheele et al. 2019). The global trade in American Bullfrogs (primarily for food) is connected to the disease's spread because the species can persist with low-level Bd infections without developing chytridiomycosis (Yap et al. 2018). Previous studies suggested Foothill Yellow-legged Frogs may not be susceptible to Bd-associated mass mortality; skin peptides strongly inhibited growth of the fungus in the lab, and the only detectable difference between Bd+ and Bd- juvenile Foothill Yellow-legged Frogs was slower growth (Davidson et al. 2007). At Pinnacles National Park in 2006, 18% of post-metamorphic Foothill Yellow-legged Frogs tested positive for Bd; all were asymptomatic and at least one Bd+ Foothill Yellow-legged Frog subsequently tested negative, demonstrating an ability to shed the fungus (Lowe 2009). However, recent studies have found historical evidence of Bd contributing to the extirpation of Foothill Yellow-legged Frogs in southern California, an acute die-off in 2013 in the Alameda Creek watershed, and another in 2018 in Coyote Creek (Adams et al. 2017a,b; Kupferberg and Catenazzi 2019). Evaluation of museum specimens indicates lower Bd prevalence (proportion of individuals infected) in Foothill Yellow-legged Frogs than most other co-occurring amphibians in southern California in the first part of the 20th century, but it spiked in the 1970s just prior to the last observation of an individual in 1977 (Adams et al. 2017b). Two museum specimens collected in 1966,

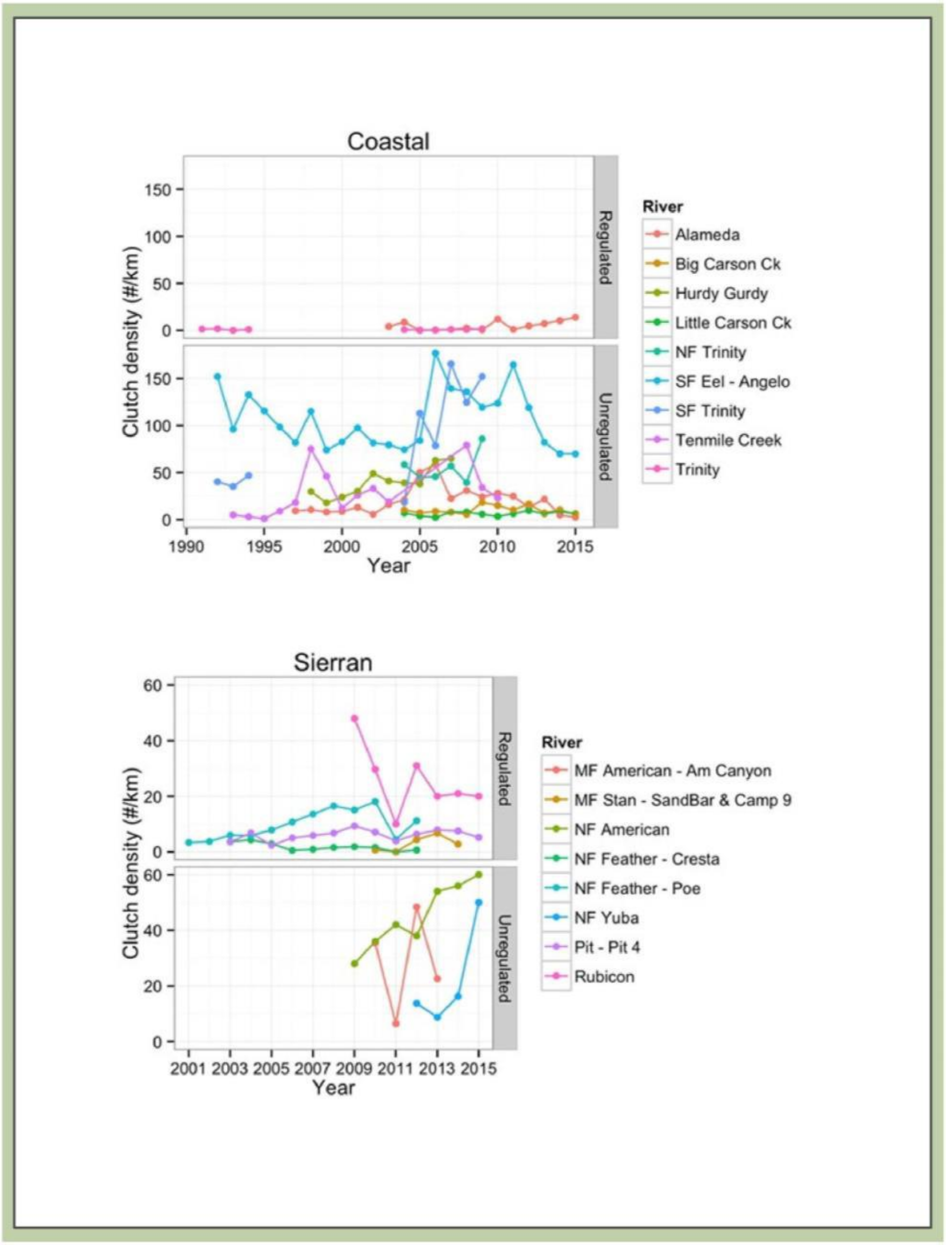

Figure 19. Foothill Yellow-legged Frog Egg mass density estimates along the coast from 1990-2015 and the Sierra Nevada from 2001-2015 from multiple studies compiled by R. Peek and S. Kupferberg (2019)

Commented [RAP14]: See comment in figure list at top, I'd cite this as Peek and Kupferberg 2016 (this is the figure we made for the poster)

one from Santa Cruz County and the other from Alameda County, provide the earliest evidence of Bd in Foothill Yellow-legged Frogs in central California (Padgett-Flohr and Hopkins 2009). In contrast to the southern California results, Foothill Yellow-legged Frogs possessed the highest Bd prevalence among all amphibians tested in coastal Humboldt County in 2013 and 2014; however, zoospore (the aquatic dispersal agent) loads were well below the presumed lethal density threshold (Ecoclub Amphibian Group et al. 2016).

In addition to bullfrogs, the native Pacific Treefrog (*Pseudacris regilla*) seems immune to the lethal effects of chytridiomycosis, and owing to its broad ecological tolerances, more terrestrial lifestyle, and relatively large home range size and dispersal ability, the species is ubiquitous across California (Padgett-Flohr and Hopkins 2009). In a laboratory experiment, Bd-infected Pacific Treefrogs shed an average of 68 zoospores per minute, making them the prime candidate for spreading and maintaining Bd in areas where bullfrogs do not occur (Padgett-Flohr and Hopkins 2009, Reeder et al. 2012). In the wild, Pacific Treefrog populations persisted at 100% of sites in the Sierra Nevada (above 1500 m [4920 ft]) where a sympatric ranid species had been extirpated from 72% of its formerly occupied sites due to a Bd outbreak (Reeder et al. 2012). This is consistent with the results of a model that incorporated Bd habitat suitability, host availability, and invasion history in North America, which concluded west coast mountain ranges were at the greatest risk from the disease (Yap et al. 2018).

Several other pathogens and parasites have been encountered with Foothill Yellow-legged Frogs, but none have been ascribed to large-scale mortality events. Another fungus, a water mold (*Saprolegnia* sp.) carried by fish, is an important factor in amphibian embryo mortality in the Pacific Northwest (Blaustein et al. 1994, Kiesecker and Blaustein 1997). Fungal infections of Foothill Yellow-legged Frog egg masses, potentially from *Saprolegnia*, have been observed in the mainstem Trinity River (Ashton et al. 1997). *Saprolegnia* infection is more likely to occur in ponds and lakes, particularly if stocked by hatchery-raised fish into previously fishless areas and when frogs use communal oviposition sites, so it likely does not represent a major source of mortality in Foothill Yellow-legged Frogs (Blaustein et al. 1994, Kiesecker and Blaustein 1997). However, they may be more susceptible to *Saprolegnia* infection when exposed to other environmental stressors that compromise their immune defenses (Blaustein et al. 1994, Kiesecker and Blaustein 1997).

The trematode parasite *Ribeiroia ondatrae* is responsible for limb malformations in ranids (Stopper et al. 2002). *Ribeiroia ondatrae* was detected on a single Foothill Yellow-legged Frog during a study on malformations, but its morphology was normal (Kupferberg et al. 2009a). The results of the study instead linked malformations in Foothill Yellow-legged Frog tadpoles and young-of-year to the Anchor Worm (*Lernae cyprinacea*), a parasitic copepod from Eurasia (Ibid.). Prevalence of malformations was low, under 4% of the population in both years of study, but there was a pattern of infected individuals metamorphosing at a smaller size, which as previously mentioned can have implications on fitness (Ibid.). Three other species of helminths (parasitic worms) were encountered during the study (*Echinostoma* sp., *Manodistomum* sp., and *Gyrodactylus* sp.); their relative impact on their hosts is unknown, but at least one Foothill Yellow-legged Frog had 700 echinstome cysts in its kidney (Ibid.). Bursey et al. (2010) discovered 13 species of helminths in and on Foothill Yellow-legged Frogs from

Humboldt County. Most are common in anurans, and some are generalists with multiple possible hosts, but studies on their impact on Foothill Yellow-legged Frogs are lacking (Ibid.).

Introduced Species

Species not native to an area, but introduced, can alter food webs and ecosystem processes through predation, competition, hybridization, disease transmission, and habitat modification. Native species lack evolutionary history with introduced species, and early life stages of native anurans are particularly susceptible to predation by aquatic non-native species (Kats and Ferrer 2003). Because introduced species often establish in highly modified habitats, it can be difficult to differentiate between impacts from habitat degradation and the introduced species (Fisher and Shaffer 1996). However, native amphibians have been frequently found successfully reproducing in heavily altered habitats when introduced species were absent, suggesting introduced species themselves can impose an appreciable adverse effect (Ibid.). Numerous introduced species have been documented to adversely impact Foothill Yellow-legged Frogs or are suspected of doing so.

American Bullfrogs were introduced to California from the eastern U.S. around the turn of the 20th century, likely in response to overharvest of native ranids by the frog-leg industry that accompanied the Gold Rush (Jennings and Hayes 1985). Nearly 50 years ago, Moyle (1973) reported that distributions of Foothill Yellow-legged Frogs and bullfrogs in the Sierra Nevada foothills were nearly mutually exclusive. He speculated that bullfrog predation and competition may be causal factors in their disparate distributions in addition to the habitat degradation from dams and diversions that facilitated the bullfrog invasion in the first place. In a study along the South Fork Eel River and one of its tributaries, Foothill Yellow-legged Frog abundance was nearly an order of magnitude lower in reaches were bullfrogs were well established (Kupferberg 1997a). At a site in Napa Valley, after bullfrogs were eradicated, Foothill Yellow-legged Frogs, among other native species, recolonized the area (J. Alvarez pers. comm. 2018). In a mesocosm experiment, Foothill Yellow-legged Frog survival in control enclosures measured half that of enclosures containing bullfrog and Foothill Yellow-legged Frog tadpoles, and they weighed approximately one-quarter ~~lighter~~ less at metamorphosis (Kupferberg 1997a). The mechanism for these declines appeared to be the reduction of ~~high quality~~high-quality algae by bullfrog tadpole grazing, as opposed to any behavioral or chemical interference (Ibid.). Adult bullfrogs, which can get very large (9.0-15.2 cm [3.5-6.0 in]), also directly consume Foothill Yellow-legged Frogs, including adults (Moyle 1973, Crayon 1998, Powell et al. 2016). Silver (2017) noted that she never heard Foothill Yellow-legged Frogs calling in areas with bullfrogs, which has implications for breeding success; she speculated the lack of vocalizations may have been a predator avoidance strategy.

As discussed briefly in the Pathogens and Parasites section, American Bullfrogs act as reservoirs and vectors of the lethal chytrid fungus. In museum specimens from both southern and central California, Bd was detected in bullfrogs before it was detected in Foothill Yellow-legged Frogs in the same area (Padgett-Flohr and Hopkins 2009, Adams et al. 2017b). During a die-off from chytridiomycosis that commenced in 2013, Bd prevalence and load in Foothill Yellow-legged Frogs was positively predicted by bullfrog presence (Adams et al. 2017a). A similar die-off in 2018 from a nearby county appears to be related to transmission by bullfrogs as well (Kupferberg and Catenazzi 2019). In addition, male Foothill

Yellow-legged Frogs have been observed amplexing female bullfrogs, which may not only constitute wasted reproductive effort but could serve to increase their likelihood of contracting Bd (Lind et al. 2003a). In fact, adult males were more likely to be infected with Bd than females or juveniles during the recent die-off in Alameda Creek (Adams et al. 2017a). African Clawed Frogs (*Xenopus laevis*) have also been implicated in the spread of Bd in California because like bullfrogs, they are asymptomatic carriers (Padgett-Flohr and Hopkins 2009). However, African Clawed-Frog distribution only minimally overlaps with the Foothill Yellow-legged Frog's range unlike the widespread bullfrog (Stebbins and McGuinness 2012).

Hayes and Jennings (1986) observed a negative association between the abundance of introduced fish and Foothill Yellow-legged Frogs. Rainbow trout (*Onchorynchus mykiss*) and green sunfish (*Lepomis cyanellus*) are suspected of destroying egg masses (Van Wagner 1996). Bluegill sunfishes (*L. macrochirus*) are likely predators; in captivity when offered eggs and tadpoles of two ranid species, they consumed both life stages but a significantly greater number of tadpoles (Werschkul and Christensen 1977). Common hatchery-stocked fish like brook (*Salvelinus fontinalis*) and rainbow trout commonly carry of *Saprolegnia* (Blaustein et al. 1994). In addition, presence of non-native fish can facilitate bullfrog invasions by reducing the density of macroinvertebrates that prey on their tadpoles (Adams et al. 2003). Foothill Yellow-legged Frog tadpoles raised from eggs from sites with and without smallmouth bass (*Micropterus dolomieu*) did not differ in their responses to exposure to the non-native, predatory bass and a native, non-predatory fish (Paoletti et al. 2011). This result suggests that Foothill Yellow-legged Frogs have not yet evolved a recognition of bass as a threat, which makes them more vulnerable to predation (Ibid.).

Introduced into several areas within the Coast Range and Sierra Nevada, signal crayfish have been recorded preying on Foothill Yellow-legged Frog egg masses and are suspected of preying on their tadpoles based on observations of tail injuries that looked like scissor snips (Riegel 1959, Wiseman et al. 2005). The introduced red swamp crayfish (*Procambarus clarkii*) likely also preys on Foothill Yellow-legged Frogs. Because Foothill Yellow-legged Frogs evolved with native crayfish in northern California, individuals from those areas may more effectively avoid crayfish predation than in other parts of the state where they are not native (Riegel 1959, USFWS 1998, Kats and Ferrer 2003). The Foothill Yellow-legged Frog's naivety to crayfish was demonstrated in a study that showed they did not change behavior when exposed to signal crayfish chemical cues, but once the crayfish was released and consuming Foothill Yellow-legged Frog tadpoles, the survivors, likely reacting to chemical cues from dead tadpoles, did respond (Kerby and Sih 2015).

Sedimentation

Several anthropogenic activities, some of which are described in greater detail below, can artificially increase sedimentation into waterways occupied by Foothill Yellow-legged Frogs and adversely impact biodiversity (Moyle and Randall 1998). These activities include but are not limited to mining, agriculture, overgrazing, timber harvest, and poorly constructed roads (Ibid.). Increased fine sediments can substantially degrade Foothill Yellow-legged Frog habitat quality. Heightened turbidity decreases light penetration that phytoplankton and other aquatic plants require for photosynthesis (Cordone and Kelley

1961). When silt particles fall out of the water column, they can destroy algae by covering the bottom of the stream (Ibid.). Algae are not only important for Foothill Yellow-legged Frog tadpoles as forage but also oxygen production (Ibid.). Sedimentation may impede attachment of egg masses to substrate (Ashton et al. 1997). The effect of silt accumulation on embryonic development is unknown, but it does make them less visible, which could decrease predation risk (Fellers 2005). Fine sediments can fill interstitial spaces between rocks that tadpoles use for shelter from high velocity flows and cover from predators and that serve as sources for aquatic invertebrate prey for post-metamorphic Foothill Yellow-legged Frogs (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b).

Mining

Current mining practices, as well as legacy effects from historical mining operations, may adversely impact Foothill Yellow-legged Frogs through contaminants, direct mortality, habitat destruction and degradation, and behavioral disruption. While mercury in streams can result from atmospheric deposition, storm-induced runoff of naturally occurring mercury, agricultural runoff, and geothermal springs, runoff from historical mine sites mobilizes a significant amount of mercury (Foe and Croyle 1998, Alpers et al. 2005, Hothem et al. 2010). Beginning in the mid-1800s, extensive mining occurred in the Coast Range to supply mercury for gold mining in the Sierra Nevada, causing widespread contamination of both mountain ranges and the rivers in the Central Valley (Foe and Croyle 1998). Studies on Foothill Yellow-legged Frog tissues collected from the Cache Creek (Coast Ranges) and Greenhorn Creek (Sierra Nevada) watersheds revealed mercury bioaccumulation concentrations as high as 1.7 and 0.3 µg/g (ppm), respectively (Alpers et al. 2005, Hothem et al. 2010). For context, the U.S. Environmental Protection Agency's mercury criterion for issuance of health advisories for fish consumption is 0.3 µg/g; concentrations exceeded this threshold in Foothill Yellow-legged Frog tissues at 62% of sampling sites in the Cache Creek watershed (Hothem et al. 2010). Bioaccumulation of this powerful neurotoxin can cause deleterious impacts on amphibians including inhibited growth, decreased survival to metamorphosis, increased malformations, impaired reproduction, and other sublethal effects (Zillioux et al. 1993, Unrine et al. 2004). In a study measuring Sierra Nevada watershed health, Moyle and Randall (1998) reportedly found very low biodiversity in streams that were heavily polluted by acidic water leaching from historical mines. Acidic drainage measured as low as 3.4 pH from some mined areas in the northern Sierra Nevada (Alpers et al. 2005).

Widespread suction dredging for gold occurred in the Foothill Yellow-legged Frog's California range until enactment of a moratorium on issuing permits in 2009 (Hayes et al. 2016). Suction dredging vacuums up the contents of the streambed, passes them through a sluice box to separate the gold, and then deposits the tailings on the other side of the box (Harvey and Lisle 1998). While most habitat disturbance is localized and minor, it can be especially detrimental if it degrades or destroys breeding and rearing habitat through direct disturbance or sedimentation (Ibid.). In addition, this activity can lead to direct mortality of early life stages through entrainment, and those eggs and tadpoles that do survive passing through the suction dredge may experience greater mortality due to subsequent unfavorable physiochemical conditions and possible increased predation risk (Ibid.). Suction dredging can also reduce the availability of invertebrate prey, although this impact is typically short-lived (Ibid.). Suction dredging alters stream morphology, and relict tailing ponds can serve as breeding habitat for bullfrogs in areas

that would not normally support them (Fuller et al. 2011). However, in some areas these mining holes have reportedly benefited Foothill Yellow-legged Frogs by creating cool persistent pools that adult females appeared to prefer at one Sierra Nevada site (Van Wagner 1996). Senate Bill 637 (2015) directs the Department to work with the State Water Resources Control Board (SWRCB) to develop a statewide water quality permit that would authorize the use of vacuum or suction dredge equipment in California under conditions set forth by the two agencies. SWRCB staff, in coordination with Department staff, are in the process of collecting additional information to inform the next steps that will be taken by the SWRCB (SWRCB 2019).

Instream aggregate (gravel) mining continues today and can have similar impacts to suction dredge mining by removing, processing, and relocating stream substrates (Olson and Davis 2009). This type of mining typically removes bars used as Foothill Yellow-legged Frog breeding habitat and reduces habitat heterogeneity by creating flat wide channels (Kupferberg 1996a). Typically when listed salmonids are present, mining must be conducted above the wetted edge, but this practice can create perennial off-channel bullfrog breeding ponds (M. van Hattem pers. comm. 2018).

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Agriculture

Direct loss of Foothill Yellow-legged Frog habitat from wildland conversion to agriculture is rare because the typically rocky riparian areas they inhabit are usually not conducive to farming, but removal of riparian vegetation directly adjacent to streams for agriculture is more common and widespread. The U.S. Department of Agriculture classifies 3.9 million ha (9.6 million ac) in California as cropland, which amounts to less than 10% of the state's land area, and 70% of this occurs in the Central Valley between Redding and Bakersfield (Martin et al. 2018). In addition, several indirect impacts can adversely affect Foothill Yellow-legged Frogs at substantial distances from agricultural operations, such as effects from runoff (sediments and agrochemicals), drift and deposition of airborne pollutants, water diversions, and creation of novel habitats like impoundments that facilitate spread of detrimental non-native species. As sedimentation and introduced species impacts were previously discussed, this section instead focuses on the other possible adverse impacts.

Agrochemicals

Many species of amphibians, particularly ranids, have experienced declines throughout California, but the most dramatic declines have occurred in the Sierra Nevada east of the San Joaquin Valley where 60% of the total pesticide usage in the state was sprayed (Sparling et al. 2001). Agrochemicals applied to crops in the Central Valley can volatilize and travel in the atmosphere and deposit in higher elevations (LeNoir et al. 1999). Pesticide concentrations diminish as elevations increase in the lower foothills but change little from 533 to 1,920 m (1,750-6,300 ft), which coincides with the Foothill Yellow-legged Frog's elevational range (Ibid). Foothill Yellow-legged Frog absence at historically occupied sites in California significantly correlated with agricultural land use within 5 km (3 mi), and a positive relationship exists between Foothill Yellow-legged Frog declines and the amount of upwind agriculture, suggesting airborne agrochemicals may be a contributing factor (Figure 20; Davidson et al. 2002). Cholinesterase-inhibitors (most organophosphates and carbamates), which disrupt nerve impulse transmission, were

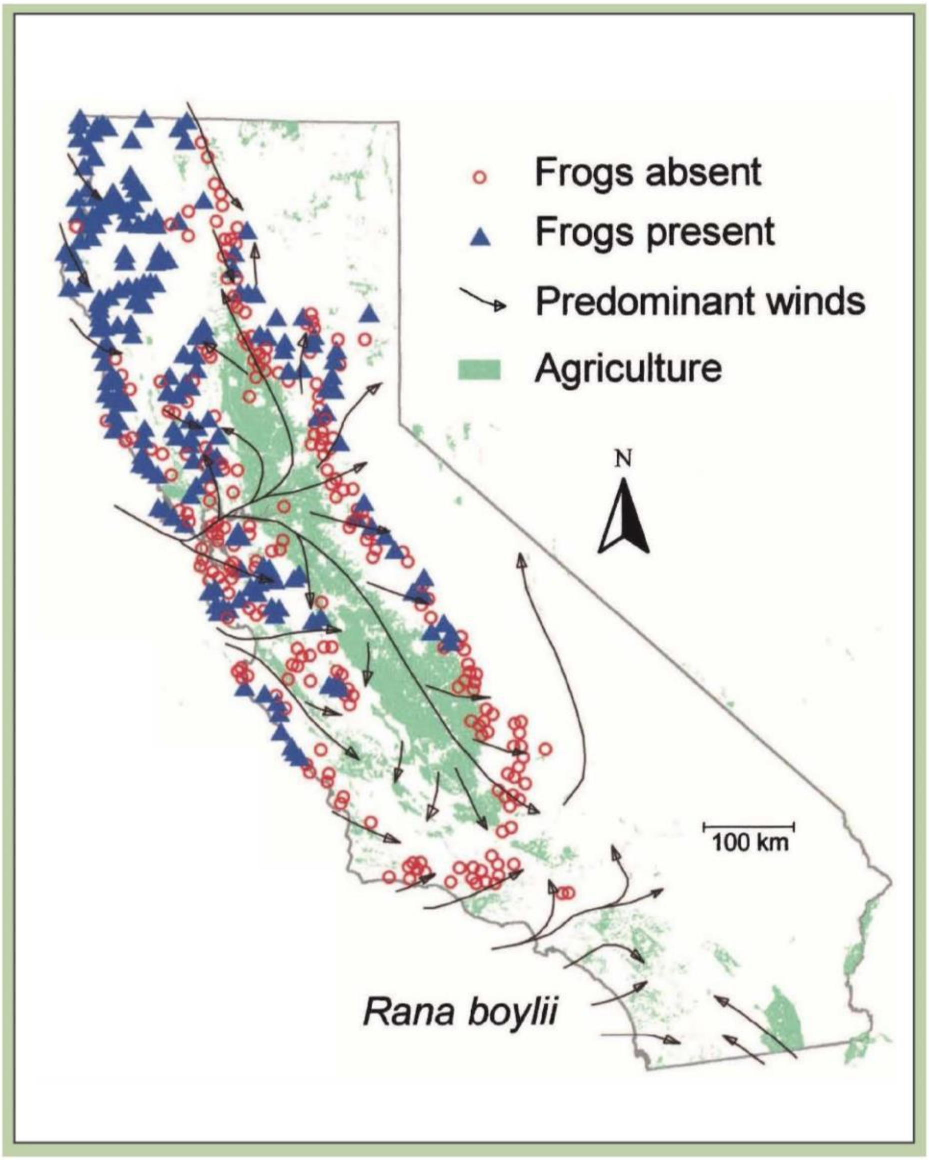

Figure 20. Relationship of Foothill Yellow-legged Frog occupancy to agriculture from Davidson et al. (2002)

more strongly associated with population declines than other pesticide types (Davidson 2004). Olson and Davis (2009) and Lind (2005) also reported a negative correlation between Foothill Yellow-legged Frog presence and proximity and quantity of nearby agriculture in Oregon and across the species' entire range, respectively.

Lethal and sublethal effects of agrochemicals on amphibians can take two general forms: direct toxicity and food-web effects. Sublethal doses of agrochemicals can interact with other environmental stressors to reduce fitness. Foothill Yellow-legged Frog tadpoles showed significantly greater vulnerability to the lethal and sublethal effects of carbaryl than Pacific Treefrogs (Kerby and Sih 2015). An inverse relationship exists between carbaryl concentration and Foothill Yellow-legged Frog activity, and their 72-h LC_{50} (concentration at which 50% die) measured one-fifth that of Pacific Treefrogs (Ibid.). Carbaryl slightly decreased Foothill Yellow-legged Frog development rate, but it significantly increased susceptibility to predation by signal crayfish despite nearly no mortality in the pesticide- and predator-only treatments (Ibid.). Sparling and Fellers (2009) also found Foothill Yellow-legged Frogs were significantly more sensitive to pesticides (chlorpyrifos and endosulfan in this study) than Pacific Treefrogs; their 96-hr LC_{50} was nearly five-times less than for treefrogs. Endosulfan was nearly 121 times more toxic to Foothill Yellow-legged Frogs than chlorpyrifos, and water samples from the Sierra Nevada have contained endosulfan concentrations within their lethal range and sometimes greater than the LC_{50} for the species (Ibid.). Sublethal effects included smaller body size, slower development rate, and increased time to metamorphosis (Ibid.). Sparling and Fellers (2007) determined the organophospates chlorpyrifos, malathion, and diazinon can harm Foothill Yellow-legged Frog populations, and their oxon derivatives (the resultant compounds once they begin breaking down in the body) were 10 to 100 times more toxic than their respective parental forms.

Extrapolating the results of studies on other ranids to Foothill Yellow-legged Frogs should be undertaken with caution; however, those studies can demonstrate additional potential adverse impacts of exposure to agrochemicals. Relyea (2005) discovered that Roundup®, a common herbicide, could cause rapid and widespread mortality in amphibian tadpoles via direct toxicity, and overspray at the manufacturer's recommended application concentrations would be highly lethal. Atrazine, another common herbicide, has been implicated in disrupting reproductive processes in male Northern Leopard Frogs (*Rana pipiens*) by slowing gonadal development, inducing hermaphroditism, and even oocyte (egg) growth (Hayes et al. 2003). However, recent research on sex reversal in wild populations of Green Frogs (*R. clamitans*) suggests it may be a relatively common natural process unrelated to environmental contaminants, requiring more research (Lambert et al. 2019). Malathion, a common organophosphate insecticide, that rapidly breaks down in the environment, applied at low concentrations caused a trophic cascade that resulted in reduced growth and survival of two species of ranid tadpoles (Relyea and Diecks 2008). Malathion caused a reduction in the amount of zooplankton, which resulted in a bloom of phytoplankton and an eventual decline in periphyton, an important food source for tadpoles (Ibid.). In contrast, Relyea (2005) found that some insecticides increased amphibian tadpole survival by reducing their invertebrate predators. Runoff from agricultural areas can contain fertilizers that input nutrients into streams and increase productivity, but they can also result in harmful algal blooms (Cordone and

Kelley 1961). In addition, exposure to pesticides can result in immunosuppression and reduce resistance to the parasites that cause limb malformations (Kiesecker 2002, Hayes et al. 2006).

Cannabis

An estimated 60-70% of the cannabis (*Cannabis indica* and *C. sativa*) used in the U.S. from legal and illegal sources is grown in California, and most comes from the Emerald Triangle, an area comprised of Humboldt, Mendocino, and Trinity counties (Ferguson 2019). Small-scale illegal cannabis farms have operated in this area since at least the 1960s but have expanded rapidly, particularly trespass grows on public land primarily by Mexican cartels, since the passage of the Compassionate Use Act in 1996 (Mallery 2010, Bauer et al. 2015). Like other forms of agriculture, it involves clearing the land, diverting water, and using herbicides and pesticides; however, in addition, many of these illicit operations use large quantities of fertilizers and highly toxic banned pesticides to kill anything that may threaten the crop, and they leave substantial amounts of non-biodegradable trash and human excrement (Mallery 2010, Thompson et al. 2014, Carah et al. 2015).

Measurements of environmental impacts of illegal cannabis grows have been hindered by the difficult and dangerous nature of accessing many of these sites; however, some analyses have been conducted, often using aerial images and geographic information systems (GIS). An evaluation of 54% of watersheds within and bordering Humboldt County revealed that while cannabis grow sites are generally small (< 0.5 ha [1.2 ac]) and comprised a tiny fraction of the study area (122 ha [301 ac]), they were widespread (present in 83% of watersheds) but unevenly distributed, indicating impacts are concentrated in certain watersheds (Butsic and Brenner 2016, Wang et al. 2017). The results also showed that 68% of grows were > 500 m (0.3 mi) from developed roads, 23% were located on slopes steeper than 30%, and 5% were within 100 m (328 ft) of critical habitat for threatened salmonids (Butsic and Brenner 2016). These characteristics suggest wildlands adjacent to cannabis cultivations are at heightened risk of habitat fragmentation, erosion, sedimentation, landslides, and impacts to waterways critical to imperiled species (Ibid.).

A separate analysis in the same general area estimated potentially significant impacts from water diversions alone. Cannabis requires a substantial amount of water during the growing season, so it is often cultivated near sources of perennial surface water for irrigation, commonly diverting from springs and headwater streams (Bauer et al. 2015). In the least impacted of the study watersheds, Bauer et al. (2015) calculated that diversions for cannabis cultivation could reduce the annual seven-day low flow by up to 23%, and in some of the heavily impacted watersheds, water demands for cannabis could exceed surface water availability. If not regulated carefully, cannabis cultivation could have substantial impacts on sensitive aquatic species like Foothill Yellow-legged Frogs in watersheds in which it is concentrated.

For context, cannabis cultivation was responsible for approximately 1.1% of forest cover lost within study watersheds in Humboldt County from 2000 to 2013, while timber harvest accounted for 53.3% (Wang et al. 2017). Cannabis requires approximately two times as much water per day as wine grapes, the other major irrigated crop in the region (Bauer et al. 2015). Impacts from cannabis cultivation have been observed by Foothill Yellow-legged Frog researchers working on the Trinity River and South Fork

Eel River in the form of lower flows in summer, increased egg stranding, and more algae earlier in the season in recent years (S. Kupferberg and M. Power pers. comm. 2015; D. Ashton pers. comm. 2017; S. Kupferberg, M. van Hattem, and W. Stokes pers. comm. 2017). In addition, Gonsolin (2010) reported illegal cannabis cultivations on four headwater streams that drained into his study area along Coyote Creek, three of which were occupied by Foothill Yellow-legged Frogs. The cultivators had removed vegetation adjacent to the creeks, terraced the slopes, diverted water, constructed small water impoundments, poured fertilizers directly into the impoundments, and applied herbicides and pesticides, as evidenced by leftover empty containers littering the site.

Commercial sale of cannabis for recreational use became legal in California on January 1, 2018, through passage of the Control, Regulate and Tax Adult Use of Marijuana Act (2016), and with it an environmental permitting system and habitat restoration fund was established. The number of applications for temporary licenses per watershed is depicted in Figure 21. Two of the expected outcomes of passage of this law were that the profit-margin on growing cannabis would fall to the point that it would discourage illegal trespass grows and move the bulk of the cultivation out of remote forested areas into existing agricultural areas like the Central Valley (CSOS 2016). However, until cannabis is legalized at the federal level, these results may not occur since banks are reluctant to work with growers due to federal prohibitions subjecting them to prosecution for money laundering (ABA 2019). Additional details on cannabis permitting at the state level can be found under the Existing Management section.

Vineyards

Vineyard operators historically built on-stream dams and removed almost all the riparian vegetation to make room for vines and for ease of irrigation (M. van Hattem pers. comm. 2019). They still divert a substantial amount of water for irrigation, and they build on- and off-stream impoundments that support bullfrogs (Ibid.). The acreage of land planted in wine grapes in California began rising dramatically in the 1970s and now accounts for 90% of wine produced in the U.S. (Geisseler and Horwath 2016, Alston et al. 2018). The number of wineries in California rose from approximately 330 to nearly 2,500 between 1975 and 2006; however, expansion slowed and has reversed slightly recently with 24,300 ha (60,000 ac), or 6.5% of total area planted, removed between 2015 and 2017 (Volpe et al. 2010, CDFA 2018). In 2015, 347,000 ha (857,000 ac) were planted in grapes with 70% located in the San Joaquin Valley; 66%, 21%, and 13% were planted in wine, raisin, and table grapes, respectively (Alston et al. 2018).

Expansion of wineries in the coastal counties converted natural areas such as oak woodlands and forests to vineyards (Merenlender 2000, Napa County 2010). The area of Sonoma County covered in grapes increased by 32% from 1990 to 1997, and 42% of these new vineyards were planted above 100 m (328 ft) with 25% on slopes greater than 18% (Merelender 2000). For context, only 18% of vineyards planted before 1990 occurred above 100 m (328 ft) and less than 6% on slopes greater than 18% (Ibid.). This conversion took place on approximately 773 ha (1,909 ac) of conifer and dense hardwood forest, 149 ha (367 ac) of shrubland, and 2,925 ha (7,229 ac) of oak grassland savanna (Ibid.).

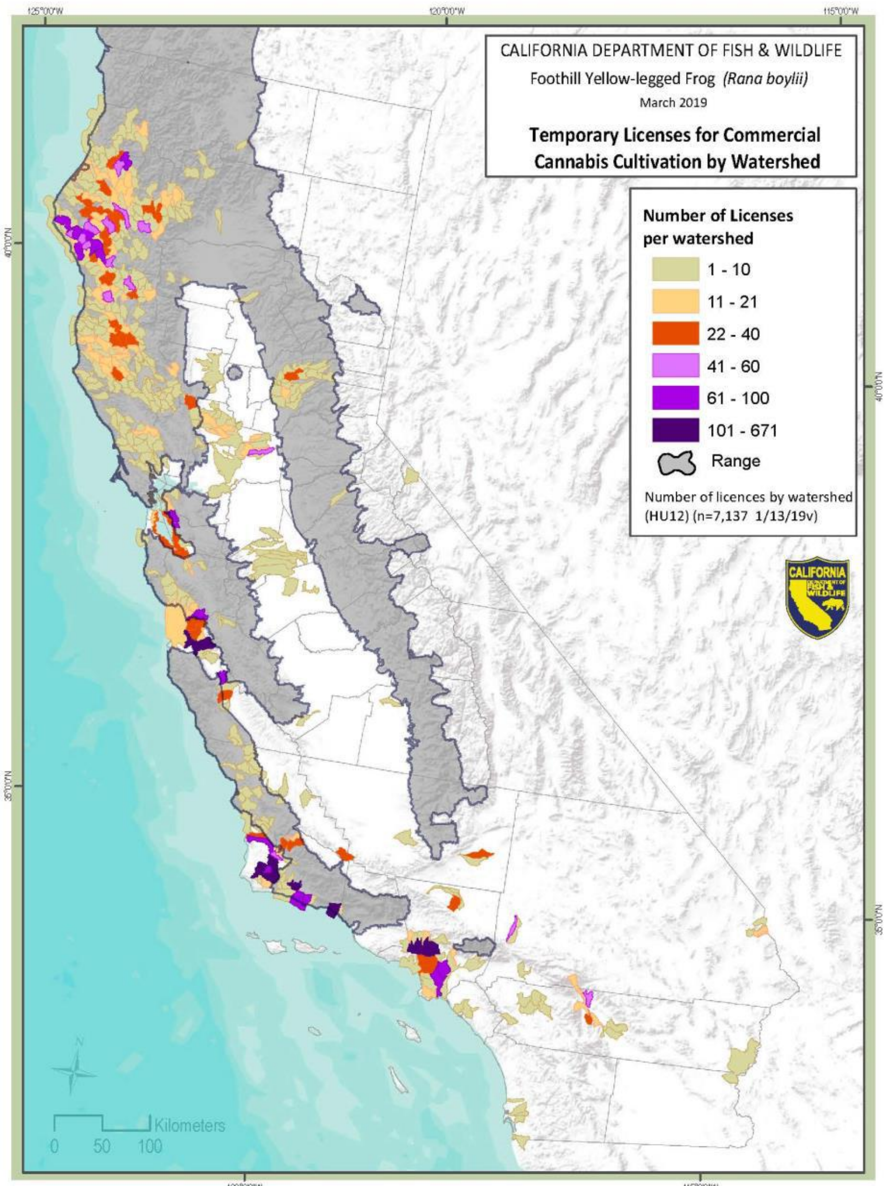

Figure 21. Cannabis cultivation temporary licenses by watershed in California (CDFA, NHD)

Recent expansion of oak woodland conversion to vineyards in Napa County was highest in its eastern hillsides (Napa County 2010). The County estimates that 1,085 and 1,240 ha (2,682-3,065 ac) of woodlands will be converted to vineyards between 2005 and 2030 (Ibid.). For context, 297 ha (733 ac) were converted from 1992 to 2003 (Ibid.). In addition, wine grapes were second only to almonds in terms of overall quantity of pesticides applied in California in 2016, but the quantity per unit area (2.9 kg/ha [2.6 lb/ac]) was 160% greater for the wine grapes (CDPR 2018). Vineyard expansion into hillsides has continued into sensitive headwater areas, and like cannabis cultivation, even small vineyards can have substantial impacts on Foothill Yellow-legged Frog habitat through sedimentation, water diversions, spread of harmful non-native species, and pesticide contamination (Merelender 2000, K. Weiss pers. comm. 2018).

Livestock Grazing

Livestock grazing can be an effective habitat management tool, including control of riparian vegetation encroachment, but overgrazing can significantly degrade the environment (Siekert et al. 1985). Cattle display a strong preference for riparian areas and have been implicated as a major source of habitat damage in the western U.S. where the adverse impacts of overgrazing on riparian vegetation are intensified by arid and semi-arid climates (Behnke and Raleigh 1978, Kauffman and Krueger 1984, Belsky et al. 1999). The severity of grazing impacts on riparian systems can be influenced by the number of animals, duration and time of year, substrate composition, and soil moisture (Benhke and Raleigh 1978, Kauffman et al. 1983, Marlow and Pogacnik 1985, Siekert et al. 1985). In addition to habitat damage, cattle can directly trample any life stage of Foothill Yellow-legged Frog.

Signs of overgrazing include impacts to the streambanks such as increased slough-offs and cave-ins that collapse undercuts used as refuge (Kauffman et al. 1983). Overgrazing reduces riparian cover, increases erosion and sedimentation, which as described above can result in silt degradation of breeding, rearing, and invertebrate food-producing areas (Cordone and Kelley 1961, Behnke and Raleigh 1978, Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). Loss of streamside and instream vegetative cover and changes to channel morphology can increase water temperatures and velocities (Behnke and Raleigh 1978). Water quality can be affected by increased turbidity and nutrient input from excrement, and seasonal water quantity can be impacted through changes to channel morphology (Belsky et al. 1999). In addition, increased nutrients and temperatures can promote blooms of harmful cyanobacteria like *Microcystis aeruginosa*, which releases a toxin when it expires that can cause liver damage to amphibians as well as other animals including humans (Bobzien and DiDonato 2007, Zhang et al. 2013).

While some recent studies indicate livestock grazing continues to damage stream and riparian ecosystems, its impact on Foothill Yellow-legged Frogs in California is unknown (Belsky et al. 1999, Hayes et al. 2016). In Oregon, the species' presence was correlated with significantly less grazing than where they were absent according to Borisenko and Hayes's 1999 report (as cited in Olson and Davis 2009). However, Fellers (2005) reported that apparently some Coast Range foothill populations occupying streams draining east into the San Joaquin Valley were doing well at the time of publication despite being heavily grazed.

Urbanization and Road Effects

Habitat conversion and fragmentation combined with modified environmental disturbance regimes can substantially jeopardize biological diversity (Tracey et al. 2018). This threat is most severe in areas like California with Mediterranean-type ecosystems that are biodiversity hot spots, fire-prone, and heavily altered by human land use (Ibid.). From 1990 to 2010, the fastest-growing land use type in the conterminous U.S. was new housing construction, which rapidly expanded the wildland-urban interface (WUI) where houses and natural vegetation meet or intermix on the landscape (Radeloff et al. 2018).

Of several variables tested, proportion of urban land use within a 5 km (3.1 mi) radius of a site was associated with Foothill Yellow-legged Frog declines (Davidson et al. 2002). Lind (2005) also found significantly less urban development nearby and upwind of sites occupied by Foothill Yellow-legged Frogs, suggesting pollutant drift may be a contributing factor. Changes in wildfires may also contribute to the species' declines; 95% of California's fires are human-caused, and wildfire issues are greatest at the WUI (Syphard et al. 2009, Radeloff et al. 2018). Population density, intermix WUI (where wildland and development intermingle as opposed to an abrupt interface), and distance to WUI explained the most variability in fire frequency (Syphard et al. 2007). In addition to wildfires, habitat loss, and fragmentation, urbanization can impact adjacent ecosystems through non-native species introduction, native predator subsidization, and disease transmission (Bar-Massada et al. 2014).

Projections show growth in California's population to 51 million people by 2060 from approximately 40 million currently (PPIC 2019). This will increase urbanization, the WUI, and habitat fragmentation. The Department of Finance projects the Inland Empire, the San Joaquin Valley, and the Sacramento metropolitan area will be the fastest-growing regions of the state over the next several decades (Ibid.). This puts the greatest pressure in areas outside of the Foothill Yellow-legged Frog's range; however, because the environmental stressors associated with urbanization can span far beyond its physical footprint, they may still adversely affect the species.

Highways are frequently recognized as barriers to dispersal that fragment habitats and populations; however, single-lane roads can pose significant risks to wildlife as well (Cook et al. 2012, Brehme et al. 2018). Foothill Yellow-legged Frogs are at risk of being killed by vehicles when roads are located near their habitat (Cook et al. 2012, Brehme et al. 2018). Fifty-six juvenile Foothill Yellow-legged Frogs were found on a road adjacent to Sulphur Creek (Mendocino County), seven of which had been struck and killed (Cook et al. 2012). When fords (naturally shallow areas) are used as vehicle crossings, they can create sedimentation and poor water quality, and in some cases, the fords are gravel or cobble bars used by Foothill Yellow-legged Frogs for breeding that could result in direct mortality (K. Blanchard pers. comm. 2018, R. Bourque pers. comm. 2018). Construction of culverts under roads to keep vehicles out of the streambed can result in varying impacts. In some cases, they can impede dispersal and create deep scoured pools that support predatory fish and frogs, but when properly constructed, they can facilitate frog movement up and down the channel with reduced road mortality (Van Wagner 1996, GANDA 2008). In areas where non-native species are not a threat, but premature drying is, pools created by culverts can provide habitat in otherwise unsuitable areas (M. Grefsrud pers. comm. 2019). An evaluation of the impact of roads on 166 native California amphibians and reptiles through direct

mortality and barriers to movement concluded that Foothill Yellow-legged Frogs, at individual and population levels, were at moderate risk of road impacts in aquatic habitat but very low risk of impacts in terrestrial habitat (Brehme et al. 2018). For context, all chelonids (turtles and tortoises), 72% of snakes, 50% of anurans, 18% of lizards, and 17% of salamander species in California were ranked as having a high or very high risk of negative road impacts in the same evaluation (Ibid.).

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Poorly constructed roadways near rivers and streams can result in substantial erosion and sedimentation, leading to reduced amphibian densities (Welsh and Ollivier 1998). Proximity of roads to Foothill Yellow-legged Frog habitat contributes to petrochemical runoff and poses the threat of spills (Ashton et al. 1997). A diesel spill on Hayfork Creek (Trinity County) resulted in mass mortality of Foothill Yellow-legged Frog tadpoles and partial metamorphs (Bury 1972). Roads have also been implicated in the spread of disease and may have aided in the spread of Bd in California (Adams et al. 2017b).

Frogs use auditory and visual cues to defend territories and attract mates, and some studies reveal that realistic levels of traffic noise can impede transmission and reception of these signals (Bee and Swanson 2007). Some male frogs have been observed changing the frequency of their calls to increase the distance they can be heard over traffic noise, but if females have evolved to recognize lower pitched calls as signs of superior fitness, this potential trade-off between audibility and attractiveness could have implications for reproductive success (Parris et al. 2009). In a separate study, traffic noise caused a change in male vocal sac coloration and an increase in stress hormones, which changed sexual selection processes and suppressed immunity (Troïanowski et al. 2017). Because Foothill Yellow-legged Frogs mostly call underwater and are not known to use color displays, communication cues may not be adversely affected by traffic noise, but their stress response is unknown.

Timber Harvest

Because Foothill Yellow-legged Frogs tend to remain close to the water channel (i.e., within the riparian corridor) and current timber harvest practices minimize disturbance in riparian areas for the most part, adverse effects from timber harvest are expected to be relatively low (Hayes et al. 2016, CDFW 2018b). However, some activities have a potential to negatively impact Foothill Yellow-legged Frogs or their habitat, including direct mortality and increased sedimentation during construction and decommissioning of watercourse crossings and infiltration galleries, tree felling, log hauling, and entrainment by water intakes or desiccation of eggs and tadpoles through stranding from dewatering during drafting operations (CDFW 2018b,c). In addition to impacts previously described under the Sedimentation and Road Effects section, when silt runoff into streams is accompanied by organic materials, such as logging debris, impaired water quality can result, including reduced dissolved oxygen, which is important in embryonic and tadpole development (Cordone and Kelley 1961).

Because Foothill Yellow-legged Frogs are heliotherms (i.e, they bask in the sun to raise their body temperature) and sensitive to thermal extremes, some moderate timber harvest may benefit the species (Zweifel 1955, Fellers 2005). Ashton (2002) reported 85% of his Foothill Yellow-legged Frog observations occurred in second-growth forests (37-60 years post-harvest) as opposed to late-seral forests and postulated that the availability of some open canopy areas played a major part in this

disparity. Foothill Yellow-legged Frogs are typically absent in areas with closed canopy (Welsh and Hodgson 2011). Reduced canopy also raises stream temperatures, which could improve tadpole development and promote algal and invertebrate productivity in otherwise cold streams (Olson and Davis 2009; Catenazzi and Kupferberg 2013,2017).

Recreation

Several types of recreation can adversely impact Foothill Yellow-legged Frogs, and some are more severe and widespread than others. One of the main potential factors identified by herpetologists as contributing to disappearance of Foothill Yellow-legged Frogs in southern California was increased and intensified recreation in streams (Adams et al. 2017b). The greater number of people traveling into the backcountry may have facilitated the spread Bd to these areas, and while no evidence shows stress from disturbance or other environmental pressures increases susceptibility to Bd, the stress hormone corticosterone has been implicated in immunosuppression (Hayes et al. 2003, Adams et al. 2017b).

The amount of Foothill Yellow-legged Frog habitat disturbed by off-highway motor vehicles (OHV) throughout its range in California is unknown, but its impacts can be significant, particularly in areas with small isolated populations (Kupferberg et al. 2009c, Kupferberg and Furey 2015). An example is the Carnegie State Vehicular Recreation Area (CVSRA), located in the hills southwest of Tracy in the Corral Hollow Creek watershed (Alameda and San Joaquin counties). The above-described road effects apply: sedimentation, crushing along trail crossings, and potential noise effects (Ibid.). In addition, dust suppression activities employed by CSVRA use magnesium chloride ($MgCl_2$), which has the potential to harm developing embryos and tadpoles (Karraker et al. 2008, Hopkins et al. 2013, OHMVRC 2017). Based on museum records, Foothill Yellow-legged Frogs were apparently abundant in Corral Hollow Creek, but they are extremely rare now and are already extirpated or at risk of extirpation (Kupferberg et al. 2009c, Kupferberg and Furey 2015).

Motorized and non-motorized recreational boating can also impact Foothill Yellow-legged Frogs. The impacts of jet boat traffic were investigated in Oregon; in areas with frequent use and high wakes breaking on shore, Foothill Yellow-legged Frogs were absent (Borisenko and Hayes 1999 as cited in Olson and Davis 2009). This wake action had the potential to dislodge egg masses, strand tadpoles, disrupt adult basking behavior, and erode shorelines (Ibid.). Jet boat tours and races on the Klamath River (Del Norte and Humboldt counties) may have an impact on Foothill Yellow-legged Frog use of the mainstem (M. van Hattem pers. comm. 2019). In addition, using gravel bars as launch and haul out sites for boat trailers, kayaks, or river rafts can result in direct loss of egg masses and tadpoles or damage to breeding and rearing habitat and can disrupt post-metamorphic frog behavior (Ibid.). As described above, pulse flows released for whitewater boating in the late spring and summer can result in scouring and stranding of egg masses and tadpoles (Borisenko and Hayes 1999 as cited in Olson and Davis 2009, Kupferberg et al. 2009b). In addition, the velocities that resulted in stunted growth and increased vulnerability to predation in Foothill Yellow-legged Frog tadpoles were less than the increased velocities experienced in nearshore habitats during intentional release of recreational flows for whitewater boating, as well as hydropeaking for power generation (Kupferberg et al. 2011b).

Commented [RAP17]: May want to rephrase this sentence, I understand it but it may be less clear for folks that aren't familiar.

Hiking, horse-riding, camping, fishing, and swimming, particularly in sensitive breeding and rearing habitat can also adversely impact Foothill Yellow-legged Frog populations (Borisenko and Hayes 1999 in Olson and Davis 2009). Because Foothill Yellow-legged Frog breeding activity was being disturbed and egg masses were being trampled by people and dogs using Carson Falls (Marin County), the land manager established an educational program, including employing docents on weekends that remind people to stay on trails and tread lightly to try to reduce the loss of Foothill Yellow-legged Frog reproductive effort (Prado 2005). In addition, within his study site, Van Wagner (1996) reported that a property owner moved rocks that were being used as breeding habitat to create a swimming hole. The extent to which this is more than a small, local problem is unknown, but as the population of California increases, recreational pressures in Foothill Yellow-legged Frog habitat are likely to increase commensurately.

Drought

Drought is a common phenomenon in California and is characterized by lower than average precipitation. Lower precipitation in general results in less surface water, and water availability is critical for obligate stream-breeding species. Even in the absence of drought, a positive relationship exists between precipitation and latitude within the Foothill Yellow-legged Frog's range in California, and mean annual precipitation has a strong influence on Foothill Yellow-legged Frog presence at historically occupied sites (Davidson et al. 2002, Lind 2005). Figure 22 depicts the recent historical annual average precipitation across the state as well as during the most recent drought and how they differ. Southern California is normally drier than northern California, but the severity of the drought was even greater in the south.

Reduced precipitation can result in deleterious effects to Foothill Yellow-legged Frogs beyond the obvious premature drying of aquatic habitat. When stream flows recede during the summer and fall, sometimes the isolated pools that stay perennially wet are the only remaining habitat. This phenomenon concentrates aquatic species, resulting in several potentially significant adverse impacts. Stream flow volume was negatively correlated with Bd load during a recent chytridiomycosis outbreak in the Alameda Creek watershed (Adams et al. 2017a). The absence of high peak flows in winter coupled with wet years allowed bullfrogs to expand their distribution upstream, and the drought-induced low flows in the fall concentrated them with Foothill Yellow-legged Frogs in the remaining drying pools (Ibid.). This mass mortality event appeared to have been the result of a combination of drought, disease, and dam effects (Ibid.). This die-off occurred in a regulated reach that experiences heavy recreational use and presence of crayfish and bass (Ibid.). Despite these threats, the density of breeding females in this reach was greater in 2014 and 2015 than the in the unregulated reach upstream because the latter dried completely before tadpoles could metamorphose during the preceding drought years (S. Kupferberg, R. Peek, and A. Catenazzi pers. comm. 2015).

In addition to increasing the spread of pathogens, drought-induced stream drying can increase predation and competition by introduced fish and frogs in the pools they are forced to share (Moyle 1973, Hayes and Jennings 1988, Drost and Fellers 1996). This concentration in isolated pools can also result in increased native predation as well as facilitate spread of Bd. An aggregation of six adult Foothill

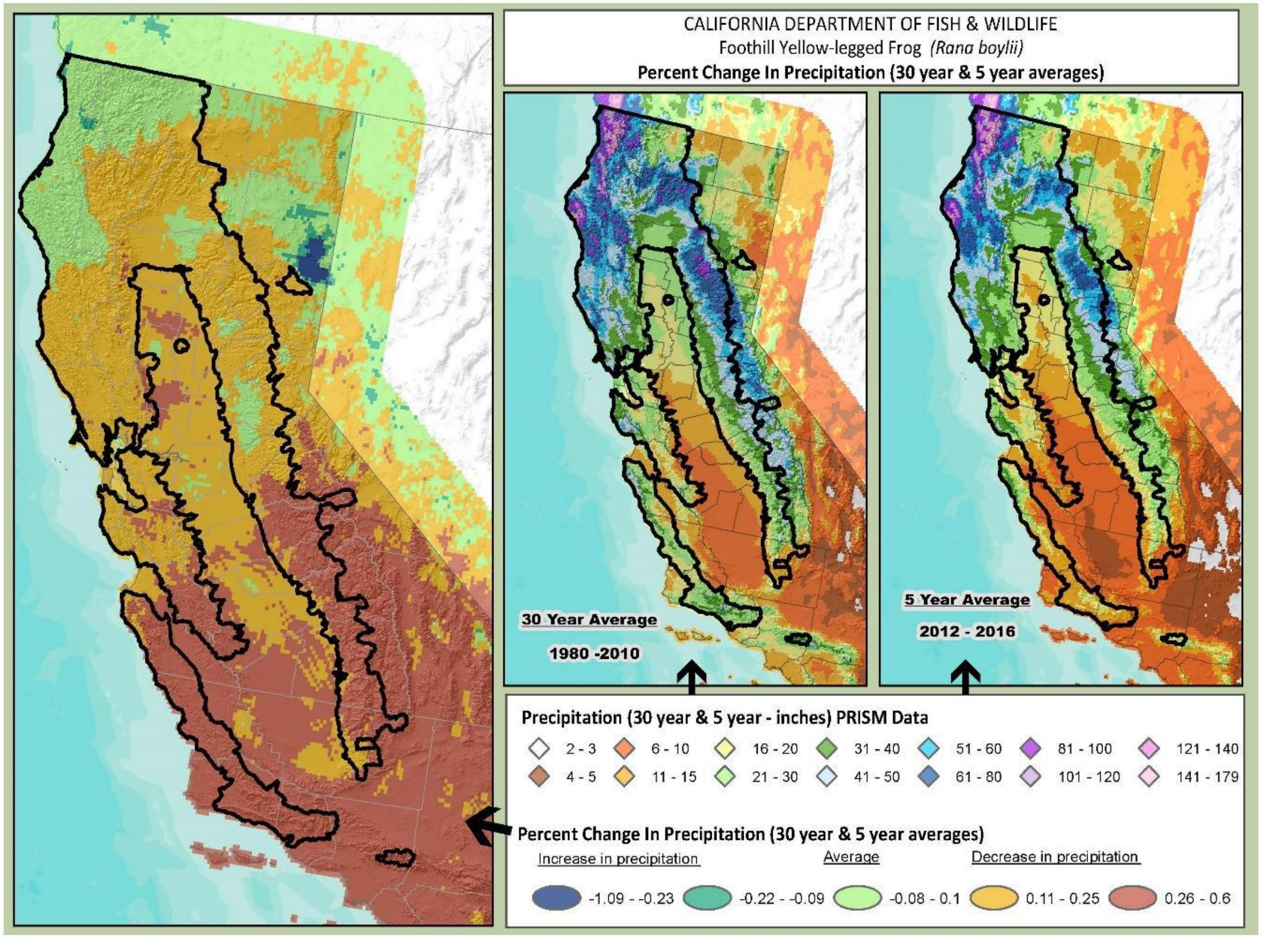

Figure 22. Change in precipitation from 30-year average and during the recent drought (PRISM)

Yellow-legged Frogs was observed perched on a rock above an isolated pool where a gartersnake was foraging on tadpoles during the summer; this close contact may reduce evaporative water loss when they are forced out of the water during high temperatures, but it can also increase disease transmission risk (Leidy et al. 2009.). Gonsolin (2010) also documented a late summer aggregation of juvenile Foothill Yellow-legged Frogs out of water during extremely high temperatures. In addition, drought-induced low flow, high water temperatures, and high densities of tadpoles were associated with outbreaks of malformation-inducing parasitic copepods (Kupferberg et al. 2009a).

Rapidly receding spring flows can result in stranding egg masses and tadpoles. However, this risk is likely less significant when it is drought-induced on an unregulated stream vs. a result of dam operations since Foothill Yellow-legged Frogs have evolved to initiate breeding earlier and shorten the breeding period in drought years (Kupferberg 1996a). If pools stay wet long enough to support metamorphosis, complete drying at the end of the season may benefit Foothill Yellow-legged Frogs if it eliminates introduced species like warm water fish and bullfrogs. Moyle (1973) noted that the only intermittent streams occupied by Foothill Yellow-legged Frogs in the Sierra Nevada foothills had no bullfrogs. At a long-term study site in upper Coyote Creek in 2015, Foothill Yellow-legged Frogs had persisted in reaches that had at least some summer water through the three preceding years of the most severe drought in over a millennium, albeit at much lower abundance than a decade before (Gonsolin 2010, Griffin and Anchokaitis 2014, J. Smith pers. comm. 2015). The population's abundance appeared to have never recovered from the 2007-2009 drought before the 2012-2016 drought began (J. Smith pers. comm. 2015). In 2016, after a relatively wet winter, Foothill Yellow-legged Frogs bred en masse, and only a single adult bullfrog was detected, an unusually low number for that area (CDWR 2016, J. Smith pers. comm. 2016). It appeared the population may rebound; however, in 2018, it experienced lethal chytridiomycosis outbreak, and like the Alameda Creek die-off probably resulted from crowding during drought, presence of bullfrogs as Bd-reservoirs and predators and competitors, and the stress associated with the combination of the two (Kupferberg and Catenazzi 2019).

Drought effects can also exacerbate other environmental stressors. During the most recent severe drought, tree mortality increased dramatically from 2014 to 2017 and reached approximately 129 million dead trees (OEHHA 2018). Multiple years of high temperatures and low precipitation left them weakened and more susceptible to pathogens and parasites (Ibid.). Vast areas of dead and dying trees are more prone to severe wildfires, and they lose their carbon sequestration function while also emitting methane, which is an extremely damaging greenhouse gas (CNRA 2016). Post-wildfire, storms can result in erosion of fine sediments from denuded hillsides into the stream channel (Florsheim et al. 2017). If the storms are short duration and low precipitation, as happens during droughts, their magnitude may not be sufficient to transport the material downstream, resulting in a longer temporal loss or degradation of stream habitat (Ibid.). Reduced rainfall may also infiltrate the debris leading to subsurface flows rather than the surface water Foothill Yellow-legged Frogs require (Ibid.). Extended droughts increase risk of the stream being uninhabitable or inadequate for breeding for multiple years, which would result in population-level impacts and possible extirpation (Ibid.).

Wildland Fire and Fire Management

Fire is an important element for shaping and maintaining the species composition and integrity of many California ecosystems (Syphard et al. 2007, SBFFP 2018). Prior to European settlement, an estimated 1.8 to 4.9 million ha (4.5-12 million ac) burned annually (4-11% of total area of the state), ignited both deliberately by Native Americans and through lightning strikes (Keeley 2005, SBFFP 2018). The impacts of wildland fires on Foothill Yellow-legged Frogs are poorly understood and likely vary significantly across the species' range with differences in climate, vegetation, soils, stream-order, slope, frequency, and severity (Olson and Davis 2009). Mortality from direct scorching is unlikely because Foothill Yellow-legged Frogs are highly aquatic, and most wildfires occur during the dry period of the year when the frogs are most likely to be in or near the water (Pilliod et al. 2003, Bourque 2008). Field observations support this presumption; sightings of post-metamorphic Foothill Yellow-legged Frogs immediately after fires in the northern Sierra Nevada and North Coast indicate they are not very vulnerable to the direct effects of fire (S. Kupferberg and R. Peek pers. comm. 2018). Similarly, Foothill Yellow-legged Frogs were observed two months, and again one year, after a low- to moderate-intensity fire burned an area in the southern Sierra Nevada in 2002, and the populations were extant and breeding as recently as 2017 (Lind et al. 2003b, CNDDB 2019). While water may provide a refuge during the fire, it is also possible for temperatures during a fire, or afterward due to increased solar exposure, to near or exceed a threshold resulting lethal or sublethal harm; this would likely impact embryos and tadpoles with limited dispersal abilities (Pilliod et al. 2003).

Intense fires remove overstory canopy, which provides insulation from extreme heat and cold, and woody debris that increases habitat heterogeneity (Pilliod et al. 2003, Olson and Davis 2009). If this happens frequently enough, it can permanently change the landscape. For example, frequent high-severity burning of crown fire-adapted ecosystems can prevent forest regeneration since seeds require sufficient time between fires to mature, and repeated fires can deplete the seed bank (Stephens et al. 2014). Smoke and ash change water chemistry through increased nutrient and heavy metal inputs that can reach concentrations harmful to aquatic species during the fire and for days, weeks, or years after (Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Erosion rates on granitic soils, which make up a large portion of the Foothill Yellow-legged Frog's range, can be over 60 times greater in burned vs. unburned areas and can increase sedimentation for over 10 years (Megahan et al. 1995, Hayes et al. 2016). Post-fire nutrient inputs into streams could benefit Foothill Yellow-legged Frogs through increased productivity and more rapid growth and development (Pilliod et al. 2003). While the loss of leaf litter that accompanies fire alters the food web, insects are expected to recolonize rapidly, and the lack of cover could increase their vulnerability to predation by Foothill Yellow-legged Frogs (Ibid.).

Low-intensity fires likely have no adverse effect on Foothill Yellow-legged Frogs (Olson and Davis 2009). If they occur in areas with dense canopy, wildfires can improve habitat quality for Foothill Yellow-legged Frogs by reducing riparian cover, providing areas to bask, and increasing habitat heterogeneity, which is likely to outweigh any adverse effects from some fire-induced mortality (Russell et al. 1999, Olson and Davis 2009). In a preliminary analysis of threats to Foothill Yellow-legged Frogs in Oregon, proximity to stand-replacing fires was not associated with absence (Olson and Davis 2009).

Euro-American colonization of California significantly altered the pattern of periodic fires with which California's native flora and fauna evolved through fire exclusion, land use practices, and development (OEHHA 2018). Fire suppression can lead to canopy closure, which reduces habitat quality by limiting thermoregulatory opportunities (Olson and Davis 2009). In addition, fire suppression and its subsequent increase in fuel loads combined with expanding urbanization and rising temperatures have resulted in a greater likelihood of catastrophic stand-replacing fires that can significantly alter riparian systems for decades (Pilliod et al. 2003). Firebreaks, in which vegetation is cleared from a swath of land, can result in similar impacts to roads and road construction (Ibid.). Fire suppression can also include bulldozing within streams to create temporary reservoirs for pumping water, which can cause more damage than the fire itself to Foothill Yellow-legged Frogs in some cases (S. Kupferberg and R. Peek pers. comm. 2018). In addition, fire suppression practices can involve applying hundreds of tons of ammonia-based fire retardants and surfactant-based fire suppressant foams from air tankers and fire engines (Pilliod et al. 2003). Some of these chemicals are highly toxic to some anurans (Little and Calfee 2000).

Fire suppression has evolved into fire management with a greater understanding of its importance in ecosystem health (Keeley and Syphard 2016). Several strategies are employed including prescribed burns, mechanical fuels reduction, and allowing some fires to burn instead of necessarily extinguishing them (Pilliod et al. 2003). Like wildfires themselves, fire management strategies have the potential to benefit or harm Foothill Yellow-legged Frogs. Prescribed fires and mechanical fuels removal lessen the likelihood of catastrophic wildfires, but they can also result in loss of riparian vegetation, excessive sedimentation, and increased water temperatures (Ibid.). Salvage logging after a fire may result in similar impacts to timber harvest but with higher rates of erosion and sedimentation (Ibid.). A balanced approach to wildland fires is likely to have the greatest beneficial impact on species and ecosystem health (Stephens et al. 2012).

Floods and Landslides

As previously described, Foothill Yellow-legged Frog persistence is highly sensitive to early life stage mortality (Kupferberg et al. 2009c). While aseasonal dam releases are a major source of egg mass and tadpole scouring, storm-driven floods are also capable of it (Ashton et al. 1997). Van Wagner (1996) concluded that the high discharge associated with heavy rainfall could account for a significant source of mortality in post-metamorphic Foothill Yellow-legged Frogs as well as eggs and tadpoles; he observed two adult females and several juveniles swept downstream with fatal injuries post-flooding. Severe flooding, specifically two 500-year flood events in early 1969 in Evey Canyon (Los Angeles County), resulted in massive riparian habitat destruction (Sweet 1983). Prior to the floods, Foothill Yellow-legged Frogs were widespread and common, but only four subsequent sightings were documented between 1970 and 1974 and none since (Sweet 1983, Adams 2017b). Sweet (1983) speculates that because Foothill Yellow-legged Frogs overwinter in the streambed in that area, the floods may have reduced the population's abundance below an extinction threshold. Four other herpetologists interviewed about Foothill Yellow-legged Frog extirpations in southern California listed severe flooding as a likely cause (Adams et al. 2017b).

As mentioned above, landslides are a frequent consequence of post-fire rainstorms and can result in lasting impacts to stream morphology, water quality, and Foothill Yellow-legged Frog populations. On the other hand, Olson and Davis (2009) suggest that periodic landslides can have beneficial effects by transporting woody debris into the stream that can increase habitat complexity and by replacing sediments that are typically washed downstream over time. Whether a landslide is detrimental or beneficial is likely heavily influenced by amount of precipitation and the underlying system. As previously described, too little precipitation could lead to prolonged loss of habitat through failure to transport material downstream, and too much precipitation can result in large-scale habitat destruction and direct mortality.

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Climate Change

Global climate change threatens biodiversity and may lead to increased frequency and severity of drought, wildfires, flooding, and landslides (Williams et al. 2008, Keely and Syphard 2016). Data show a consistent trend of warming temperatures in California and globally; 2014 was the warmest year on record, followed by 2015, 2017, and 2016 (OEHHA 2018). Climate model projections for annual temperature in California in the 21st century range from 1.5 to 4.5°C (2.7-8.1°F) greater than the 1961-1990 mean (Cayan et al. 2008). Precipitation change projections are less consistent than those for temperature, but recent studies indicate increasing variability in precipitation, and increasingly dry conditions in California resulting from increased evaporative water loss primarily due to rising temperatures (Cayan et al. 2005, Williams et al. 2015, OEHHA 2018). Precipitation variability and proportion of dry years were negatively associated with Foothill Yellow-legged Frog presence in a range-wide analysis (Lind 2005). In addition, low precipitation intensified the adverse effects of dams on the species (Ibid.).

California recently experienced the longest drought since the U.S. Drought Monitor began reporting in 2000 (NIDIS 2019). Until March 5, 2019, California experienced drought effects in at least a portion of the state for 376 consecutive weeks; the most intense period occurred during the week of October 28, 2014 when D4 (the most severe drought category) affected 58.4% of California's land area (Figure 23; NIDIS 2019). A recent modeling effort using data on historical droughts, including the Medieval megadrought between 1100 and 1300 CE, indicates the mean state of drought from 2050 to 2099 in California will likely exceed the Medieval-era drought, under both high and moderate greenhouse gas emissions models (Cook et al. 2015). The probability of a multidecadal (35 yr) drought occurring during the late 21st century is greater than 80% in all models used by Cook et al. (2015). If correct, this would represent a climatic shift that not only falls outside of contemporary variability in aridity but would also be unprecedented in the past millennium (Ibid.).

As a result of increasing temperatures, a decreasing proportion of precipitation falls as snow, resulting in more runoff from rainfall during the winter and a shallower snowpack that melts more rapidly (Stewart 2009). A combination of reduced seasonal snow accumulation and earlier streamflow timing significantly reduces surface water storage capacity and increases the risk for winter and spring floods, which may require additional and taller dams and result in alterations to hydroelectric power generation flow regimes (Cayan et al. 2005, Knowles et al. 2006, Stewart 2009). The reduction in snowmelt volume

is expected to impact the northern Sierra (Feather, Yuba, and American River watersheds) to a greater extent than the southern portion (Young et al. 2009). The earlier shift in peak snowmelt timing is predicted to exceed four to six weeks across the entire Sierra Nevada depending on the amount of warming that occurs this century (Ibid.). In addition, the snow water equivalent is predicted to significantly decline by 2070-2099 over the 1961-1990 average in the Trinity, Sacramento, and San Joaquin drainages from -32% to -79%, and effectively no snow is expected to fall below 1000 m (3280 ft) in the high emissions/sensitive model (Cayan et al. 2008).

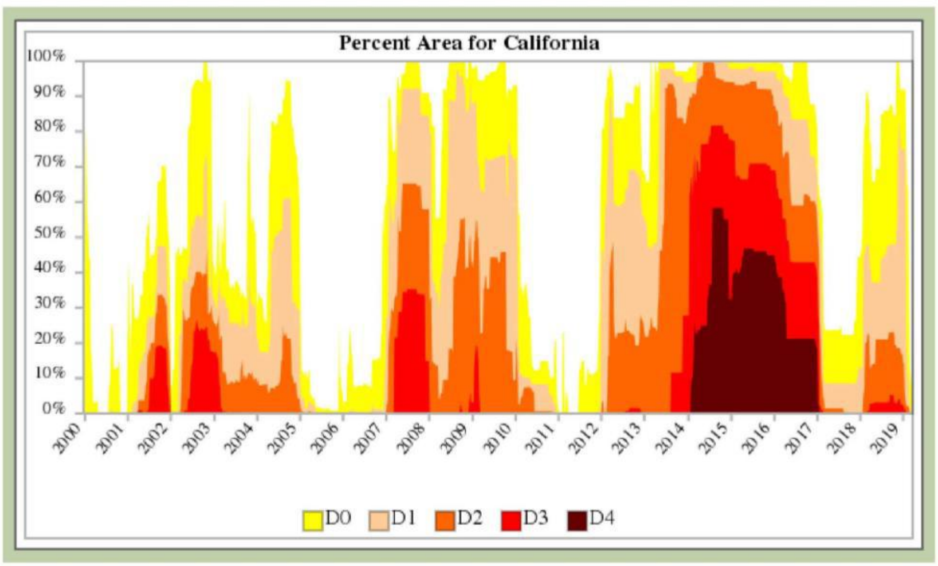


Figure 23. Palmer Hydrological Drought Indices 2000-present (NIDIS)

The earlier shift of snowmelt and lower water content will result in lower summer flows, which will intensify the competition for water among residential, agricultural, industrial, and environmental needs (Field et al. 1999, Cook et al. 2015). In unregulated systems, as long as water is present through late summer, an earlier hydrograph recession that triggers Foothill Yellow-legged Frog breeding could result in a longer time to grow larger prior to metamorphosis, which improves probability of survival (Yarnell et al. 2010, Kupferberg 2011b). However, if duration from peak to base flow shortens, it can result in increased sedimentation and reduced habitat complexity in addition to stranding (Yarnell et al. 2010).

Fire frequency relates to temperature, fuel loads, and fuel moisture (CCSP 2008). Therefore, increasing periods of drought combined with extreme heat and low humidity that stress or kill trees and other vegetation create ideal conditions for wildland fires (Ibid). Not surprisingly, the area burned by wildland fires over the western U.S. increased since 1950 but rose rapidly in the mid-1980s (Westerling et al. 2006, OEHHA 2018). As temperatures warmed and snow melted earlier, large-wildfire frequency and duration increased, and wildfire seasons lengthened (Westerling et al. 2006, OEHHA 2018).

In California, latitude inversely correlates with temperature and annual area burned, but the climate-fire relationship is substantially different across the state, and future wildfire regimes are difficult to predict (Keeley and Syphard 2016). For example, the relationship between spring and summer temperature and area burned in the Sierra Nevada is highly significant but not in southern California (Ibid.). Climate has a greater influence on fire regimes in mesic than arid environments, and the most influential climatological factor (e.g., precipitation, temperature, season, or their interactions) shifts over time (Ibid.). Nine of the 10 largest fires in California since 1932 have occurred in the past 20 years, 4 within the past 2 years (Figure 24; CAL FIRE 2019). However, it is possible this trend will not continue; climate- and wildfire-induced changes in vegetation could reduce wildfire severity in the future (Parks et al. 2016).

Wildfires themselves can accelerate the effects of climate change. Wildfires emit short-lived climate pollutants like black carbon (soot) and methane that are tens to thousands of times greater than carbon dioxide (the main focus of greenhouse gas reduction) in terms of warming effect and are responsible for 40% or more of global warming to date (CNRA 2016). Healthy forests can sequester large amounts of carbon from the atmosphere, but recently carbon emissions from wildfires have exceeded their uptake by vegetation in California (Ackerly et al. 2018).

With increased variability and changes in precipitation type, magnitude, and timing comes more variable and extreme stream flows (Mallakpour et al. 2018). Models for stream flow in California project higher high flows, lower low flows, wetter rainy seasons, and drier dry seasons (Ibid.). The projected water cycle extremes are related to strengthening El Niño and La Niña events, and both severe flooding and intense drought are predicted to increase by at least 50% by the end of the century (Yoon et al. 2015). These changes increase the likelihood of Foothill Yellow-legged Frog egg mass and tadpole scouring and stranding, even in unregulated rivers.

A species' vulnerability to climate change is a function of its sensitivity to climate change effects, its exposure to them, and its ability to adapt its behaviors to survive with them (Dawson et al. 2011). Myriad examples exist of species shifting their geographical distribution toward the poles and to higher elevations and changing their growth and reproduction with increases in temperature over time (Parmesan and Yohe 2003). However, in many places, fragmentation of suitable habitat by anthropogenic barriers (e.g., urbanization, agriculture, and reservoirs) limits a species' ability to shift its range (Pounds et al. 2007). The proportion of sites historically occupied by Foothill Yellow-legged Frogs that are now extirpated increases significantly on a north-to-south latitudinal gradient and at drier sites within California, suggesting climate change may contribute to the spatial pattern of the species' declines (Davidson et al. 2002).

An analysis of the climate change sensitivity of 195 species of plants and animals in northwestern North America revealed that, as a group, amphibians and reptiles were estimated to be the most sensitive (Case et al. 2015). Nevertheless, examples exist of amphibians adjusting their breeding behaviors (e.g., calling and migrating to breeding sites) to occur earlier in the year as global warming increases (Beebee 1995, Gibbs and Breisch 2001). Because of the rapid change in temperature, Beebee (1995) posits these are examples of behavioral and physiological plasticity rather than natural selection. However, for

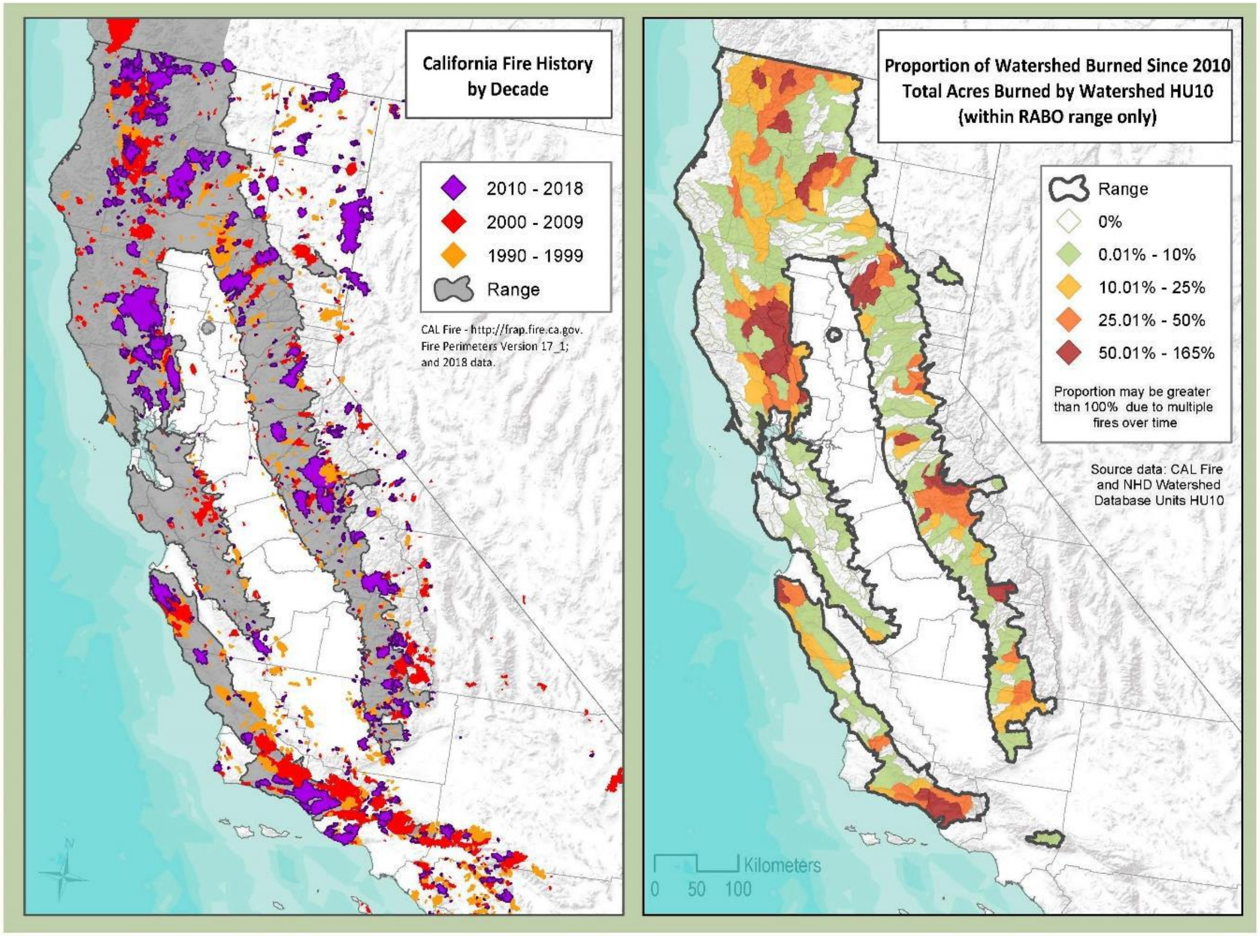


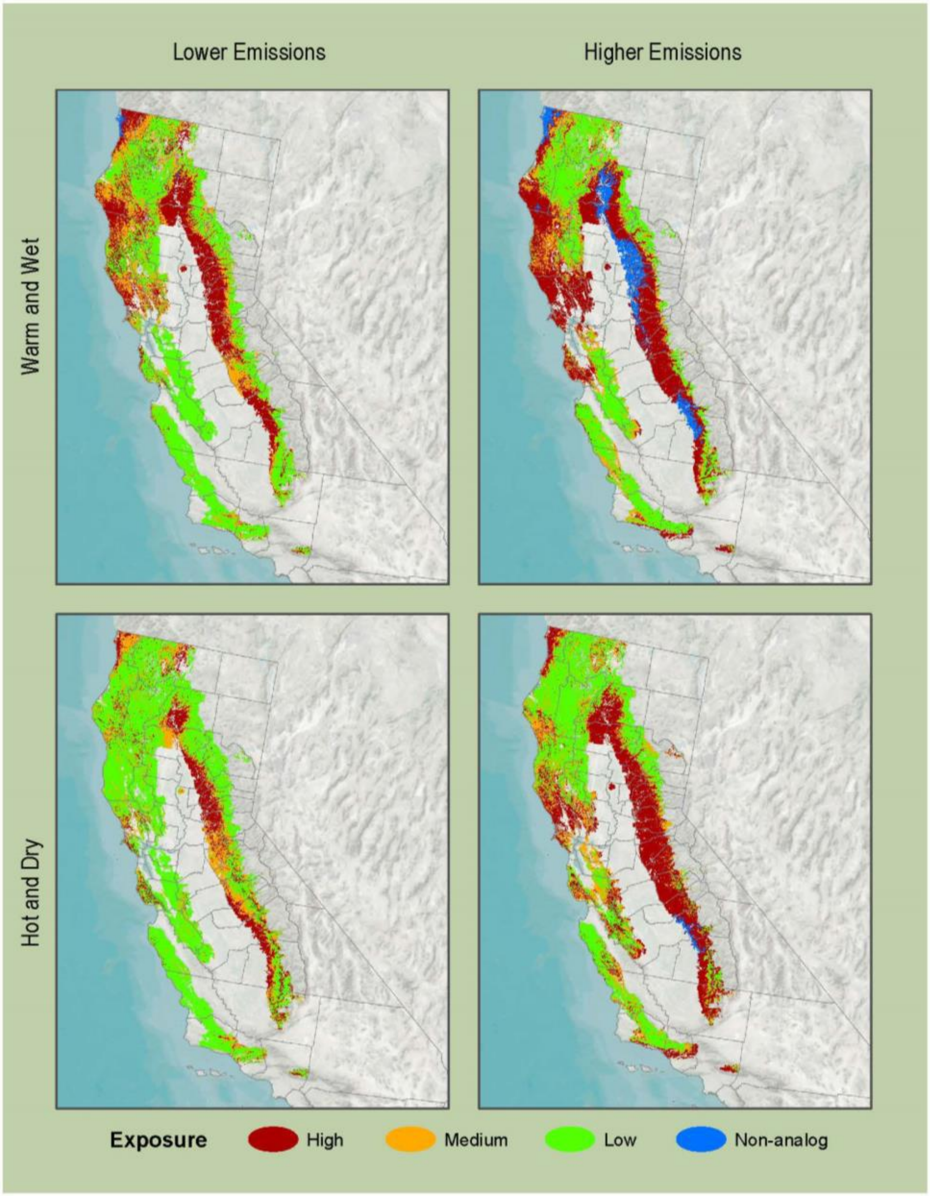
Figure 24. Fire history (1990-2018) and proportion of watershed burned (2010-2018) in California (CAL FIRE, NHD)

species with short generation times or in areas less affected by climate change, populations may be able to undergo evolutionary adaptation to the changing local environmental conditions (Hoffman and Sgrò 2011).

As previously described in the Seasonal Activity and Movements section, Foothill Yellow-legged Frog breeding is closely tied to water temperature, flow, and stage, and the species already adjusts its timing of oviposition by as much as a month or more in the same location during different water years, so the species may have enough inherent flexibility to reduce their vulnerability. The species appears fairly resilient to drought, fire, and flooding, at least in some circumstances. For example, after the 2012-2016 drought, the Loma Fire in late 2016, and severe winter flooding and landslides in 2016 and 2017, Foothill Yellow-legged Frog adults and metamorphs, as well as aquatic insects and rainbow trout, were abundant throughout Upper Llagas Creek in fall of 2017, and the substrate consisted of generally clean gravels and cobbles with only a slight silt coating in some pools (J. Smith pers. comm. 2017). The frogs and fish likely took refuge in a spring-fed pool, and the heavy rains scoured the fine sediments that eroded downstream (Ibid.). These refugia from the effects of climate change reduce the species' exposure, thereby reducing their vulnerability (Case et al. 2015).

Climate change models that evaluate the Foothill Yellow-legged Frog's susceptibility from a species and habitat perspective yield mixed results. An investigation into the possible effects of climate on California's native amphibians and reptiles used ecological niche models, future climate scenarios, and general circulation models to predict species-specific climatic suitability in 2050 (Wright et al. 2013). The results suggested approximately 90-100% of localities currently occupied by Foothill Yellow-legged Frogs are expected to remain climatically suitable in that time, and the proportion of currently suitable localities predicted to change ranges from -20% to 20% (Ibid.). However, a second study using a subset of these models found that 66.4% of currently occupied cells will experience reduced environmental suitability in 2050 (Warren et al. 2014). This analysis included 90 species of native California mammals, birds, reptiles, and amphibians. For context, over half of the taxa were predicted to experience > 80% reductions, a consistent pattern reflected across taxonomic groups (Ibid.).

A third analysis investigated the long-term risk of climate change by modeling the relative environmental stress a vegetative community would undergo in 2099 given different climate and greenhouse gas emission scenarios (Thorne et al. 2016). This model does not incorporate any Foothill Yellow-legged Frog-specific data; it strictly projects climatic stress levels vegetative communities will experience within the species' range boundaries (Ibid.). Unsurprisingly, higher emissions scenarios resulted in a greater proportion of habitat undergoing climatic stress (Figure 25). Perhaps counterintuitively, the warm and wet scenario resulted in a greater amount of stress than the hot and dry scenario. When high emissions and warm and wet changes are combined, a much greater proportion of the vegetation communities will experience "non-analog" conditions, those outside of the range of conditions currently known in California (Ibid.).



Source - model extracts from -Thorne, J.H. et al. (2016) A climate change vulnerability assessment of California's terrestrial vegetation. CDFW.

Figure 25. Vegetative community exposure to climate change in 2099 based on Thorne et al. (2016).

Habitat Restoration and Species Surveys

Potential conflicts between managing riverine habitat below dams for both cold-water adapted salmonids and Foothill Yellow-legged Frogs was discussed previously. In addition to problems with temperatures and pulse flows, some stream restoration projects aimed at physically creating or improving salmonid habitat can also adversely affect the species. For example, boulder deflectors were placed in Hurdygurdy Creek (Del Norte County) to create juvenile steelhead rearing habitat; deflectors change broad, shallow, low-velocity reaches into narrower, deeper, faster reaches preferred by the fish (Fuller and Lind 1992). Foothill Yellow-legged Frogs were documented using the restoration reach as breeding habitat annually prior to placement of the boulders, but no breeding was detected in the following three years, suggesting this project eliminated the conditions the frogs require (Ibid.). In addition, a fish ladder to facilitate salmonid migration above the Alameda Creek Diversion Dam was recently constructed on a Foothill Yellow-legged Frog lek site, and the frogs may become trapped in the ladder (M. Grefsrud pers. comm. 2019). Use of rotenone to eradicate non-native fish as part of a habitat restoration project is rare, but if it is applied in streams occupied by Foothill Yellow-legged Frogs, it can kill tadpoles but is unlikely to impact post-metamorphic frogs (Fontenot et al. 1994). Metamorphosing tadpoles may be able to stay close enough to the surface to breathe air and survive but may display lethargy and experience increased susceptibility to predation (Ibid.).

Commonly when riparian vegetation is removed, regulatory agencies require a greater amount to be planted as mitigation to offset the temporal loss of habitat. This practice can have adverse impacts on Foothill Yellow-legged Frogs by reducing habitat suitability. Foothill Yellow-legged Frogs have been observed moving into areas where trees were recently removed, and they are known to avoid heavily shaded areas (Welsh and Hodgson 2011, M. Grefsrud pers. comm. 2019).

Biologists conducting surveys in Foothill Yellow-legged Frog habitat can trample egg masses or larvae if they are not careful. One method for sampling fish is electroshocking, which runs a current through the water that stuns the fish temporarily allowing them to be captured. Post-metamorphic frogs are unlikely to be killed by electroshocking; however, at high frequencies (60 Hz), they may experience some difficulty with muscle coordination for a few days (Allen and Riley 2012). This could increase their risk of predation. At 30 Hz, there were no differences between frogs that were shocked and controls (Ibid.). Tadpoles are more similar to fish in tail muscle and spinal structure and are at higher risk of injuries; however, researchers who reported observing stunned tadpoles noted they appeared to recover completely within several seconds (Ibid.). Adverse effects to Foothill Yellow-legged Frogs from electrofishing may only happen at frequencies higher than those typically used for fish sampling (Ibid.)

Small Population Sizes

Small populations are at greater risk of extirpation, primarily through the disproportionately greater impact of demographic, environmental, and genetic stochasticity on them compared to large populations, so any of the threats previously discussed will likely have an even greater adverse impact on small populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). This risk of extinction from genetic stochasticity is amplified when connectivity between the small populations, and thus gene flow,

is impeded (Fahrig and Merriam 1985, Taylor et al. 1993, Lande and Shannon 1996, Palstra and Ruzzante 2008). Genetic diversity provides capacity to evolve in response to environmental changes, and the "rescue effect" of gene flow is important in minimizing probability of local extinction (Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). However, the rescue effect is diminished in conditions of high local environmental stochasticity of recruitment or survival (Eriksson et al. 2014). In addition, populations living near their physiological limits and lacking adaptive capacity may not be able to evolve in response to rapid changes (Hoffmann and Sgrò 2011). Furthermore, while pathogens or parasites rarely result in host extinction, they can increase its likelihood in small populations by driving the host populations below a critically low threshold beneath which demographic stochasticity can lead to extinction, even if they possess the requisite genetic diversity to adapt to a changed environment (Gomulkiewicz and Holt 1995, Adams et al. 2017b).

A Foothill Yellow-legged Frog PVA revealed that, even with no dam effects considered (e.g., slower growth and increased egg and tadpole mortality), populations with the starting average density of adult females in regulated rivers (4.6/km [2.9/mi]) were four times more likely to go extinct within 30 years than those with the starting average density of adult females from unregulated rivers (32/km [120/mi]) (Kupferberg et al. 2009c). When the density of females in sparse populations was used (2.1/km [1.3/mi], the 30-year risk of extinction increased 13-fold (Ibid.). With dam effects, a number of the risk factors above contribute to the additional probability of local extinction such as living near their lower thermal tolerance and reduced recruitment and survival from scouring and stranding flows, poor food quality, and increased predation and competition (Kupferberg 1997a; Hoffmann and Sgrò 2011; Kupferberg et al. 2011a,b; Kupferberg et al. 2012; Eriksson et al. 2014). These factors act synergistically, contributing in part to the small size, high divergence, and low genetic diversity exhibited by many Foothill Yellow-legged Frog populations located in highly regulated watersheds (Kupferberg et al. 2012, Peek 2018).

EXISTING MANAGEMENT

Land Ownership within the California Range

Using the Department's Foothill Yellow-legged Frog range boundary and the California Protected Areas Database (CPAD), a GIS dataset of lands that are owned in fee title and protected for open space purposes by over 1,000 public agencies or non-profit organizations, the total area of the species' range in California comprises 13,620,447 ha (33,656,857 ac) (CPAD 2019, CWHR 2019). Approximately 37% is owned by federal agencies, 80% of which (4,071,178 ha [10,060,100 ac]) is managed by the Forest Service (Figure 26). Department of Fish and Wildlife-managed lands, State Parks, and other State agency-managed lands constitute around 2.6% of the range. The remainder of the range includes < 1% Tribal lands, 2.3% other conserved lands (e.g., local and regional parks), and 57% private and government-managed lands that are not protected for open space purposes. It is important to note that even if included in the CPAD, a property's management does not necessarily benefit Foothill Yellow-legged Frogs, but in some cases changes in management to conserve the species may be easier to undertake than on private lands or public lands not classified as conserved.

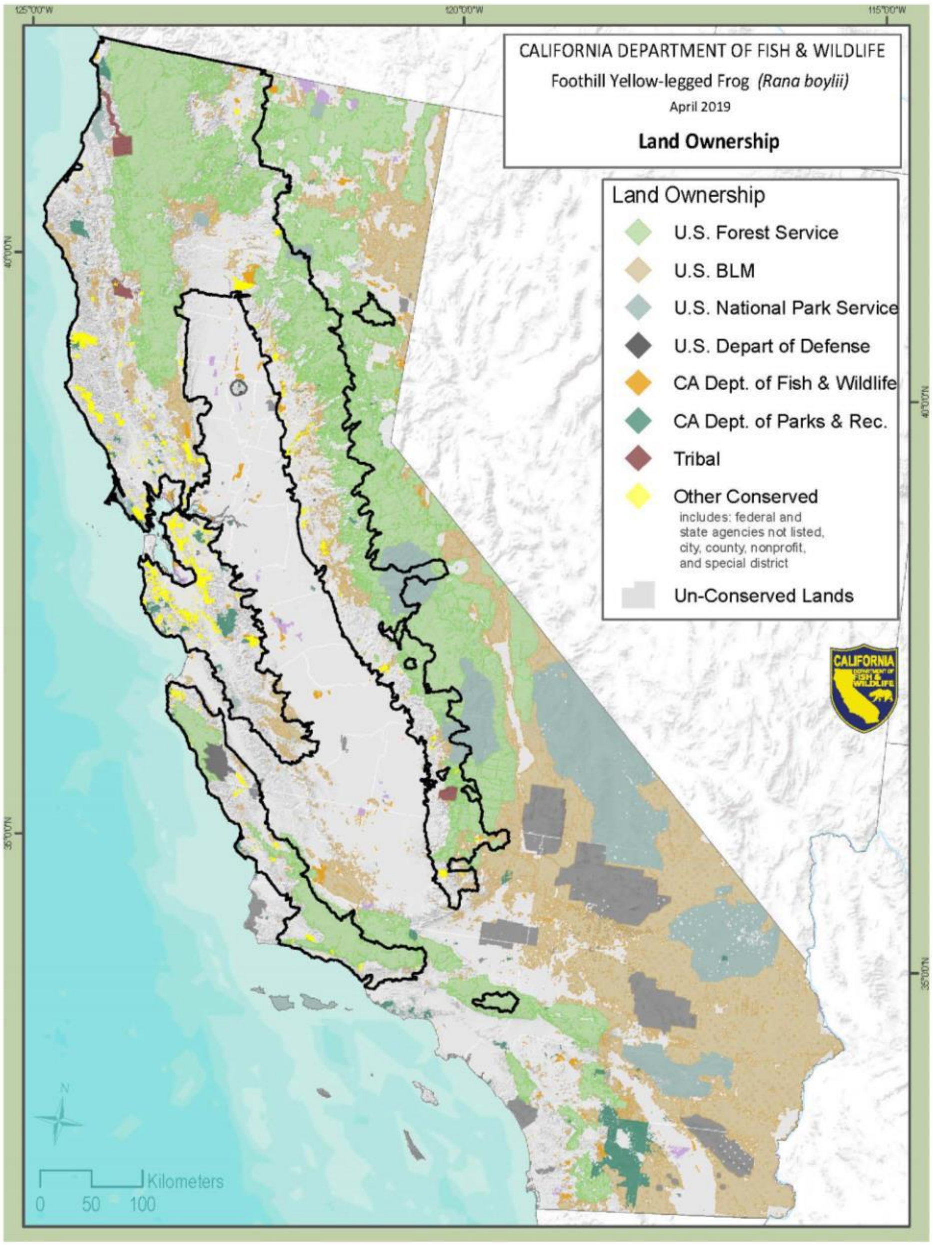


Figure 26. Conserved, Tribal, and other lands (BLM, CMD, CPAD, CWHR, DOD)

Statewide Laws

The laws and regulations governing land management within the Foothill Yellow-legged Frog's range vary by ownership. Several state and federal environmental laws apply to activities undertaken in California that may provide some level of protection for Foothill Yellow-legged Frogs and their habitat. The following is not an exhaustive list.

National Environmental Policy Act and California Environmental Quality Act

Most federal land management actions must undergo National Environmental Policy Act of 1969 (NEPA; 42 U.S.C. § 4321, et seq.) analysis. NEPA requires federal agencies to document, consider alternatives, and disclose to the public the impacts of major federal actions and decisions that may significantly impact the environment. As a BLM and Forest Service Sensitive Species, impacts to Foothill Yellow-legged Legged Frogs are considered during NEPA analysis; however, the law has no requirement to minimize or mitigate adverse effects.

The California Environmental Quality Act (CEQA) is similar to NEPA; it requires state and local agencies to identify, analyze, and consider alternatives, and to publicly disclose environmental impacts from projects over which they have discretionary authority (Pub. Resources Code § 21000 et seq.). CEQA differs substantially from NEPA in requiring mitigation for significant adverse effects to a less than significant level unless overriding considerations are documented. CEQA requires an agency find projects may have a significant effect on the environment if they have the potential to substantially reduce the habitat, decrease the number, or restrict the range of any rare, threatened, or endangered species (Cal. Code Regs., tit. 14, §§ 15065(a)(1), 15380.). CEQA establishes a duty for public agencies to avoid or minimize such significant effects where feasible (Cal. Code regs., tit. 14, § 15021). Impacts to Foothill Yellow-legged Frogs, as an SSC, should be identified, evaluated, disclosed, and mitigated or justified under the Biological Resources section of an environmental document prepared pursuant to CEQA. However, a lead agency is not required to make a mandatory finding of significance conclusion unless it determines on a project-specific basis that the species meets the CEQA criteria for rare, threatened, or endangered.

Clean Water Act and Porter-Cologne Water Quality Control Act

The Clean Water Act originated in 1948 as the Federal Water Pollution Control Act of 1948. It was heavily amended in 1972 and became known as the Clean Water Act (CWA). The purpose of the CWA was to establish regulations for the discharge of pollutants into waters of the United States and establish quality standards for surface waters. Section 404 of the CWA forbids the discharge of dredged or fill material into waters and wetlands without a permit from the ACOE. The CWA also requires an alternatives analysis, and the ACOE is directed to issue their permit for the least environmentally damaging practicable alternative. The definition of waters of the United States has changed substantially over time based on Supreme Court decisions and agency rule changes.

The Porter-Cologne Water Quality Act was established by the State in 1969 and is similar to the CWA in that it establishes water quality standards and regulates discharge of pollutants into state waters, but it

also administers water rights which regulate water diversions and extractions. The SWRCB and nine Regional Water Boards share responsibility for implementation and enforcement of Porter-Cologne as well as the CWA's National Pollutant Discharge Elimination System permitting.

Federal and California Wild and Scenic Rivers Acts

In 1968, the U.S. Congress passed the federal Wild and Scenic Rivers Act (WSRA) (16 U.S.C. § 1271, et seq.) which created the National Wild and Scenic River System. The WSRA requires the federal government to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The WSRA prohibits the federal government from building, licensing, funding or otherwise aiding in the building of dams or other project works on rivers or segments of designated rivers. The WSRA does not give the federal government control of private property including development along protected rivers.

California's Wild and Scenic Rivers Act was enacted in 1972 so rivers that "possess extraordinary scenic, recreational, fishery, or wildlife values shall be preserved in their free-flowing state, together with their immediate environments, for the benefit and enjoyment of the people of the state." (Pub. Res. Code, § 5093.50). Designated waterways are codified in Public Resources Code sections 5093.50-5093.70. In 1981, most of California's designated Wild and Scenic Rivers were adopted into the federal system. Currently in California, 3,218 km (1,999.6 mi) of 23 rivers are protected by the WSRA, most of which are located in the northwest. Foothill Yellow-legged Frogs have been observed in 11 of the 17 designated rivers within their range (CNDDB 2019).

Lake and Streambed Alteration Agreements

Fish and Game Code Section 1602 requires entities to notify the Department of activities that "divert or obstruct the natural flow of, or substantially change or use any material from the bed, channel, or bank of any river, stream, or lake, or deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake." If the activity may substantially adversely affect an existing fish and wildlife resource, the Department may enter into a lake or streambed alteration agreement with the entity that includes reasonable measures necessary to protect the fish or wildlife resource (Fish & G. Code, §1602, subd. (a)(4)(B)). A lake or stream alteration agreement does not authorize take of species listed as candidates, threatened, or endangered under CESA (see Protection Afforded by Listing for CESA compliance requirements).

Medicinal and Adult-Use Cannabis Regulation and Safety Act

The commercial cannabis cultivation industry is unique in that any entity applying for an annual cannabis cultivation license from California Department of Food and Agriculture (CDFA) must include "a copy of any final lake or streambed alteration agreement…or written verification from the California Department of Fish and Wildlife that a lake or streambed alteration agreement is not required" with their license application (Cal. Code Regs., tit. 3, § 8102, subd. (v)). The SWRCB also enforces the laws related to waste discharge and water diversions associated with cannabis cultivation (Cal. Code Regs., tit. 3, § 8102, subd. (p)).

Forest Practice Act

The Forest Practice Act was originally enacted in 1973 to ensure that logging in California is undertaken in a manner that will also preserve and protect the State's fish, wildlife, forests, and streams. This law and the regulations adopted by the California Board of Forestry and Fire Protection (BOF) pursuant to it are collectively referred to as the Forest Practice Rules. The Forest Practice Rules implement the provisions of the Forest Practice Act in a manner consistent with other laws, including CEQA, Porter-Cologne, CESA, and the Timberland Productivity Act of 1982. The California Department of Forestry and Fire Protection (CAL FIRE) enforces these laws and regulations governing logging on private land.

Federal Power Act

The Federal Power Act and its major amendments are implemented and enforced by FERC and require licenses for dams operated to generate hydroelectric power. One of the major amendments required that these licenses "shall include conditions for the protection, mitigation and enhancement of fish and wildlife including related spawning grounds and habitat" (ECPA 1986). Hydropower licenses granted by FERC are usually valid for 30-50 years. If a licensee wants to renew their license, it must file a Notice of Intent and a pre-application document five years before the license expires to provide time for public scoping, any potentially new studies necessary to analyze project impacts and alternatives, and preparation of environmental documents. The applicant must officially apply for the new license at least two years before the current license expires.

As a federal agency, FERC must comply with federal environmental laws prior to issuing a new license or relicensing an existing hydropower project, which includes NEPA and ESA. As a result of environmental compliance or settlement agreements formed during the relicensing process, some operations have been modified and habitat restored to protect fish and wildlife. For example, the Lewiston Dam relicensing resulted in establishment of the Trinity River Restoration Program, which takes an ecosystem-approach to studying dam effects and protecting and restoring fish and wildlife populations downstream of the dam (Snover and Adams 2016). Similarly, relicensing of the Rock Creek-Cresta Project on the North Fork Feather River resulted in establishment of a multi-stakeholder Ecological Resources Committee (ERC). As a result of the ERC's studies and recommendations, pulse flows for whitewater boating were suspended for several years following declines of Foothill Yellow-legged Frogs, and the ERC is currently working toward augmenting the population in an attempt to increase abundance to a viable level.

Administrative and Regional Plans

Forest Plans

NORTHWEST FOREST PLAN

In 1994, BLM and the Forest Service adopted the Northwest Forest Plan to guide the management of over 97,000 km^2 (37,500 mi^2) of federal lands in portions of northwestern California, Oregon, and Washington. The Northwest Forest Plan created an extensive network of forest reserves including

Riparian Reserves. Riparian Reserves apply to all land designations to protect riparian dependent resources. With the exception of silvicultural activities consistent with Aquatic Conservation Strategy objectives, timber harvest is not permitted within Riparian Reserves, which can vary in width from 30 to 91 m (100-300 ft) on either side of streams, depending on the classification of the stream or waterbody (USFS and BLM 1994). Fuel treatment and fire suppression strategies and practices implemented within these areas are designed to minimize disturbance.

Sierra Nevada Forest Plan

Land and Resource Management Plans for forests in the Sierra Nevada were changed in 2001 by the Sierra Nevada Forest Plan Amendment and subsequently adjusted via a supplemental Environmental Impact Statement and Record of Decision in 2004, referred to as the Sierra Nevada Framework (USFS 2004). This established an Aquatic Management Strategy with Goals including maintenance and restoration of habitat to support viable populations of riparian-dependent species; spatial and temporal connectivity for aquatic and riparian species within and between watersheds to provide physically, chemically, and biologically unobstructed movement for their survival, migration, and reproduction; instream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats; the physical structure and condition of streambanks and shorelines to minimize erosion and sustain desired habitat diversity; and prevention of new introductions of invasive species and reduction of invasive species impacts that adversely affect the viability of native species. The Sierra Nevada Framework also includes Riparian Conservation Objectives and associated standards and guidelines specific to aquatic-dependent species, including the Foothill Yellow-legged Frog.

Resource Management Plans

Sequoia, Kings Canyon, and Yosemite National Parks fall within the historical range of the Foothill Yellow-legged Frog, but the species has been extirpated from these areas. The guiding principles for managing biological resources on National Park Service lands include maintenance of animal populations native to park ecosystems (Hayes et al. 2016). They also commit the agency to work with other land managers on regional scientific and planning efforts and maintenance or reintroduction of native species to the parks including conserving Foothill Yellow-legged Frogs in the Sierra Nevada (USDI NPS 1999 as cited in Hayes et al. 2016). A Sequoia and Kings Canyon National Parks Resource Management Plan does not include specific management goals for Foothill Yellow-legged Frogs, but it does include a discussion of the factors leading to the species' decline and measures to restore the integrity of aquatic ecosystems (Ibid.). The Yosemite National Park Resource Management Plan includes a goal of restoring Foothill Yellow-legged Frogs to the Upper Tuolumne River below Hetch Hetchy Reservoir (USDI NPS 2003 as cited in Hayes et al. 2016).

FERC Licenses

Dozens of hydropower dams have been relicensed in California since 1999, and several are in the process of relicensing (FERC 2019). In addition to following the Federal Power Act and other applicable federal laws, Porter-Cologne Water Quality Act requires non-federal dam operators to obtain a Water Quality Certification (WQC) from the SWRCB. Before it can issue the WQC, the SWRCB must consult with

the Department regarding the needs of fish and wildlife. Consequently, SWRCB includes conditions in the WQC that seek to minimize adverse effects to native species, and Foothill Yellow-legged Frogs have received some special considerations due to their sensitivity to dam operations during these licensing processes. As discussed above, the typical outcome is formation of an ERC-type group to implement the environmental compliance requirements and recommend changes to flow management to reduce impacts. Foothill Yellow-legged Frog-specific requirements fall into three general categories: data collection, modified flow regimes, and standard best management practices.

Data Collection

When little is known about the impacts of different flows and temperatures on Foothill Yellow-legged Frog occupancy and breeding success, data are collected and analyzed to inform recommendations for future modifications to operations such as temperature trigger thresholds. These surveys include locating egg masses and tadpoles, monitoring temperatures and flows, and recording their fate (e.g., successful development and metamorphosis, displacement, desiccation) during different flow operations and different water years. Examples of licenses with these conditions include the Lassen Lodge Project (FERC 2018), Rock Creek-Cresta Project (FERC 2009a), and El Dorado Project (EID 2007).

Modified Flow Regimes

When enough data exist to understand the effect of different operations on Foothill Yellow-legged Frog occupancy and success, license conditions may include required minimum seasonal instream flows, specific thermal regimes, gradual ramping rates to reduce the likelihood of early life stage scour or stranding, or freshet releases (winter/spring flooding simulation) to maintain riparian processes, and cancellation or prohibition of recreational pulse flows during the breeding season. Examples of licenses with these conditions include the Poe Hydroelectric Project (SWRCB 2017), Upper American Project (FERC 2014), and Pit 3, 4, 5 Project (FERC 2007b).

Best Management Practices

Efforts to reduce the impacts from maintenance activities and indirect operations include selective herbicide and pesticide application, aquatic invasive species monitoring and control, erosion control, and riparian buffers. Examples of licenses with these conditions include the South Feather Project (SWRCB 2018), Spring Gap-Stanislaus Project (FERC 2009b), and Chili Bar Project (FERC 2007a).

Habitat Conservation Plans and Natural Community Conservation Plans

Non-federal entities can obtain authorization for take of federally threatened and endangered species incidental to otherwise lawful activities through development and implementation of a Habitat Conservation Plan (HCP) pursuant to Section 10 of the ESA. The take authorization can extend to species not currently listed under ESA but which may become listed as threatened or endangered over the term of the HCP, which is often 25-75 years. California's companion law, the Natural Community Conservation Planning Act of 1991, takes a broader approach than either CESA or ESA. A Natural Community Conservation Plan (NCCP) identifies and provides for the protection of plants, animals, and their

habitats, while allowing compatible and appropriate economic activity. There are currently four HCPs that include Foothill Yellow-legged Frogs as a covered species, two of which are also NCCPs.

Humboldt Redwood (formerly Pacific Lumber) Company

The Humboldt Redwood Company (HRC) HCP covers 85,672 ha (211,700 ac) of private Coast Redwood and Douglas-fir forest in Humboldt County (HRC 2015). It is a 50-year HCP/incidental take permit (ITP) that was executed in 1999, revised in 2015 as part of its adaptive management strategy, and expires on March 1, 2049. The HCP includes an Amphibian and Reptile Conservation Plan and an Aquatics Conservation Plan with measures designed to sustain viable populations of Foothill Yellow-legged Frogs and other covered aquatic herpetofauna. These conservation measures include prohibiting or limiting tree harvest within Riparian Management Zones (RMZ), controlling sediment by maintaining roads and hillsides, restricting controlled burns to spring and fall in areas outside of the RMZ, conducting effectiveness monitoring throughout the life of the HCP, and use the data collected to adapt monitoring and management plans accordingly.

Watershed assessment surveys include observations of Foothill Yellow-legged Frogs and have documented their widespread distribution on HRC lands with a pattern of fewer near the coast in the fog belt and more inland (S. Chinnici pers. comm. 2017). The watersheds within the property are largely unaffected by dam-altered flow regimes or non-native species, so aside from the operations described under Timber Harvest above that are minimized to the extent feasible, the focus on suitable temperatures and denser canopy cover for salmonids may reduce habitat suitability for Foothill Yellow-legged Frogs over time (Ibid.).

San Joaquin County Multi-Species Habitat Conservation and Open Space Plan

The San Joaquin County Multi-Species Habitat Conservation and Open Space Plan (SJMSCP) is a 50-year HCP/ITP that was signed by the USFWS on November 14, 2000 (San Joaquin County 2000). The SJMSCP covers almost all of San Joaquin County except federal lands, a few select projects, and some properties with certain land uses, roughly 364,000 ha (900,000 ac). At the time of execution, approximately 70 ha (172 ac) of habitat within the SJMSCP area in the southwest portion of the county were considered occupied by Foothill Yellow-legged Frogs with another 1,815 ha (4,484 ac) classified as potential habitat, but it appears the species had been considered extirpated before then (Jennings and Hayes 1994, San Joaquin County 2000, Lind 2005). The HCP estimates around 8% of the combined modeled habitat would be converted to other uses over the permit term, but the establishment of riparian preserves with buffers around Corral Hollow Creek, where the species occurred historically, was expected to offset those impacts (San Joaquin County 2000, SJCOG 2018). However, the HCP did not require surveys to determine if Foothill Yellow-legged Frogs are benefiting (M. Grefsrud pers. comm. 2019).

East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan

The East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan (ECCC HCP/NCCP) is a multi-jurisdictional 30-year plan adopted in 2007 that covers over 70,423 ha (174,018 ac) in eastern Contra Costa County (Jones & Stokes 2006). The Foothill Yellow-legged Frog appears to be

extirpated from the ECCC HCP/NCCP area (CNDDB 2019). Nevertheless, suitable habitat was mapped, and impacts were estimated at well under 1% of both breeding and migratory habitat (Jones & Stokes 2006). One of the HCP/NCCP's objectives is acquiring high-quality Foothill Yellow-legged Frog habitat that has been identified along Marsh Creek (Ibid.). In 2017, the Viera North Peak 65 ha (160 ac) property was acquired that possesses suitable habitat for Foothill Yellow-legged Frogs (ECCCHC 2018).

SANTA CLARA VALLEY HABITAT PLAN

The Santa Clara Valley Habitat Plan (SCVHP) is a 50-year HCP/NCCP covering over 210,237 ha (519,506 ac) in Santa Clara County (ICF 2012). As previously mentioned, Foothill Yellow-legged Frogs appear to have been extirpated from lower elevation sites, particularly below reservoirs in this area. Approximately 17% of modeled Foothill Yellow-legged Frog habitat, measured linearly along streams, was already permanently preserved, and the SCVHP seeks to increase that to 32%. The maximum allowable habitat loss is 11 km (7 mi) permanent loss and 3 km (2 mi) temporary loss, while 167 km (104 mi) of modeled habitat is slated for protection. By mid-2018, 8% of impact area had been accrued and 3% of habitat protected (SCVHA 2019).

GREEN DIAMOND AQUATIC HABITAT CONSERVATION PLAN

Green Diamond Resources Company has an Aquatic Habitat Conservation Plan (AHCP) covering 161,875 ha (400,000 ac) of their land that is focused on cold-water adapted species, but many of the conservation measures are expected to benefit Foothill Yellow-legged Frogs as well (K. Hamm pers. comm. 2017). Examples include slope stability and road management measures to reduce stream sedimentation from erosion and landslides, and limiting water drafting during low flow periods with screens over the pumps to avoid entraining animals (Ibid.). Although creating more open canopy areas and warmer water temperatures is not the goal of the AHCP, the areas that are suitable for Foothill Yellow-legged Frog breeding are likely to remain that way because they are wide channels that receive sufficient sunlight (Ibid.).

SUMMARY OF LISTING FACTORS

CESA's implementing regulations identify key factors relevant to the Department's analyses and the Fish and Game Commission's decision on whether to list a species as threatened or endangered. A species will be listed as endangered or threatened if the Commission determines that the species' continued existence is in serious danger or is threatened by any one or any combination of the following factors: (1) present or threatened modification or destruction of its habitat; (2) overexploitation; (3) predation; (4) competition; (5) disease; or (6) other natural occurrences or human-related activities (Cal. Code Regs., tit. 14, § 670.1, subd. (i).

This section provides summaries of information from the foregoing sections of this status review, arranged under each of the factors to be considered by the Commission in determining whether listing is warranted.

Present or Threatened Modification or Destruction of Habitat

Most of the factors affecting ability to survive and reproduce listed above involve destruction or degradation of Foothill Yellow-legged Frog habitat. The most widespread, and potentially most significant, threats are associated with dams and their flow regimes, particularly in areas where they are concentrated and occur in a series along a river. Dams and the way they are operated can have up- and downstream impacts to Foothill Yellow-legged Frogs. They can result in ~~confusing~~ aseasonal or asynchronous ~~natural~~ breeding cues, scouring and stranding of egg masses and tadpoles, reducing quality and quantity of breeding and rearing habitat, reducing tadpole growth rate, impeding gene flow among populations, and establishing and spreading non-native species (Hayes et al. 2016). These impacts appear to be most severe when the dam is operated for the generation of hydropower utilizing hydropeaking and pulse flows (Kupferberg et al. 2009c, Peek 2018). Foothill Yellow-legged Frog abundance below dams is an average of five times lower than in unregulated rivers (Kupferberg et al. 2012). The number, height, and distance upstream of dams in a watershed influenced whether Foothill Yellow-legged Frogs still occurred at sites where they had been present in 1975 in California (Ibid.). Water diversions for agricultural, industrial, and municipal uses also reduce the availability and quality of Foothill Yellow-legged Frog habitat. Dams are concentrated in the Bay Area, Sierra Nevada, and southern California (Figure 17), while hydropower plants are densest in the northern and central Sierra Nevada (Figure 18).

With predicted increases in the human population, ambitious renewable energy targets, higher temperatures, and more extreme and variable precipitation falling increasingly more as rain rather than snow, the need for more and taller dams and water diversions for hydroelectric power generation, flood control, and water storage and delivery is not expected to abate in the future. California voters approved Proposition 1, the Water Quality, Supply and Infrastructure Improvement Act of 2014, which dedicated $2.7 billion to water storage projects (PPIC 2018). In 2018, the California Water Commission approved funding for four new dams in California: expansion of Pacheco Reservoir (Santa Clara County), expansion of Los Vaqueros Reservoir (Contra Costa County), Temperance Flat Dam (new construction) on the San Joaquin River (Fresno County), and the off-stream Sites Reservoir (new construction) diverting the Sacramento River (Colusa County) (CWC 2019). No historical records of Foothill Yellow-legged Frogs from the Los Vaqueros or Sites Reservoir areas exist in the CNDDB, and one historical (1950) collection is documented from the Pacheco Reservoir area (CNDDB 2019). However, the proposed Temperance Flat Dam site is downstream of one of the only known extant populations of Foothill Yellow-legged Frogs in the East/Southern Sierra clade (Ibid.).

The other widespread threat to Foothill Yellow-legged Frog habitat is climate change, although the severity of its impacts is somewhat uncertain. While drought, wildland fires, floods, and landslides are natural and ostensibly necessary disturbance events for preservation of native biodiversity, climate change is expected to result in increased frequency and severity of these events in ways that may exceed species' abilities to adapt (Williams et al. 2008, Hoffmann and Sgrò 2011, Keely and Syphard 2016). These changes can lead to increased competition, predation, and disease transmission as species become concentrated in areas that remain wet into the late summer (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Loss of riparian vegetation from wildland fires can result in increased stream temperatures or concentrations of nutrients and trace heavy metals that inhibit growth and survival (Spencer and Hauer 1991, Megahan et al. 1995, Burton et al. 2016). Stream sedimentation from landslides following fire or excessive precipitation can destroy or degrade breeding and rearing habitat (Harvey and Lisle 1998, Olson and Davis 2009, Kupferberg et al. 2011b). At least some models predict unprecedented dryness in the latter half of the century (Cook et al. 2015). The effects of climate change will be realized across the Foothill Yellow-legged Frog's range, and the~~their~~ severity of these effects will likely differ in ways that are difficult to predict. However, the impacts from extended droughts will likely be greatest in the areas that are naturally more arid, the lower elevations and latitudes of southern California and the foothills surrounding the Central Valley (Figure 21).

While most future urbanization is predicted to occur in areas outside of the Foothill Yellow-legged Frog's range, it has already contributed to the loss and fragmentation of Foothill Yellow-legged Frog habitat in California. In addition, the increased predation, wildland fires, introduced species, road mortality, disease transmission, air and water pollution, and disturbance from recreation that can accompany urbanization expand its impact far beyond its physical footprint (Davidson et al. 2002, Syphard et al. 2007, Cook et al. 2012, Bar-Massada et al. 2014). Within the Foothill Yellow-legged Frog's historical range, these effects appear most significant and extensive in terms of population extirpations in southern California and the San Francisco Bay Area.

Several other activities have the potential to destroy or degrade Foothill Yellow-legged Frog habitat, but they are less common across the range. They also tend to have relatively small areas of impact, although they can be significant in those areas, particularly if populations are already small and declining. These include impacts from mining, cannabis cultivation, vineyard expansion, overgrazing, timber harvest, recreation, and some stream habitat restoration projects (Harvey and Lisle 1998, Belsky et al. 1999, Merelender 2000, Pilliod et al. 2003, Bauer et al. 2015, Kupferberg and Furey 2015).

Overexploitation

Foothill Yellow-legged Frogs are not threatened by overexploitation. There is no known pet trade for Foothill Yellow-legged Frogs (Lind 2005). During the massive frog harvest that accompanied the Gold Rush, some Foothill Yellow-legged Frogs were collected, but because they are relatively small and have irritating skin secretions, there was much less of a market for them (Jennings and Hayes 1985). Within these secretions is a peptide with antimicrobial activity that is particularly potent against *Candida albicans*, a human pathogen that has been developing resistance to traditional antifungal agents (Conlon et al. 2003). However, the peptide's therapeutic potential is limited by its strong hemolytic activity, so further studies will focus on synthesizing analogs that can be used as antifungals, and collection of Foothill Yellow-legged Frogs for lab cultures is unlikely (Ibid.).

Like all native California amphibians, collection of Foothill Yellow-legged Frogs is unlawful without a permit from the Department. They may only be collected for scientific, educational, or propagation reasons through a Scientific Collecting Permit (Fish & G. Code § 1002 et seq.). The Department has the discretion to limit or condition the number of individuals collected or handled to ensure no significant adverse effects. Incidental harm from authorized activities on other aquatic species can be avoided or minimized by the inclusion of special terms and conditions in permits.

Predation

Predation is a likely contributor to Foothill Yellow-legged Frog population declines where the habitat is degraded by one or many other risk factors (Hayes and Jennings 1986). Predation by native gartersnakes can be locally substantial; however, it may only have an appreciable population-level impact if the availability of escape refugia is diminished. For example, when streams dry and only pools remain, Foothill Yellow-legged Frogs are more vulnerable to predation by native and non-native species because they are concentrated in a small area with little aquatic cover.

Several studies have demonstrated the synergistic impacts of predators and other stressors. Foothill Yellow-legged Frogs, primarily as demonstrated through studies on tadpoles, are more susceptible to predation when exposed to some agrochemicals, cold water, high velocities, excess sedimentation, and even the presence of other species of predators (Harvey and Lisle 1998, Adams et al. 2003, Olson and Davis 2009, Kupferberg et al. 2011b, Kerby and Sih 2015, Catenazzi and Kupferberg 2018). Foothill Yellow-legged Frog tadpoles appear to be naïve to chemical cues from some non-native predators; they have not evolved those species-specific predator avoidance behaviors (Paoletti et al. 2011). Furthermore, early life stages are often more sensitive to environmental stressors, making them more vulnerable to predation, and Foothill Yellow-legged Frog population dynamics are highly sensitive to egg and tadpole mortality (Kats and Ferrer, 2003, Kupferberg et al. 2009c). Predation pressure is likely positively associated with proximity to anthropogenic changes in the environment, so in more remote or pristine places, it probably does not have a serious population-level impact.

Competition

Intra- and interspecific competition in Foothill Yellow-legged Frogs has been documented. Intraspecific male-to-male competition for females has been reported (Rombough and Hayes 2007). Observations include physical aggression and a non-random mating pattern in which larger males were more often engaged in breeding (Rombough and Hayes 2007, Wheeler and Welsh 2008). A behavior resembling clutch-piracy, where a satellite male attempts to fertilize already laid eggs, has also been documented (Rombough and Hayes 2007). These acts of competition play a role in population genetics, but they likely do not result in serious physical injury or mortality. Intraspecific competition among Foothill Yellow-legged Frog tadpoles was negligible (Kupferberg 1997a).

Interspecific competition appears to have a greater possibility of resulting in adverse impacts. Kupferberg (1997a) did not observe a significant change in tadpole mortality for Foothill Yellow-legged Frogs raised with Pacific Treefrogs compared to single-species controls. However, when reared together, Foothill Yellow-legged Frog tadpoles lost mass, while Pacific Treefrog tadpoles increased mass (Kerby and Sih 2015). As described previously under Introduced Species, Foothill Yellow-legged Frog tadpoles experienced significantly higher mortality and smaller size at metamorphosis when raised with bullfrog tadpoles (Kupferberg 1997a). The mechanism of these declines appeared to be exploitative competition, as opposed to interference, through the reduction of available algal resources from bullfrog tadpole grazing in the shared enclosures (Ibid.).

The degree to which competition threatens Foothill Yellow-legged Frogs likely depends on the number and density of non-native species in the area rather than intraspecific competition, and co-occurrence of Foothill Yellow-legged Frog and bullfrog tadpoles may be somewhat rare since the latter tends to breed in lentic (still water) environments (M. van Hattem pers. comm. 2019). Interspecific competition with other native species may have some minor adverse consequences on fitness.

Disease

Currently, the only disease known to pose a serious risk to Foothill Yellow-legged Frogs is Bd. Until 2017, the only published studies on the impact of Bd on Foothill Yellow-legged Frog suggested it could reduce growth and body condition but was not lethal (Davidson et al. 2007, Lowe 2009, Adams et al. 2017b). However, two recent mass mortality events caused by chytridiomycosis proved they are susceptible to lethal effects, at least under certain conditions like drought-related concentration and presence of bullfrogs (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Some evidence indicates disease may have played a principal role in the disappearance of the species from southern California (Adams et al. 2017b). Bd is likely present in the environmental throughout the Foothill Yellow-legged Frog's range, and with bullfrogs and treefrogs acting as carriers, it will remain a threat to the species; however, given the dynamics of the two recent die-offs in the San Francisco Bay area, the probability of future outbreaks may be greater in areas where the species is under additional stressors like drought and introduced species (Adams et al. 2017a, Kupferberg and Catenazzi 2019). Therefore, as with predation, Foothill Yellow-legged Frogs are less likely to experience the adverse impacts of diseases in more remote areas with fewer anthropogenic changes to the environment.

Other Natural Events or Human-Related Activities

Agrochemicals, particularly organophosphates that act as endocrine disruptors, can travel substantial distances from the area of application through atmospheric drift and have been implicated in the disappearance and declines of many species of amphibians in California including Foothill Yellow-legged Frogs (LeNoir et al. 1999, Davidson 2004, Lind 2005, Olson and Davis 2009). Foothill Yellow-legged Frogs appear to be significantly more sensitive to the adverse impacts of some pesticides than other native species (Sparling and Fellers 2009, Kerby and Sih 2015). These include smaller body size, slower development rate, increased time to metamorphosis, immunosuppression, and greater vulnerability to predation and malformations (Kiesecker 2002, Hayes et al. 2006, Sparling and Fellers 2009, Kerby and Sih 2015). Some of the most dramatic declines experienced by ranids in California occurred in the Sierra Nevada east of the San Joaquin Valley where over half of the state's total pesticide usage occurs (Sparling et al. 2001).

Many Foothill Yellow-legged Frog populations are small, isolated from other populations, and possess low genetic diversity (McCartney-Melstad et al. 2018, Peek 2018). Genetic diversity is important in providing a population the capacity to evolve in response to environmental changes, and connectivity among populations is important for gene exchange and in minimizing probability of local extinction

(Lande and Shannon 1996, Williams et al. 2008, Eriksson et al. 2014). Small populations are at much greater risk of extirpation primarily through the disproportionate impact of demographic, environmental, and genetic stochasticity than robust populations (Lande and Shannon 1996, Palstra and Ruzzante 2008). Based on a Foothill Yellow-legged Frog PVA, populations in regulated rivers face a 4- to 13-fold greater extinction risk in 30 years than populations in unregulated rivers due to smaller population sizes (Kupferberg et al. 2009c). The threat posed by small population sizes is significant and the general pattern shows increases in severity from north to south; however, many sites, primarily in the northern Sierra Nevada, in watersheds with large hydropower projects are also at high risk.

PROTECTION AFFORDED BY LISTING

It is the policy of the State to conserve, protect, restore and enhance any endangered or threatened species and its habitat (Fish & G. Code, § 2052). The conservation, protection, and enhancement of listed species and their habitat is of statewide concern (Fish & G. Code, § 2051(c)). CESA defines “take” as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill (Fish & G. Code, § 86). The Fish and Game Code provides the Department with related authority to authorize “take” of species listed as threatened or endangered under certain circumstances (see, e.g., Fish & G. Code, §§ 2081, 2081.1, 2086, & 2835).

If the Foothill Yellow-legged Frog is listed under CESA, impacts of take caused by activities authorized through incidental take permits must be minimized and fully mitigated according to state standards (Fish & G. Code, § 2081, subd. (b)). These standards typically include protection of land in perpetuity with an easement, development and implementation of a species-specific adaptive management plan, and funding through an endowment to pay for long-term monitoring and maintenance to ensure the mitigation land meets performance criteria. Obtaining an incidental take permit is voluntary. The Department cannot force compliance; however, any person violating the take prohibition may be criminally and civilly liable under state law.

Additional protection of Foothill Yellow-legged Frogs following listing would be expected to occur through state and local agency environmental review under CEQA. CEQA requires affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on rare, threatened, and endangered species. In common practice, potential impacts to listed species are examined more closely in CEQA documents than potential impacts to unlisted species. Where significant impacts are identified under CEQA, the Department expects project-specific avoidance, minimization, and mitigation measures to benefit the species. State listing, in this respect, and consultation with the Department during state and local agency environmental review under CEQA, would be expected to benefit the Foothill Yellow-legged Frog in terms of reducing impacts from individual projects, which might otherwise occur absent listing.

For some species, CESA listing may prompt increased interagency coordination and the likelihood that state and federal land and resource management agencies will allocate funds toward protection and recovery actions. In the case of the Foothill Yellow-legged Frog, some multi-agency efforts exist, often associated with FERC license requirements, to improve habitat conditions and augment declining populations. The USFWS is leading an effort to develop regional Foothill Yellow-legged Frog conservation strategies, and CESA listing may result in increased priority for limited conservation funds.

LISTING RECOMMENDATION

CESA directs the Department to prepare this report regarding the status of the Foothill Yellow-legged Frog in California based upon the best scientific information available (Fish & G. Code, § 2074.6). CESA also directs the Department based on its analysis to indicate in the status report whether the petitioned action (i.e., listing as threatened) is warranted (Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

Under CESA, an endangered species is defined as "a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease" (Fish & G. Code, § 2062). A threatened species is defined as "a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA]" (Fish and G. Code, § 2067).

The Department includes and makes its recommendation in its status report as submitted to the Commission in an advisory capacity based on the best available science. In consideration of the scientific information contained herein, the Department has determined that listing the Foothill Yellow-legged Frog under CESA by genetic clade is the prudent approach due to the disparate degrees of imperilment among them. In areas of uncertainty, the Department recommends the higher protection status until clade boundaries can be better defined.

NORTHWEST/NORTH COAST: Not warranted at this time.

Clade-level Summary: This is the largest clade with the most robust populations (highest densities) and the greatest genetic diversity. This area is the least densely populated by humans; contains relatively few hydroelectric dams, particularly further north; and has the highest precipitation in the species' California range. The species is still known to occur in most, if not all, historically occupied watersheds; presumed extirpations are mainly concentrated in the southern portion of the clade around the heavily urbanized San Francisco Bay area. The proliferation of cannabis cultivation, particularly illicit grows in and around the Emerald Triangle, the apparent increase in severe wildland fires in the area, and potential climate change effects are cause for concern, so the species should remain a Priority 1 SSC here with continued monitoring for any change in its status.

WEST/CENTRAL COAST: Endangered.

Clade-level Summary: Foothill Yellow-legged Frogs appear to be extirpated from a relatively large proportion of historically occupied sites within this clade, particularly in the heavily urbanized northern portion around the San Francisco Bay. In the northern portion of the clade, nearly all the remaining populations (which may be fewer than a dozen) are located above dams, which line the mountains surrounding the Bay Area, and two are known to have undergone recent disease-associated die-offs. These higher elevation sites are more often intermittent or ephemeral streams than the lower in the watersheds. As a result, the more frequent and extreme droughts that have dried up large areas seem to have contributed to recent declines. Illegal cannabis cultivation, historical mining effects, overgrazing, and recreation likely contributed to declines and may continue to threaten remaining populations.

SOUTHWEST/SOUTH COAST: Endangered.

Clade-level Summary: The most extensive extirpations have occurred in this clade, and only two known extant populations remain. Both are small with apparently low genetic diversity, making them especially vulnerable to extirpation. This is also an area with a large human population, many dams, and naturally arid, fire-prone environments, particularly in the southern portion of the clade. Introduced species are widespread, and cannabis cultivation is rivaling the Emerald Triangle in some areas (e.g., Santa Barbara County). Introduced species, expanded recreation, disease, and flooding appear to have contributed to the widespread extirpations in southern California over 40 years ago.

FEATHER RIVER: Threatened.

Clade-level Summary: This is the smallest clade and has a high density of hydroelectric dams. It also recently experienced one of the largest, most catastrophic wildfires in California history. Despite these threats, Foothill Yellow-legged Frogs appear to continue to be relatively broadly distributed within the clade, although with all the dams in the area, most populations are likely disconnected. The area is more mesic and experienced less of a change in precipitation in the most recent drought than the clades south of it. The clade is remarkable genetically and morphologically as it is the only area where Foothill Yellow-legged Frogs and Sierra Nevada Yellow-legged Frogs overlap and can hybridize. The genetic variation within the clade is greater than the other clades except for the Northwest/North Coast. Most of the area within the clade's boundaries is Forest Service-managed, and little urbanization pressure or known extirpations exist in this area. Recent FERC licenses in this area require Foothill Yellow-legged Frog specific conservation, which to date has included cancelling pulse flows, removing encroaching vegetation, and translocating egg masses and in situ head-starting to augment a population that had recently declined.

NORTHEAST/NORTHERN SIERRA: Threatened.

Clade-level Summary: The Northeast/Northern Sierra clade shares many of the same threats as the Feather River clade (e.g., relatively small area with many hydroelectric dams). The area is also more mesic and experienced less of a change in precipitation during the recent drought than more southern clades. However, this pattern may not continue as some models suggest loss of snowmelt will be greater in the northern Sierra Nevada, and one of the climate change exposure models suggests a comparatively large proportion of the lower elevations will experience climatic conditions not currently known from the area (i.e., non-analog) by the end of the century. Recent surveys suggest the area continues to support several populations of the species, some of which seem to remain robust, with a fairly widespread distribution. However, genetic analyses from several watersheds suggest many of these populations are isolated and diverging, particularly in regulated reaches with hydropeaking flows.

EAST/SOUTHERN SIERRA: Endangered.

Clade-level Summary: Like the Southwest/South Coast clade, widespread extirpations in this area were observed as early as the 1970s. Dams and introduced species were credited as causal factors in these declines in distribution and abundance, and mining and disease may also have contributed. This area is relatively arid, and drought effects appear greater here than in northern areas that exhibit both more precipitation and a smaller difference between drought years and the historical average. There is a relatively high number of hydroelectric power generating dams in series along the major rivers in this clade and at least one new proposed dam near one of the remaining populations. This area is also the most heavily impacted by agrochemicals from the San Joaquin Valley.

Commented [RAP19]: Just realizing the use of hydropower, hydroelectric and hydroelectric power may benefit from one global term. It seems to switch around throughout, and ultimately all means the same…for simplicity I'd recommend using "hydropower" globally.

MANAGEMENT RECOMMENDATIONS

The Department has evaluated existing management recommendations and available literature applicable to the management and conservation of the Foothill Yellow-legged Frog to arrive at the following recommendations. These recommendations, which represent the best available scientific information, are largely derived the from the Foothill Yellow-legged Frog Conservation Assessment, the California Energy Commission's Public Interest Energy Research Reports, the Recovery Plans of West Coast Salmon and Steelhead, and the California Amphibian and Reptile Species of Special Concern (Kupferberg et al. 2009b,c; 2011a; NMFS 2012, 2013, 2014, 2016; Hayes et al. 2016, Thomson et al. 2016).

Conservation Strategies

Maintain current distribution and genetic diversity by protecting existing Foothill Yellow-legged Frog populations and their habitats and providing opportunities for increased connectivity and ~~genetic exchange~~gene flow. Increase abundance to viable levels in populations at risk of extirpation due to small sizes, when appropriate, through in situ or ex situ captive rearing and/or translocations. Use habitat suitability and hydrodynamic habitat models to identify historically occupied sites that may currently support Foothill Yellow-legged Frogs, or they could with minor habitat improvements or modified management. Re-establish extirpated populations in suitable habitat through captive propagation, rearing, and/or translocations. Prioritize areas in the southern portions of the species' range where extirpations and loss of diversity have been the most severe.

If establishing reserves, prioritize areas containing high genetic variation in Foothill Yellow-legged Frogs (and among various native species) and climatic gradients where selection varies over small geographical area. ~~because e~~Environmental heterogeneity can provide a means of maintaining phenotypic variability, which increases the adaptive capacity of populations as conditions change. These reserves should provide connectivity to other occupied areas to facilitate gene flow and allow for ongoing selection to fire, drought, thermal stresses, and changing species interactions.

Commented [RAP20]: Great sentence but should split it up into two parts.

Research and Monitoring

Attempt to rediscover potentially remnant populations in areas where they are considered extirpated, prioritizing the southern portions of the species' range. Collect environmental DNA in addition to conducting visual encounter surveys to improve detectability. Concurrently assess presence of threats and habitat suitability to determine if future reintroductions may be possible. Collect genetic samples from any Foothill Yellow-legged Frogs captured for use in landscape genomics analyses and possible future translocation or captive propagation efforts. Attempt to better clarify clade boundaries where there is uncertainty. Study whether small populations are at risk of inbreeding depression, whether genetic rescue should be attempted, and if so, whether that results in hybrid vigor or outbreeding depression.

Continue to evaluate how water operations affect Foothill Yellow-legged Frog population demographics. Establish more long-term monitoring programs in regulated and unregulated (reference) rivers across the species' range but particularly in areas like the Sierra Nevada where most large hydropower dams in the species' range are concentrated. Assess whether the timing of pulse flows influences population dynamics, particularly whether early releases have a disproportionately large adverse effect by eliminating the reproductive success of the largest, most fecund females, who appear to breed earlier in the season. Investigate survival rates in poorly-understood life stages, such as tadpoles, young of the year, and juveniles. Determine the extent to which pulse flows contribute to displacement and mortality of post-metamorphic life stages.

Collect habitat variables that correlate with healthy populations to develop more site-specific habitat suitability and hydrodynamic models. Study the potential synergistic effect of increased flow velocity and decreased temperature on tadpole fitness. Examine the relationship between changes in flow, breeding and rearing habitat connectivity, and scouring and stranding to develop site-specific benign ramping rates. Incorporate these data and demographic data into future PVAs for use in establishing frog-friendly flow regimes in future FERC relicensing or license amendment efforts and habitat restoration projects. Ensure long-term funding for post-license or restoration monitoring to evaluate attainment of expected results and for use in adapting management strategies accordingly.

Evaluate the distribution of other threats such as cannabis cultivation, vineyard expansion, livestock grazing, mining, timber harvest, and urbanization and roads in the Foothill Yellow-legged Frog's range. Study the short- and long-term effects of wildland fires and fire management strategies. Assess the extent to which these potential threats pose a risk to Foothill Yellow-legged Frog persistence in both regulated and unregulated systems.

Investigate how reach-level or short-distance habitat suitability and hydrodynamic models can be extrapolated to a watershed level. Study habitat connectivity needs such as the proximity of breeding sites and other suitable habitats along a waterway necessary to maintain gene flow and functioning meta-population dynamics.

Habitat Restoration and Watershed Management

Remove or update physical barriers like dams and poorly constructed culverts and bridges to improve connectivity and natural stream processes. Remove anthropogenic features that support introduced predators and competitors such as abandoned mine tailing ponds that support bullfrog breeding. Conduct active eradication and management efforts to decrease the abundance of bullfrogs, non-native fish, and crayfish (where they are non-native). In managed rivers, manipulate stream flows to negatively affect non-native species not adapted to a winter flood/summer drought flow regime.

Adopt a multi-species approach to channel restoration projects and managed flow regimes (thermal, velocity, timing) and mimic the natural hydrograph to the greatest extent possible. When this is impractical or infeasible, focus on minimizing adverse impacts by gradually ramping discharge up and down, creating and maintaining gently sloping and sun-lit gravel bars and warm calm edgewater habitats for tadpole rearing, and mixing hypolimnetic water (from the lower colder stratum in a reservoir) with warmer surface water before release if necessary to ensure appropriate thermal conditions for successful metamorphosis. Promote restoration and maintenance of habitat heterogeneity (different depths, velocities, substrates, etc.) and connectivity to support all life stages and gene flow. Avoid damaging Foothill Yellow-legged Frog breeding habitat when restoring habitat for other focal species like anadromous salmonids.

Regulatory Considerations and Best Management Practices

Develop range-wide minimum summer baseflow requirements that protect Foothill Yellow-legged Frogs and their habitat with appropriate provisions to address regional differences using new more ecologically-meaningful approaches such as modified percent-of-flow strategies for watersheds (e.g., Mierau et al. 2018). Limit water diversions during the dry season and construction of new dams by focusing on off-stream water storage strategies.

Ensure and improve protection of riparian systems. Require maintenance of appropriate riparian buffers and canopy coverage (i.e., partly shaded) around occupied habitat or habitat that has been identified for potential future reintroductions. Restrict instream work to dry periods where possible. Prohibit fording in and around breeding habitat. Avoid working near streams after the first major rains in the fall when Foothill Yellow-legged Frogs may be moving upslope toward tributaries and overwintering sites. Use a 3 mm (0.125 in) mesh screen on water diversion pumps and limit the rate and amount of water diverted such that depth and flow remain sufficient to support Foothill Yellow-legged Frogs of all life stages occupying the immediate area and downstream. Install exclusion fencing where appropriate, and if Foothill Yellow-legged Frog relocation is required, conduct it early in the season because moving egg masses is easier than moving tadpoles.

Reduce habitat degradation from sedimentation, pesticides, herbicides, and other non-point source waste discharges from adjacent land uses including along tributaries of rivers and streams. Limit mining to parts of rivers not used for oviposition, such as deeper pools or reaches with few tributaries, and at times of year when frogs are more common in tributaries (i.e., fall and winter). Manage recreational activities in or adjacent to Foothill Yellow-legged Frog habitat (e.g., OHV and hiking trails, camp sites, boating ingress/egress, flows, and speeds) in a way that minimizes adverse impacts. Siting cannabis grows in areas with better access to roads, gentler slopes, and ample water resources could significantly reduce threats to the environment. Determine which, when, and where agrochemicals should be restricted to reduce harm to Foothill Yellow-legged Frogs and other species. Ensure all new road crossings and upgrades to existing crossings (bridges, culverts, fills, and other crossings) accommodate at least 100-year flood flows and associated bedload and debris.

Partnerships and Coordination

Establish collaborative partnerships with agencies, universities, and non-governmental organizations working on salmon and steelhead recovery and stream restoration. Anadromous salmonids share many of the same threats as Foothill Yellow-legged Frogs, and recovery actions such as barrier removal, restoration of natural sediment transport processes, reduction in pollution, and eradication of non-native predators would benefit frogs as well. Ensure Integrated Regional Water Management Plans and fisheries restoration programs take Foothill Yellow-legged Frog conservation into consideration during design, implementation, and maintenance.

Encourage local governments to place conditions on new developments to minimize negative impacts on riparian systems. Promote and implement initiatives and programs that improve water conservation use efficiency, reduce greenhouse gas emissions, promote sustainable agriculture and smart urban growth, and protect and restore riparian ecosystems. Shift reliance from on-stream storage to off-stream storage, resolve frost protection issues (water withdrawals), and ensure necessary flows for all life stages in all water years.

Establish a Department-coordinated staff and citizen scientist program to systematically monitor occupied stream reaches across the species' range.

Education and Enforcement

Support programs to provide educational outreach and local involvement in restoration and watershed stewardship, such as Project Wild, Adopt a Watershed, school district environmental camps, and other programs teaching the effects of human land and water use on Foothill Yellow-legged Frog survival.

Provide additional funding for increased law enforcement to reduce ecologically harmful stream alterations and water pollution and to ensure adequate protection for Foothill Yellow-legged Frogs at pumps and diversions. Identify and address illegal water diverters and out-of-compliance diverters, seasons of diversion, off-stream reservoirs, well pumping, and bypass flows to protect Foothill Yellow-legged Frogs. Prosecute violators accordingly.

ECONOMIC CONSIDERATIONS

The Department is charged in an advisory capacity in the present context to provide a written report and a related recommendation to the Commission based on the best scientific information available regarding the status of Foothill Yellow-legged Frog in California. The Department is not required to prepare an analysis of economic impacts (See Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

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