

## CALIFORNIA RED-LEGGED FROG

### *Rana draytonii*

USFWS: Threatened

CDFG: Special Concern

### Species Account

#### Background

**Status and Description.** The California red-legged frog (*Rana draytonii*) was federally listed as threatened on May 23, 1996, (USFWS 1996) effective June 24, 1996 and is a California Department of Fish and Game Species of Special Concern. In 2002, the U. S. Fish and Wildlife Service published a recovery plan for the frog. and critical habitat was designated 4/13/04 (USFWS 2004). Critical habitat has been designated and redesignated several time for the California red-legged frog (May 23, 1996, 61 FR 25813; April 13, 2006, 71 FR 19243) as a result on various lawsuits. The final proposed rule for critical habitat was issued September 16, 2008, FR Federal Register Vol. 73, No. 180. and designated on May 17, 2010, FR Vol 75, No. 51



California red-legged frogs, range from 1.5 to 5 inches in length, making them the largest native frog in the western United States (Wright and Wright 1949). Adult females are significantly longer than males, with an average snout-to-urostyle length of 5.4 inches versus 4.6 inches for adult males (Hayes and Miyamoto 1984). The hind legs and lower abdomen of adult frogs are often characterized by a reddish or salmon pink color, and the back is brown, gray, olive, or reddish brown, marked with small black flecks and larger irregular dark blotches (Stebbins 2003). Dorsal spots often have light centers, and in some individuals form a network of black lines (Stebbins 2003). Dorsolateral folds are prominent. Tadpoles range in length from 0.55 to 3.15 inches, and are a dark brown or olive, marked with darker spots (Storer 1925).

**Taxonomic Remarks.** The California red-legged frog is part of a wide-ranging species complex of western North American anurans that have been a long-standing source of confusion with respect to species boundaries and composition (Shaffer *Et Al.* 2004). The group is restricted to the Pacific Coast of North America from southern British Columbia, Canada to northern Baja. The two red-legged frogs were originally described as distinct species, the northern red-legged frog (*R. aurora*) and the California red-legged frog (*R. draytonii*) (Baird and Girard C. 1852). In 1917, Camp reclassified *R. aurora* as a single polytypic species with two subspecies, *R. a. aurora* and *R. a. draytonii*. Two decades later, the Cascades frog (*R. cascadae*) was recognized as a species with close phylogenetic affinities to *R. aurora* (Slater J.R. 1939) and was briefly considered to be a subspecies of *aurora* (Stebbins 1962). Recent molecular work by Shaffer et al. (2004), along with several other lines of independent evidence, favors recognition of *aurora* and *draytonii* as separate species with a narrow zone of overlap in northern California. The USFWS, now recognizes the California red-legged frog as *R. draytonii* (USFWS 2010).

**Range.** Historically, the California red-legged frog was common in coastal habitats from the vicinity of Point Reyes National Seashore, Marin County, California, and inland from the vicinity of Redding, Shasta County, California, southward to northwestern Baja California, Mexico (Jennings and Hayes 1985, Hayes and Jennings 1988).

According to Hayes and Jennings (1988), California red-legged frogs have been extirpated or nearly extirpated from over 70% of their former range. Historically, the California red-legged frog was known from 46 Counties but the taxon is now extirpated from 24 of these (USFWS 2002). Today it is known only from isolated localities in the Sierra Nevada, northern coast, and northern Transverse Ranges and is believed to be nearly extirpated from the southern Transverse and Peninsular ranges (USFWS 2002). This species is still common in the San Francisco Bay area (including Marin County) and along the central coast (California Natural Diversity Data Base 2011). Monterey, San Luis Obispo, and Santa Barbara Counties support the largest extent of currently occupied habitat (USFWS 2002). The most secure aggregations of California red-legged frogs are found in aquatic sites that support substantial riparian and aquatic vegetation and lack non-native predators.

**Occurrence in the Plan Area.** In the Plan Area, the California red-legged frog is associated with the Inner Coast Range and Riparian, Stream, and Fresh Water Marsh Natural Communities. The only current records for the species in Solano County are from the hills north of I-80 and in the tri-city/county open space area roughly defined as the triangle formed by Interstate Highways 80, 680 and 780 between Vallejo, Cordelia, and Benicia. California red-legged frog habitat in the Plan Area is considered to be the hills in the western portion of the county, particularly in the areas of Vaca Mountains, Suisun Valley, Green Valley, northwest of Fairfield, and the tri-city/county open space area (see Map).

**Associated Covered and Special Management Species.** Additional Covered Species and Special Management Species that will benefit from this conservation strategy are the callippe silverspot butterfly, Valley elderberry longhorn beetle, foothill yellow-legged frog, Western pond turtle, and all other species associated with these two Natural Communities.

### **Narrative Conceptual Model**

This section provides a preliminary narrative conceptual model for California red-legged frogs. Following concepts developed by Atkinson et al. (2004), the model describes the lifecycle, biology and habitat requirements of the species, followed by potential pressures affecting populations within the Plan Area. Pressures are agents that either promote or inhibit change in the state of the environment (Atkinson et al. 2004).

**Life Cycle and Biology.** The California red-legged frog breeds from late November to early April, with earlier breeding records occurring in southern localities (Storer 1925). Males appear at breeding sites 2 to 4 weeks before females (Storer 1925). Eggs masses are deposited at the surface of the water attached to emergent vegetation, such as bulrushes (*Scirpus* spp.), cattails (*Typha* spp.), roots or twigs. In lentic environments, egg masses have been observed unattached or loosely attached to floating mats of vegetation (Reis 1999). Each egg mass contains about 2,000 to 5,000 individual eggs measuring approximately 0.08 to 0.11 inches in diameter. The California red-legged frog's critical thermal maximum is not known, but laboratory experiments by Jennings and Hayes (unpublished)

indicated that for eggs it is at least 23°C, higher than the 21°C critical thermal maximum for the northern red-legged frog (Licht 1974).

Eggs hatch in 6 to 14 days depending on water temperatures (Jennings and Hayes 1994; Jennings 1988; Stebbins 2003). Larvae typically metamorphose between July and September: 3.5 to 7 months after eggs are laid (Storer 1925; Wright and Wright 1949). Juveniles reach sexually mature in 2–3 years (Jennings and Hayes 1985), with adults living 8 to 10 years (USFWS 2002). Nevertheless, the average life span is probably much lower (USFWS 2002).

**Survivorship.** Of the various life stages, larvae probably experience the highest mortality rates. Survival rate from hatching to metamorphosis has been estimated as less than 1% (Jennings, Hayes, and Holland 1992) or 1.9% (Cook 1997). For comparison, Licht (1974) estimated the survivorship of northern red-legged frog tadpoles, juveniles and adults to be 2.5%, 52% and 68.6%, respectively.

**Diet.** The diet of California red-legged frogs is highly variable. For the northern red-legged frog, Hayes and Tennant (1985), found invertebrates to be the most common food items but vertebrates, such as pacific tree frogs (*Pseudacris regilla*) and California mice (*Peromyscus californium*), represented over half the prey mass eaten by larger frogs. Feeding activity occurs along the shoreline and on the surface of the water (Hayes and Tennant 1985). Larvae are likely eating algae (Jennings, Hayes, and Holland 1992).

**Habitat Requirements.** California red-legged frogs have been observed using a variety of habitat types, including various aquatic, riparian, and upland habitats. They include, but are not limited to, ephemeral ponds, intermittent streams, seasonal wetlands, springs, seeps, permanent ponds, perennial creeks, manmade aquatic features, marshes, dune ponds, lagoons, riparian corridors, blackberry (*Rubus* spp.) thickets, nonnative annual grasslands, and oak savannas (USFWS 2002). They are found in both natural and manmade aquatic habitats, and inhabit areas of diverse vegetation cover.

**Breeding Habitat.** Breeding sites have been documented in a variety of aquatic habitats. Larvae, juveniles, and adult frogs have been observed inhabiting streams, creeks, ponds, marshes, sag ponds, deep pools and backwaters within streams and creeks, dune ponds, lagoons, estuaries, and artificial impoundments, such as stock ponds. Furthermore, breeding has been documented in these habitat types irrespective of vegetation cover. Frogs often successfully breed in artificial ponds with little or no emergent vegetation, and have been observed to successfully breed and inhabit stream reaches that are not cloaked in riparian vegetation (USFWS 2002). Other factors are more likely to influence the suitability of aquatic breeding sites, such as the general lack of introduced aquatic predators (Adams 1999).

**Egg Mass Habitat.** Eggs masses are usually deposited at the surface of the water attached to emergent vegetation, such as bulrushes (*Scirpus* spp.), cattails (*Typha* spp.), roots or twigs. In lentic environments, egg masses have been observed unattached or loosely attached to floating mats of dead vegetation (Reis 1999; Cook 1997). A study by Reis (1999) at Pescadero Marsh, San Mateo County, found that adult frogs selected shallow and warm locations for laying eggs. Egg masses were attached to emergent and dead, free-floating vegetation, but plant species type was unimportant (Reis 1999).

**Larval Habitat.** Tadpole habitat in one study at Pescadero Marsh, San Mateo County, was best characterized by the presence of pondweed (*Potamogeton*) and cattails, the absence of pickleweed, bulrushes and predacious aquatic invertebrates, water with salinity less than 6.5 ppt, water temperatures between 15.0°C and 24.9°C, and water depths no greater than 2.5 feet. Of these characteristics, the abundance of pondweed was the most important (Reis 1999). The presence of red-legged frog tadpoles in ponds in the East Bay Regional Parks also appears to be correlated with the presence of pondweed (LSA personal observation; Steve Bobzein unpublished data).

**Metamorph and Juvenile Habitat.** Very little is known about the habitat requirements of metamorphs and juveniles. Newly metamorphosed frogs tend to inhabit warm shallow margins of ponds and streams near breeding habitat from July through September and then disperse away from the breeding habitat during warm rain events. The type of habitat they use after that is unknown.

**Adult Habitat.** Adult California red-legged frogs appear to prefer dense, shrubby or emergent riparian vegetation closely associated with deep (>2.3 feet), still, or slow-moving water (Hayes and Jennings 1988). The largest densities of California red-legged frogs currently are associated with deep pools with dense stands of overhanging willows (*Salix* Spp.) and an intermixed fringe of cattails (*Typha latifolia*) (USFWS 2002). Reis (1999) found that after laying eggs, adults were more likely found in deeper water and that plant type was unimportant. Frogs will spend considerable time resting and feeding in riparian vegetation when it is present. During the summer, if water is no longer available, frogs have been observed using boulders, rocks, or organic debris, such as downed trees, logs or moist leaf litter; industrial debris; agricultural features, such as drains, watering troughs, abandoned sheds, or hay-ricks; small mammal burrows; and incised stream channels with portions narrower and deeper than 18 inches (USFWS 2002). The type of habitat used by adult frogs during the non breeding season is highly variable and is largely determined by what is available and on the year to year variations in climate.

**Population Structure.** California red-legged frog populations appear to operate as a metapopulation, a collection of sub-populations that exchange genetic information through individual dispersal events. A classic metapopulation model assumes that subpopulations in breeding ponds blink in and out of existence, with extinction and colonization rates being a function of the spatial arrangement of ponds or aquatic breeding habitat (i.e. a “pond-as-patch” view of amphibian spatial dynamics; Marsh and Trenham 2001). Other researchers have applied this “pond-as-patch” view of amphibian spatial dynamics to other frog and toad populations and have demonstrated that the probability of a patch (i.e. pond) being occupied is positively correlated with the distance to the nearest currently occupied patch (Marsh et al. 1999). In addition, Sjogren-Gulve (1994) found that for the pool frog (*Rana lessonae*), isolated ponds far removed from occupied ponds eventually went extinct. California red-legged frog populations persist and flourish where suitable breeding and foraging habitats are interspersed throughout the landscape and are interconnected by contiguous dispersal habitat. Where this habitat mosaic exists, local extinctions may be counterbalanced by the colonization of new habitat or re-colonization of unoccupied areas of suitable habitat.

**Dispersal and Movement Patterns.** Dispersal and movement patterns for California red-legged frogs vary dramatically throughout their range and are highly correlated with rainfall and

moisture levels. For example, individuals occurring in coastal drainages appear to be active year-round (Jennings, Hayes, and Holland 1992) whereas frogs found in interior sites are less active during the cold season. Bulger et al. (2003), in a movement study of California red-legged frogs in northern Santa Cruz County, California, found that adult frogs occupied terrestrial habitats in two distinct ways, as dispersing and non-dispersing individuals. Dispersing individuals were those who made overland movements between two aquatic sites, typically before or after breeding. Non-dispersing individuals were those residing at any particular aquatic site but made short-range forays into upland habitats.

**Movement Patterns of Dispersing Individuals.** During periods of wet weather, starting with the first rains of fall, frogs have been observed making overland excursions through upland habitats to breeding sites. These long-distance movements are straight-line, point-to-point migrations through all terrain and not necessarily through riparian or other topographic corridors (Bulger et al. 2003). Most of these overland movements occur at night. In Santa Cruz County, California, dispersing frogs moved between sites separated by distances of 0.13-1.74 miles. The longest distance traversed by an individual was 2.24 miles by moving between two sites 1.74 miles apart (Bulger et al. 2003). A study of marked and radio-tagged adult frogs in San Luis Obispo County also found that frogs dispersed via upland habitats, distances of approximately 1 mile, over the course of a wet season (USFWS 2002). Despite these observations of long distance dispersal, data from Bulger et al. (2003) suggest that only a relatively small segment of the adult population is liable to disperse in any given year. Most adult frogs are resident year round at favorable breeding sites.

Very little is known about the movement patterns of metamorphs and juveniles. Newly metamorphosed frogs tend to disperse locally July through September and then disperse away from the breeding habitat during warm rain events. The distances these juveniles are capable of traveling has not been studied, but are likely dependent upon rainfall and moisture levels during and immediately following dispersal events and on habitat availability and environmental variability. Because breeding adults have a strong preference to return to natal ponds, metamorphosing juveniles are likely the primary dispersal stage and a high rate of successful metamorphosis is critical to maintain local populations, reestablish extirpated populations and establish new populations (Semlitsch 2003).

**Movement Patterns of Non-dispersing Individuals.** Most adult frogs are resident year round at favorable breeding sites, from which, they make short-range forays into upland habitats for periods of days to weeks in response to precipitation. Bulger et al. (2003) found that terrestrial habitat use by non-dispersing frogs showed a clear response to rainfall during the summer and early winter months. During isolated summer rain events, the median duration of intervals spent in terrestrial habitats was 4-6 days. By contrast, during the more regular rain events in early winter, the median duration of bouts on land ranged from 20-30 days. Frogs were virtually always within 17 feet from their pond or stream of residence during dry intervals. Overall, 90% of non-dispersing frogs were always within 44 yards of water during summer months and within 67 yards of water during the early winter months (Bulger et al. 2003). In San Luis Obispo County, frogs were observed foraging in dense riparian vegetation 33 yards from water and remained there for up to 77 days (Rathbun et al. 1993). During mid-late winter, corresponding with the peak breeding period, frogs did not respond to rainfall events and instead remained close to breeding sites. From February through May, 90% of the non-dispersing frogs were always within 7 yards of water (Bulger et

al. 2003). Similarly, the majority of California red-legged frogs observed in eastern Contra Costa County spent the entire wet season within streamside habitat (Tatarian in litt. 2000 as reported in USFWS 2002).

**Land Use Practices.** The land use practices or primary pressures that directly affect California red-legged frogs in Solano County are: urbanization, intensive agriculture, cultivated grassland/dry-land farming and livestock grazing.

**Urbanization.** Urbanization results in the direct loss of both aquatic and terrestrial habitat, the fragmentation of existing habitat (isolating breeding populations and altering dispersal and migration), the ‘perennialization’ of water sources promoting the colonization and expansion of non-native predators, and the increased densities of native predators. The development of upland habitat can have significant deleterious impacts on California red-legged frogs. For example, in the watersheds of Puget Sound, Washington, amphibian species richness was significantly lower in watersheds where more than 40% of the land area was developed (Richter and Azous 1995, 1997). This was attributed to increases in the total water level fluctuations within wetlands. Specifically, urbanization leads to higher peak flows and volumes resulting in increases in the magnitude, frequency, and duration of wetland and stream levels (Reinalt and Taylor 1997). Urbanization within the range of the California red-legged frog often results in similar effects on wetlands. Urbanization results in additional water sources into wetlands and stream courses associated with irrigation and home use activities, especially during the summer months. This often drastically alters the hydroperiod and converts intermittent streams and seasonal wetlands to perennial aquatic habitat. Such alterations allow exotic species, such as bullfrogs and nonnative warm water fish species, to invade the habitat and further effect California red-legged frog populations. California red-legged frogs are rarely found in areas where a large majority of the watershed has been developed (H.T. Harvey 1997, USFWS files).

In addition to modification of the hydroperiod, development within a watershed can also affect water and habitat quality. Increased development within a watershed increases the total amount of impervious surfaces within the watershed. An increase in impervious surfaces results in an increase of sediments containing organic matter, pesticides and fertilizers, heavy metals such as hydrocarbons, and other debris entering into streams and wetlands, decreasing the overall water quality (U.S. Environmental Protection Agency (EPA) 1993). Skinner et al. (1999) found developed watersheds had greater concentrations of toxic effluents than less developed areas with more open space. The decrease in water quality can impact native amphibians and other wetland vertebrates. Richter and Azous (1997) observed wetlands adjacent to undeveloped upland areas were more likely to have richer populations of native amphibians. Mensing et al. (1998) found that amphibian abundance was negatively influenced by land use at small scales (e.g., within 0.5 to 1.0 kilometers). Habitat fragmentation, wetland conversions, and hydrological alterations cumulatively result in changes in wetland species composition, including amphibians. Amphibian declines can be attributed to increasing numbers of nonnative competitors and predators capable of thriving in disturbed conditions (Harris 1999). Onorato et. al. (1998) found native fish species were sensitive to anthropogenic disturbances and were becoming less abundant within the study area. They also found introduced generalists were able to tolerate lower quality habitat and replaced native fish species within the system. This scenario has been demonstrated in the Santa Clara Valley, California, where the loss of California red-legged frog populations has been attributed in part to the invasion of bullfrogs into urbanized areas (H.T. Harvey and Associates 1997).

**Intensive Agriculture.** Similar to urbanization, intensive agriculture or croplands results in direct habitat loss and fragmentation, decreased watershed area, altered hydrology, increased runoff and contaminants.

**Cultivated Grassland/Dry-land Farming.** Cultivated grassland/dry-land farming may occur in a few limited areas within the range of the red-legged frog within the Plan Area. The majority of this land use type is restricted to the Montezuma Hills in the south-eastern portion of the County. Cultivated grassland and dry-farmed areas are largely similar to the non-native annual grasslands and provides very similar upland habitat for frogs. The direct affect of this land use practice may include the periodic disking or tilling of the land.

**Livestock Grazing.** Livestock grazing has both positive and negative affects on frog populations.

**Negative effects of livestock grazing.** Livestock, such as cattle, can effectively trample aquatic vegetation and cause accelerated bank erosion (especially in streams) and this can result in unsuitable habitat for amphibians. Cattle tend to congregate in and around riparian and aquatic habitats exacerbating their impacts on vegetation. This loss of streamside vegetation can result in increased erosion, increased water temperatures, and reduced numbers of available prey such as insects and small mammals.

**Beneficial effects of livestock grazing.** In some areas, livestock grazing is beneficial to California red-legged frogs. Artificially created stock ponds provide ideal breeding habitat for California red-legged frog, and grazing actually helps maintain pond suitability by keeping weedy species such bulrushes under control (USFWS 2002).

**Recreation.** Recreational activities such as hiking, fishing, horseback riding, and camping may have adverse affects on red-legged frogs. Habitat impacts associated with the use of trails, roads, and other developed recreation sites include wetland vegetation trampling, soil compaction, sedimentation, bank destruction, dammed pools, vegetation clearing, introduction of contaminants, and introduction of non-native fish and wildlife species. These impacts may result in the direct loss of egg masses and tadpoles due to trampling and decreased suitability of aquatic habitats due to the proliferation of nonnative predators, sedimentation of pools, vegetation clearing or trampling, and decreased water quality (USFWS 2002).

**Consequences of Land Use Practices.** The consequences of the above land use practices (i.e. secondary pressures) on California red-legged frogs in Solano County are:

**Habitat destruction, fragmentation and alteration.** Habitat destruction, fragmentation and alteration are probably the most serious causes of current and future amphibian population declines and species extinctions (Dodd and Smith 2003). Habitat destruction is defined as the complete elimination of a localized or regional ecosystem leading to the total loss of its former biological function (Dodd and Smith 2003). A study by Davidson et al. (2001) found that habitat destruction due to urbanization has significantly contributed to the declines of California red-legged frogs. In 1995, approximately 27 percent of the known red-legged frog occurrences were associated with urbanization threats and many areas within the range of the frog were slated for development (USFWS 1996).

Habitat fragmentation is a secondary effect of habitat destruction. The primary effect being the elimination of individuals or populations from the portion of the landscape that has been destroyed, and the secondary effect, habitat fragmentation, occurs when remaining populations are isolated because the links between habitat patches have been destroyed. The destruction of upland dispersal habitat can result in the increased isolation of breeding populations. Sjogren-Gulve and Ray (1996) applied logistic regression models to metapopulation dynamics of the pool frog and found that large scale modern forestry practices resulting in either ditching and or clear-cutting of  $\geq 5$  acre areas situated  $< 547$  yards from a pond significantly affected observed colonization and extinction probabilities. Model simulations, where large-scale forestry was practiced throughout the entire metapopulation, resulted in regional extinction 99.9 percent of the time within 53 years (Sjogren-Gulve and Ray 1996). This may be similar to the effects of large scale developments and agricultural practices within the entire range of California red-legged frog populations.

In addition to increased extinction probabilities, studies from other anuran species have shown that fragmentation can result in decreased heterozygosity and inbreeding depression (Hitchings and Beebee 1997; Reh and Seitz 1990). For example, urban populations of common frogs (*Rana temporaria*) are more genetically distinct than rural populations (Hitchings and Beebee 1997). When heterozygosity (generally defined as a measure of the genetic diversity present in a population) decreases, the overall fitness of that population decreases which, based on population viability models can result in an increased probability of extinction (Beissinger and Mccullough 2002).

Highways and major roads are also significant causes of mortality and may lead to the fragmentation of amphibian populations. Kuhn (1987, in Reh and Seitz 1990) estimated that 24 to 40 cars per hour killed 50% of common toad (*Bufo bufo*) individuals migrating across a road, while Heine (1987, in Reh and Seitz 1990) found that 26 cars per hour could reduce the survival rate of toads crossing roads to zero. In addition, Fahrig *et al.* (1995) found a significant negative correlation between traffic density and the density of anuran populations. Based on genetic analysis, Reh and Seitz (1990) found that highways effectively isolated *R. temporaria* populations. Thus, roads are an important human-caused landscape component hindering amphibian movement and thereby fragmenting amphibian populations.

Habitat alteration are changes made to the environment that adversely affect ecosystem function, although not perhaps completely or permanently (Dodd and Smith 2003). California red-legged frog habitat has been significantly altered by activities associated with urbanization, agriculture, impoundments and water management, mining, recreation and off-road vehicles, timber harvesting and livestock grazing. If poorly managed these practices can increase disturbance, contamination, and lead to the introduction of nonnative subspecies that prey on or compete with frogs.

**Introduced Predators.** Several researchers have attributed the decline and extirpation of California red-legged frogs to the introduction of bullfrogs and predatory fishes (Hayes and Jennings 1986). Bullfrogs, in their introduced range, are important predators and competitors that influence the presence and abundance of other frog species (Hecnar and M'Closkey 1997). In their introduced range, their presence is negatively correlated with the presence of California red-legged frogs (Fisher and Shaffer 1996; Moyle 1973) and they have been observed preying on



tadpole, juvenile and adult California red-legged frogs (Cook and Jennings *in litt.* 2000 as reported in USFWS 2002). In an experimental study by Lawler et al. (1999) bullfrog tadpoles reduced the survivorship of California red-legged tadpoles to 5% from 34%. In field enclosures, bullfrog adults and larvae significantly affected the growth, development and survivorship of tadpoles of the northern red-legged frog, and adult bullfrogs decreased metamorph survival by 33% (Kiesecker and Blaustein 1998a). Due to their large size, more generalized food habits (Bury and Whelan 1984), extended breeding season (Storer 1933), ability to double clutch (Emlen 1977), and the larvae's insusceptibility to fish predation (Kruse and Francis 1977), bullfrogs are thought to have a competitive advantage over California red-legged frogs.

There is significant evidence that bullfrogs negatively affect California red-legged frogs; however, efforts to quantify the role of bullfrogs in the decline of California red-legged frogs is hampered by multiple confounding factors, particularly introduced fish and habitat alteration (Doubledee et al. 2003). Hayes and Jennings (1986;1988) found a negative correlation between the abundance of introduced fish species and California red-legged frogs and argue that introduced fish have played a larger role in California red-legged frog declines than bullfrogs. In the Puget Lowlands of western Washington, bullfrogs do not appear to be excluding northern red-legged frogs from wetlands but introduced fish were a significant factor predicting the absence of native frogs (Adams 1999). Several experimental studies have documented the negative effects of introduced fish on amphibian larva. For example, Adams (2000) found that, in an enclosure experiment, bluegill sunfish (*Lepomis gibbosus*) decrease the survival of the northern red-legged frog. Experimental studies by Lawler et al. (1999), found that mosquitofish (*Gambusia affinis*) inflicted tail injury, reduced metamorph size and altered activity patterns of larval California red-legged frogs.

**Native Predators.** In addition to introduced predators, increased densities of native predators such as raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), striped skunks (*Mephitis mephitis*) and spotted skunks (*Spilogale putorius*) have increased in density due to urbanization. When these animals become problems in urban areas, a common practice of municipal animal control districts is to translocate them to less populated area (USFWS 2002). This increase in predator density may threaten California red-legged frogs. For example, in the Los Padres National Forest, a high number of raccoons and opossums were observed in riparian areas where they were preying upon arroyo toads (*Bufo californicus*) and preventing successful reproduction of western pond turtles (*Actinemys marmorata*) (USFWS 2002). The high number of raccoons and opossums were due to county and city practice of releasing trapped urban wildlife into the riparian areas of the National Forest (S. Sweet *in litt.* 2000 as cited in USFWS 2002). The increased densities of native predator populations can also be attributed to subsidized diets. Raccoons, opossums, and skunks will readily forage through garbage and consume pet food left out for neighborhood cats and dogs.

**Chemical Contaminants.** As watersheds are developed, the amount of impervious surface increases, resulting in an increase of sediments containing organic matter, pesticides and fertilizers, heavy metals, hydrocarbons, and other debris entering into streams and wetlands (U.S.Environmental Protection Agency 1993). Skinner et al. (1999) found developed watersheds had greater concentrations of toxic effluents than less developed areas with more open space. The decrease in water quality can impact native amphibians and other wetland vertebrates. Marco et al. (1999) and de Solla *et al.* (2002) found that northern red-legged frog tadpoles exposed to high concentrations of Nitrite and Nitrate experienced reduced feeding activity, swam

less vigorously, displayed disequilibrium, developed malformations of the body and died. In a comprehensive evaluation of prevailing hypotheses on the causes of declines in California red-legged frogs, Davidson et al. (2001) found a strong correlation between locations where frog numbers had declined and upwind agricultural land use. They concluded that wind-borne agrochemicals might be an important factor in red-legged frog declines.

**Climate Change.** Amphibians are extremely sensitive to small changes in temperature and moisture. Changes in global weather patterns (e.g. El Nino events or global warming) can alter breeding behavior, affect reproductive success, decrease immune functions and increase their sensitivity to chemical contaminants. The timing of amphibian breeding is largely driven by environmental cues such as temperature and moisture (Carey and Alexander 2003); because of this, their breeding phenology may be directly affected by global warming. Researchers have found that some amphibians in Europe and North America show a trend towards earlier breeding (Beebee 1995; Blaustein et al. 2001; Gibbs and Breisch 2001). Unpublished data by Doubleday et al. suggest that survivorship of California red-legged frogs in streams in San Luis Obispo County is correlated with rainfall. Thus, changes in rainfall patterns could affect the long term dynamics of frog populations.

**Altered Hydroperiod.** Urbanization results in additional water sources into wetlands and stream courses associated with irrigation and home use activities, especially during the summer months. This often drastically alters the hydroperiod and converts intermittent streams and seasonal wetlands to perennial aquatic habitat. Such alterations allow exotic species, such as bullfrogs and nonnative warm water fish species, to invade the habitat and further affect California red-legged frog populations. The introduction and expansion of bullfrogs into Sulphur Springs Creek and surrounding wetland habitat and the subsequent decline of red-legged frogs from this region is a key example in the negative effects of altered hydroperiod on red-legged frog populations.

**Synergisms.** Researchers are finding that multiple factors of decline are working synergistically to adversely affect amphibian populations on a global scale (Blaustein and Kiesecker 2002). Combinations of multiple factors, such as, habitat destruction and introduced species, or climate change, UV-B and disease have a larger negative effect on amphibians than any single factor acting alone does. In fact, factors that may have little to no effect on amphibian populations may have large negative impacts when combined with other stressors. For example, pathogens may only have marginal effects on the demography of a healthy population, but the same pathogens can cause catastrophic declines in populations in the presence of sublethal concentrations of pesticides or UV-B radiation (Berger et al. 1998, Blaustein et al. 1994, Daszak et al. 2003, Kiesecker and Skelly 2001, Laurance et al. 1996).

California red-legged frogs are currently threatened by human activities, many of which operate concurrently and cumulatively with each other and with natural disturbances (e.g. droughts and floods). For example, bullfrogs are more likely to become established in and extirpate red-legged frogs in man-made and heavily disturbed environments. Kiesecker et al. (2001) found that competition between bullfrog and northern red-legged frog tadpoles was exacerbated in an artificial enclosure experiment when resources were clumped together. Kiesecker et al. (2001) suggested that the clumping of resources in the enclosure experiment represented the effects of anthropogenic habitat modifications on the distribution of resources in aquatic habitats. When aquatic habitats are converted from shallow, ephemeral wetlands to deep permanent ponds, the lack of water level fluctuations results in the clumping of emergent vegetation in a narrow band

around the ponds perimeter (i.e. resulting in clumped rather than dispersed resources) (Kiesecker et al. 2001).

Data from field surveys within Solano County, particularly within the Lake Herman Watershed, have documented the effects of habitat alteration and introduced species on the decline of California red-legged frogs. Prior to the development of Sky Valley, perennial water sources were absent, except for small areas around several of the larger springs in the upper hill slopes, which remained fairly wet through the summer. Permanent standing water did not occur in Sulphur Springs Creek after approximately 2.75 miles upstream of Lake Herman (RMI 1994). The development of the Hiddenbrook project, encompassing track homes and golf courses, resulted in the enhancement and supplementation of habitat by created features, particularly golf course ponds and wetland creation sites. The creation of permanent water features expanded the habitat availability for frogs and other wildlife species, leading to an initial red-legged frog population expansion. By 1996, the population was believed to be in excess of 100 individuals (RMI 1996). Bullfrogs and warm water fish species were observed in ponds and in the upper portions of Sulphur Springs Creek by 1996. They have since spread throughout the Lake Herman Watershed. Corresponding to the expansion of introduced predators and competitors, the red-legged frog population crashed and are currently only found in smaller ephemeral wetlands, spring boxes and other habitat unsuitable for bullfrogs or introduced fish in the upper hill slopes of Sky Valley.

In addition to the confounding factors of anthropogenic habitat modifications and introduced predators, it appears that the introduction of one predator may facilitate the introduction of others. Specifically, recent research suggests that the introduction and spread of warm water predatory fish (ex. Centrarchids) may be facilitating the spread of bullfrogs (Jennings and Hayes 1985, Adams 1999, Kiesecker et al. 2001b). In Washington, Adams, Pearl and Bury (2003) found that the presence of non-native fish increased bullfrog tadpole survival by reducing predatory macroinvertebrate densities. In the absence of fish, native dragonfly nymphs caused zero survival of bullfrog tadpoles in a replicated field experiment unless a non-native sunfish was present to reduce dragonfly density (Adams, Pearl, and Bury 2003). This pattern was also evident in pond surveys where the best predictors of bullfrog abundance were the presence of non-native fish and bathymetry (a surrogate for habitat alterations) (Adams, Pearl, and Bury 2003). Such positive interactions among non-native species have the potential to disrupt ecosystems by amplifying invasions, and exacerbate the effect of exotic predators on California red-legged frogs.

**Data Gaps, Uncertainties And Assumptions** . The reasons for this species decline, throughout its range, are complex (Jennings 1996). Certainly, habitat alteration from agriculture, urbanization, water developments, livestock grazing, drought and the introduction of aquatic predators (nonnative predatory fish, crayfish and bullfrogs) have played a significant role in its decline (Jennings 1995). Several studies have looked at the effects of threats individually on this and similar species (Adams 2000; Kiesecker and Blaustein 1998; Lawler et al. 1999); however, considerable uncertainty still remains as to the cumulative affects of multiple factors, particularly how disease, pesticides and drought may interact with other known factors of decline (Collins and Storfer 2003; Storfer 2003).

There are also uncertainties about the basic life history of this species. For example, the dogma in the literature is that juveniles reach sexual mature in 2–3 years (Jennings and Hayes 1985), however, evidence suggests that males may breed after their first year and females may only take two years to

become sexually mature (Norman Scott personal communication). There is also evidence that the majority of adults only live to reproduce on average two years, based on a small sample size of recaptured individuals from San Simeon, San Luis Obispo County (Norman Scott personal communication). These basic life history parameters can have significant effects on population dynamics, extinction probabilities and conservation strategies (Doubledee et al. 2003).

In addition to uncertainty associated with basic biological information and parameters, a critical assumption that is being made about California red-legged frog populations is that they operate as a metapopulation, a collection of sub-populations that exchange genetic information through individual dispersal events, and that the overall dynamics of this metapopulation follow the assumptions and patterns of a classic metapopulation. This assumption is the basis for maintaining connectivity between breeding sites but considering that there is uncertainty about patterns of frog movement and dispersal it is difficult to truly assess the qualifications required for habitats to be considered connected. What is apparent from observations, however, is that frog populations persist and flourish where suitable breeding and foraging habitats are interspersed throughout the landscape and are interconnected by contiguous dispersal habitat. From the classic metapopulation model it is assumed that where this habitat mosaic exists, local extinctions may be counterbalanced by the colonization of new habitat or re-colonization of unoccupied areas of suitable habitat. The habitat requirements necessary to maintain stable frog populations may change with more information regarding the basic population dynamics of this species.

Several studies concerning the diet, movement and effects of threats have been conducted on the northern red-legged frog (*Rana aurora*) (Adams 1999, Adams 2000, Belden and Blaustein 2002, Blaustein et al. 1996, Hayes et al. 2001, Kiesecker and Blaustein 1998, Licht 1974). It is uncertain how the results of these studies apply to California red-legged frogs. The relatedness of these two taxa (discussed above) may significantly affect the applicability of these northern red-legged frog studies towards the biology and conservation of the California red-legged frog.

Finally, the main assumption of this plan is that introduced aquatic predators, particularly bullfrogs, and habitat degradation, from excessive erosion and invasive exotic plants, are the main threats affecting this species within the HCP Area (USFWS 2002) and that focusing conservation efforts on eradicating introduced aquatic predators and habitat enhancement will result in the increase of California red-legged frog populations within Core Recovery Areas. Monitoring and Adaptive Management of California red-legged frog populations within these areas will ultimately be required to assess the validity of this assumption and to assess the overall success of this conservation approach.

**Current Management and Monitoring Practices.** Management of existing reserves within the Core Recovery Area primarily focuses on providing opportunities for recreation (primarily hiking, biking and horseback riding in public open spaces) or promotion of agricultural values (Lynch Canyon). Livestock grazing is the primary management tool for most reserves. On public lands, the primary focus of the livestock grazing is wildfire fuel reduction. Certain riparian areas within Lynch Canyon have recently been fenced off to exclude livestock grazing in order to enhance riparian habitat and minimize erosion. Limited monitoring of the effects of the current management practices has been conducted and only recently have the Plan Participants begun to develop and adopt specific management plans for such public open space areas.

**Key Monitoring and Adaptive Management Issues from Conceptual Model.** The California red-legged frog breeds from late November to early April. Eggs masses, containing between 2,000 to 5,000 individual eggs, are deposited at the surface of the water attached to emergent vegetation, such as bulrushes (*Scirpus* spp.), cattails (*Typha* spp.), roots or twigs. Eggs hatch in 6 to 14 days depending on water temperatures (Jennings and Hayes 1994; Jennings 1988; Stebbins 2003). Larvae typically metamorphose between July and September: 3.5 to 7 months after eggs are laid (Storer 1925; Wright and Wright 1949). Juveniles reach sexual maturity in 2–3 years (Jennings and Hayes 1985), with adults living 8 to 10 years (USFWS 2002). Nevertheless, the average life span is probably much lower (USFWS 2002, Norman Scott personal communication). Of the various life stages, larvae probably experience the highest mortality rates. Survival rate from hatching to metamorphosis has been estimated as less than 1% (Jennings, Hayes, and Holland 1993) or 1.9% (Cook 1997).

The habitat types that this species occupies are extremely diverse, and differ among life stages. California red-legged frogs have been observed using various aquatic, riparian, and upland habitats, including, but not limited to, ephemeral ponds, intermittent streams, seasonal wetlands, springs, seeps, permanent ponds, perennial creeks, manmade aquatic features, marshes, dune ponds, lagoons, riparian corridors, blackberry (*Rubus* spp.) thickets, nonnative annual grasslands, and oak savannas (USFWS 2002). They are found in both natural and manmade aquatic habitats, and inhabit areas of diverse vegetation cover. The most secure aggregations of frogs are found in aquatic sites that support substantial riparian and aquatic vegetation and lack non-native predators (USFWS 2002).

Habitat loss and alteration, over-exploitation, and introduction of exotic predators were significant factors in the species' decline in the early-to mid-1900s (Jennings and Hayes 1985). Reservoir construction, expansion of introduced predators, grazing, and prolonged drought fragmented and eliminated many of the Sierra Nevada Foothill populations (USFWS 2002). Only a few drainages are currently known to support California red-legged frogs in the Sierra Nevada foothills, compared to more than 60 historical records. Several researchers have attributed the decline and extirpation of California red-legged frogs to the introduction of bullfrogs (*Rana catesbeiana*) and introduced predatory fishes (Hayes and Jennings 1986). This decline has been attributed to both predation and competition.

California red-legged frogs are currently threatened by human activities, many of which operate concurrently and cumulatively with each other and with natural disturbances (e.g., droughts and floods) (USFWS 2002). Current factors associated with declining populations of the frog include degradation and loss of its habitat through agriculture, urbanization, mining, overgrazing, recreation, timber harvesting, invasion of nonnative plants, impoundments, water diversions, degraded water quality, and introduced predators (Jennings 1988).

These factors have resulted in the isolation and fragmentation of habitats within many watersheds, often precluding dispersal between sub-populations and jeopardizing the viability of metapopulations (broadly defined as multiple sub-populations that occasionally exchange individuals through dispersal and are capable of colonizing or rescuing unoccupied habitat patches). The fragmentation of existing habitat and the continued colonization of existing habitat by nonnative species may represent the most significant current threat to California red-legged frogs.

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