

STATUS OF THE CALIFORNIA RED-LEGGED FROG AND CALIFORNIA TIGER SALAMANDER AT CONCORD NAVAL WEAPONS STATION, CALIFORNIA

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ABSTRACT: Concord Naval Weapons Station (CNWS) has served as a military installation since 1942 and has been known to support special-status amphibian species for many years. The California red-legged frog (*Rana aurora draytonii*), federally listed as threatened, has a long history of occurrence at CNWS. In the early 1980's, this species was thought to have little chance for survival into the future at CNWS. At the time, non-native bullfrogs (*Rana catesbeiana*) were considered abundant at CNWS. Area-restricted visual encounter surveys at CNWS from August 1998 to August 1999 showed California red-legged frogs were abundant and have essentially replaced the bullfrog at all ponds in which ranid frogs are present. The California tiger salamander (*Ambystoma californiense*), a California species of special concern and a federal candidate for listing, is also present at CNWS, but prior to our study, its distribution across the facility was not known. We found this species in five ponds and at many upland areas of CNWS. Our surveys showed the California red-legged frog and California tiger salamander do not inhabit the tidal portion of CNWS. The sustained presence of California red-legged frogs and California tiger salamanders at CNWS is likely due to a combination of factors including absence of aquatic predators, low occurrence of migration barriers, presence of upland refugia, connectivity between water resources, and low levels of human disturbance relative to urban areas that border CNWS.

Key words: California red-legged frog, *Rana aurora draytonii*, California tiger salamander, *Ambystoma californiense*, bullfrog, *Rana catesbeiana*, military base, declining amphibians.

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Concord Naval Weapons Station (CNWS) was established in 1942 and lies along the south shore of Suisun Bay in Contra Costa County, California. Historically, open space has comprised greater than 50% of the land area at CNWS. Although a large portion (>50%) of the open space at CNWS has been leased for cattle grazing, the absence of industrial or urban development in conjunction with relatively low levels of direct human disturbance has likely contributed to the prolonged occurrence of native amphibian species at CNWS. The California red-legged frog and the California tiger salamander are examples of native amphibian species that have historically occurred at CNWS.

To effectively conserve and manage native amphibian populations at CNWS, basic information on distribution and abundance are needed. We conducted surveys for amphibians at CNWS from 1998 to 1999 to determine their status. This information can assist resource managers in developing monitoring programs and conservation goals for native amphibian species at CNWS. In this paper we present results of these surveys, compare results with past findings, and discuss conservation and management alternatives for native amphibian populations at CNWS.

California red-legged frog

The California red-legged frog was listed as threatened under the Endangered Species Act in May of 1996 (Federal Register 61(101):25813-25833) because of reduced distribution and population declines. Reasons for the declines include historic overharvest for human consumption (Jennings and Hayes 1985), habitat loss and degradation (Moyle 1973, Banta and Morafka 1966, Jennings 1988), and introduction of exotic aquatic predators (Moyle 1973, Hayes and Jennings 1986, Kiesecker and Blaustein 1998, Lawler et al. 1999). Currently, the California red-legged frog is common in the Coastal Range from Point Reyes National Seashore to Santa Barbara County, including parts of the San Francisco Bay Area (Jennings and Hayes 1994), but it has nearly disappeared from other areas of historic occurrence, and is absent from California's Central Valley. In the San Francisco Bay Area, the majority of known California red-legged frog localities are within Contra Costa and Alameda counties (USFWS 2000).

Habitat of the California red-legged frog has been described as dense, shrubby riparian vegetation combined with deep (≥ 0.7 m), still or slow moving water (Hayes and

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Jennings 1988). This species often occurs in waters with undercut banks, exposed root masses, and a dense macroinvertebrate fauna (Hayes and Jennings 1988). Vegetation components include arroyo willow (*Salix lasiolepis*), cattails (*Typha* sp.) and bulrushes (*Scirpus* sp.).

California tiger salamander

The California tiger salamander has also experienced population declines throughout its range (Shaffer et al. 1993, Jennings and Hayes 1994, Stebbins and Cohen 1995). Causes include loss of breeding sites, fragmentation of habitat, increase in introduced predators, and pest control programs aimed at commensal community members such as California ground squirrels (*Spermophilus beecheyi*) (Shaffer et al. 1993, Jennings and Hayes 1994, Stebbins and Cohen 1995). Barry and Shaffer (1994) consider the California tiger salamander "gravely threatened" in the San Francisco Bay Area. The California tiger salamander is considered a species of special concern by the California Department of Fish and Game and is proposed for threatened status by the United States Fish and Wild-

life Service (USFWS). The southernmost population in Santa Barbara County was proposed listed as endangered by the USFWS because of habitat loss to urban and agricultural development (Federal Register 65 (58):15887).

The California tiger salamander has a fragmented distribution from Gray Lodge in Butte County, throughout the Central Valley and lower elevation foothills to Santa Barbara County. The species breeds during winter in temporary vernal pools and stock ponds (Jennings and Hayes 1994), but spends most of its adult life in upland, dry-season refugia such as small mammal burrows (Storer 1925, Loredó et al. 1996).

Bullfrog

The bullfrog (*Rana catesbeiana*) has been implicated in the decline of several native vertebrate species, including California red-legged frogs and California tiger salamanders (Moyle 1973, Hayes and Jennings 1986, Schwalbe and Rosen 1988). Bullfrogs were first introduced to California at an artificial pond in El Cerrito during the late 1800's, possibly as a substitute for the overharvested California red-legged frog (Heard 1904, as re-

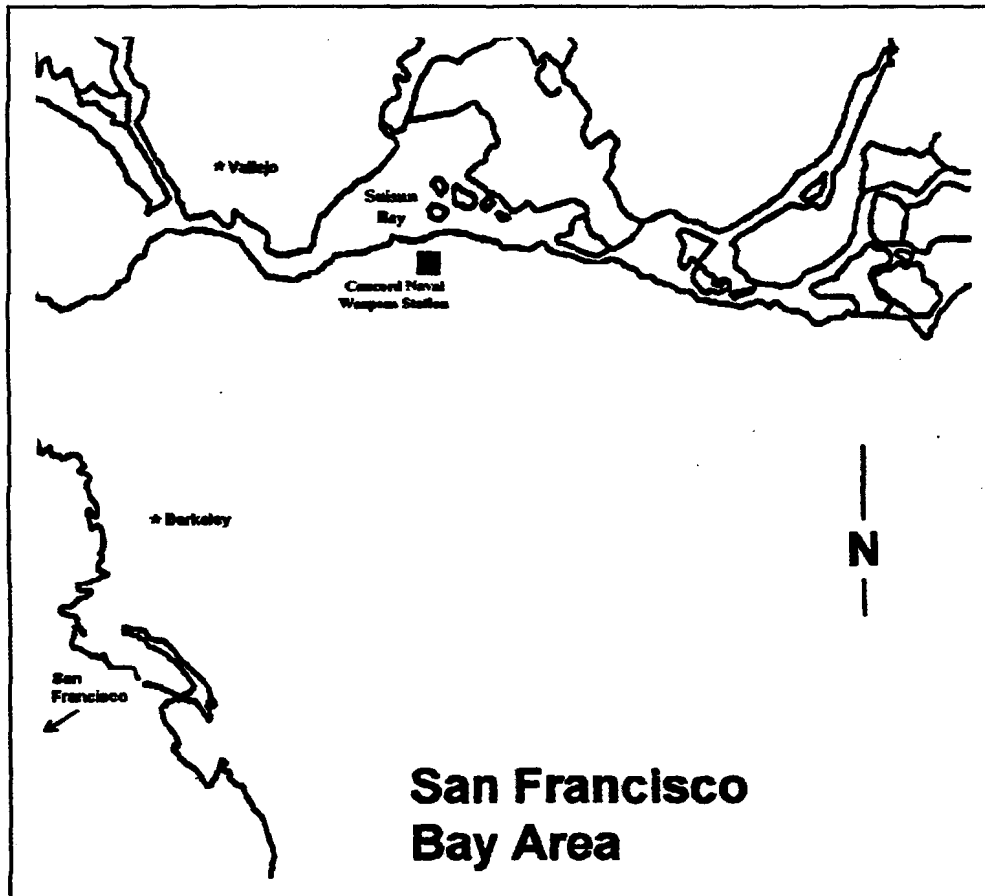


Figure 1. Location of Concord Naval Weapons Station, Contra Costa County, California.

ported in Jennings and Hayes 1985). The bullfrogs' range has expanded to include most aquatic environments in California (Bury and Luckenbach 1976, pers. obs.).

STUDY AREA

Concord Naval Weapons Station is located on the southern shore of Suisun Bay, approximately 48 km north-east of San Francisco, California (Figure 1). The Station encompasses 5,041 ha of tidal marsh and upland areas. The Station is comprised of two spatially distinct land areas, known as the Inland and Tidal areas, and are connected by a narrow road adjacent to the town of Clyde. The Inland area encompasses 2,117 ha and ranges in elevation from mean sea level (MSL) to 183 m above MSL. Diablo Creek drains from the north slope of Mount Diablo, runs through the center of the Inland area, and eventually reaches the Tidal area where it drains into marshlands of Suisun Bay. The Tidal area borders Suisun Bay and encompasses approximately 2,833 ha. Plant communities present at CNWS include oak (*Quercus* sp.) savannas, introduced annual grasslands, Fremont's cottonwood (*Populus fremontii*)/willow (*Salix* sp.) riparian corridors, freshwater marsh, tidal marsh, and anthropogenic sites such as *Eucalyptus* plantations and an abandoned rock quarry. Climate is typical of inland central California and is considered Mediterranean. Mean annual temperature is 15° C and the area receives between 38 cm and 46 cm of rain per year (Welch 1977).

METHODS

Prior to the establishment of survey sites, we examined hydrological maps to identify areas that may support breeding populations of native amphibian species at CNWS. Based on preliminary assessments, we established 19 survey sites that represented all freshwater environments likely occupied by red-legged frogs or tiger salamanders. The freshwater environments we identified were ephemeral pools and ponds, persistent ponds, seasonal creeks, and freshwater marsh.

Amphibian surveys were conducted at each site at least once per season from August 1998 to September of 1999 using area-restricted visual encounter searches (Crump and Scott 1994). Seasons in our study were spring (March to May), summer (June to August), fall (September to November), and winter (December to February). Area-restricted visual encounter surveys consist of searching a pre-defined area and counting all individuals observed. At each study site, the search area included a water feature and an adjacent border of 20 m width. Search methods included counting exposed individuals, discovering hidden individuals by searching burrow entrances and soil cracks with flashlights (at night) and mirrors (during daylight), litter raking, and turning over surface objects such as logs and rocks. Water features were searched

at the water/land interface, and a visual observation was made of the center of the water feature to see "banking" larvae or resting adults. All cover objects were returned to their original positions to minimize disturbance. The amount of time spent surveying each site was dependent upon the site's environmental complexity and weather conditions during the survey. For example, sites with limited vegetative cover required less search time than sites containing complete vegetative cover. Data recorded during surveys included location, weather conditions, date and time of survey, length of survey, identification and number of individuals of species recorded, and number and presence of life stages (e.g., eggs, larva, juveniles, adults). Physical and biological characteristics of search areas were also recorded. These included type of water feature (e.g., persistent pond), bank slope, presence of small mammal burrows, presence and type of aquatic predators, presence and identification of vegetation features, and presence/absence of grazing activity.

We analyzed data by summarizing the seasonality of amphibian species presence, activity, and relative abundance across sites sampled. Data were also examined in relation to environmental characteristics to identify those areas that appear most suitable for future enhancement or preservation. Because visibility and time required to conduct a complete search differed among environments sampled, we report our results as number observed per unit search effort.

RESULTS

We found 7 amphibian species during 179 surveys that averaged 40.3 minutes each ($sd \pm 24.9$ minutes). In addition to California red-legged frogs and California tiger salamanders, we observed the California slender salamander (*Batrachoseps attenuatus*), arboreal salamander (*Aneides lugubris*), Western (California) toad (*Bufo boreas halophilus*), Pacific chorus frog (*Pseudacris regilla*), and bullfrog. Attention here will be focused on data relevant to the California red-legged frog, California tiger salamander, and bullfrog.

California Red-legged Frog

We recorded 362 adult and 1,335 juvenile California red-legged frog sightings from August 1998 to September 1999 at 10 of the 19 sites surveyed (Table 1). We found 32 egg masses and 216 tadpoles of this species among 6 sites, including ephemeral and persistent ponds, and a freshwater marsh. Sites without red-legged frogs either lacked submerged or emergent vegetation (sites 6-8) or contained crayfish (site 14). Egg masses ($n = 32$) or tadpoles ($n = 216$) of the California red-legged frog were observed primarily in ponds (sites 2, 4, 5, 12, 13) although a single egg mass was observed within a seasonal marsh (site 1). We found egg masses from January through

March and tadpoles in August and September. Adult California red-legged frogs were observed throughout the year, although the number observed per unit survey time was greatest during September and lowest during July.

Comparisons of California red-legged frog abundance among sites where it occurred were made for the months of February, March, September, and November, which represent months when surveys were conducted at all sites where adult red-legged frogs were documented (Figure 2). Visual examination of our data showed that adults were encountered more frequently at or within the vicinity of ponds (sites 4, 5, 12, 13, and 15) and less frequently in riparian (site 11) and seasonal marsh areas (sites 1, 3). The number of California red-legged frog adults observed

per unit survey time was greatest at an ephemeral pond (site 5) during all periods of this study (Figure 2). The highest count of egg masses was also recorded at site 5 ($n = 21$ egg masses).

California tiger salamander

We found 36 adult California tiger salamanders among 10 of 19 sites surveyed (Table 1). California tiger salamander adults occurred at sites exhibiting the range of environmental characteristics we sampled, although no individuals were detected within the Tidal area (sites 16-19). The number of adult tiger salamander sightings ranged from 1 to 12 ($\bar{x} = 4$, $SD = 3.9$) among sites where it occurred. Tiger salamander eggs or larva were recorded only at ponds or rain pools that lacked submerged/emerg-

Table 1. Site characteristics and presence of California red-legged frogs (CRLF) and California tiger salamanders (CTSA) at Concord Naval Weapons Station, 1998-99.

Water Feature	Site Number	Characteristics ¹	Species/Lifestage Observed
Pond	2	a, e, h, i, k, m, o	CRLF egg mass, tadpoles CTSA adult, juvenile
	4	a, c, h, k, l, o	CRLF adult, egg mass, tadpoles CTSA adult, eggs
	5	a, c, h, i, n, o	CRLF adult, egg mass, tadpoles
	6	a, c, k, l, o	CTSA adults, juveniles
	7	a, c, k, l, o	CTSA adults, juveniles
	12	a, c, h, k, l, o	CRLF adult, egg mass, tadpoles CTSA adult, eggs, larvae
	13	b, d, h, k, l, o	CRLF adult, egg mass, tadpoles CTSA adult, larvae
	18	a, c, h, i, k, l, o	
Intermittent Drainage	9	a, f, h, i, m, o	CTSA adult
	10	a, f, h, i, m, o	CRLF adult
	11	a, f, h, i, m, o	CRLF adult
	16	a, f, h, i, k, m, o	
	17	a, f, h, i, k, m, o	
Pond/Marsh	14	b, c, h, i, j, k, l, o	
	15	b, c, f, h, i, j, l, o	CRLF adult CTSA adult
Seasonal Marsh	19	b, c, h, i, l	
	1	a, d, h, i, k, l, o	CRLF adult, egg mass, tadpoles CTSA adult
Rain Pool	3	a, d, h, i, k, l	CRLF adult
	8	a, c, g, k, m, o	CTSA adult, larvae

¹permanence of water: a = ephemeral water, b = permanent water; surrounding environment: c = annual grassland, d = oak sanannah, e = oak woodland, f = riparian corridor, g = rock quarry; vegetation features: h = emergent or submerged vegetation present, i = vegetation along margins of water; bank slope: l = < 15°, m = 15-30°, n = >30°, other: j = presence of bullfrogs, mosquitofish, or crayfish, k = grazing activity, o = small mammal burrows present.

gent vegetation or vegetation along margins of the water source, and were within grazed grassland or oak savannah (sites 4, 8, 12, 13; Table 1). California tiger salamander eggs were observed during February and March 1999. We observed the highest number of salamander eggs (n ~500 eggs) during February at an ephemeral pond surrounded by grazed annual grassland (site 12). This pond lacks emergent vegetation, vegetation at its borders, and no aquatic predators were recorded at this site.

The greatest number of California tiger salamander larvae (n=17 larvae, site 8) was observed at a small (<4.0 m³) rain pool formed between boulders 0.5 to 2 m in diameter, which are remnants of a rock quarry. The pool lacked submerged or emergent vegetation. Additionally, 4 adult tiger salamanders were recorded from the surrounding upland area at this site. We sighted 44 juvenile tiger salamanders among sites 2, 6, and 7. The greatest num-

ber of juvenile sightings (n = 36, site 7) was at a pond (117 x 60 m) within grazed grassland. The margins of this pond did not support vegetation, and submerged or emergent vegetation was absent. We sighted six juvenile tiger salamanders at site 6 and two at site 2. Site 6 is an ephemeral pond located 200 m from site 7, and exhibits similar environmental characteristics (Table 1).

Bullfrog

We observed 1 bullfrog during 179 surveys from August 1998 to September 1999. This single observation was from a large perennial pond (site 15) where both red-legged frogs and tiger salamanders co-occurred. No bullfrog tadpoles were sighted, and no vocalizations were heard during hundreds of additional hours of diurnal and nocturnal surveys for other vertebrate species we conducted during 1998 and 1999 at CNWS.

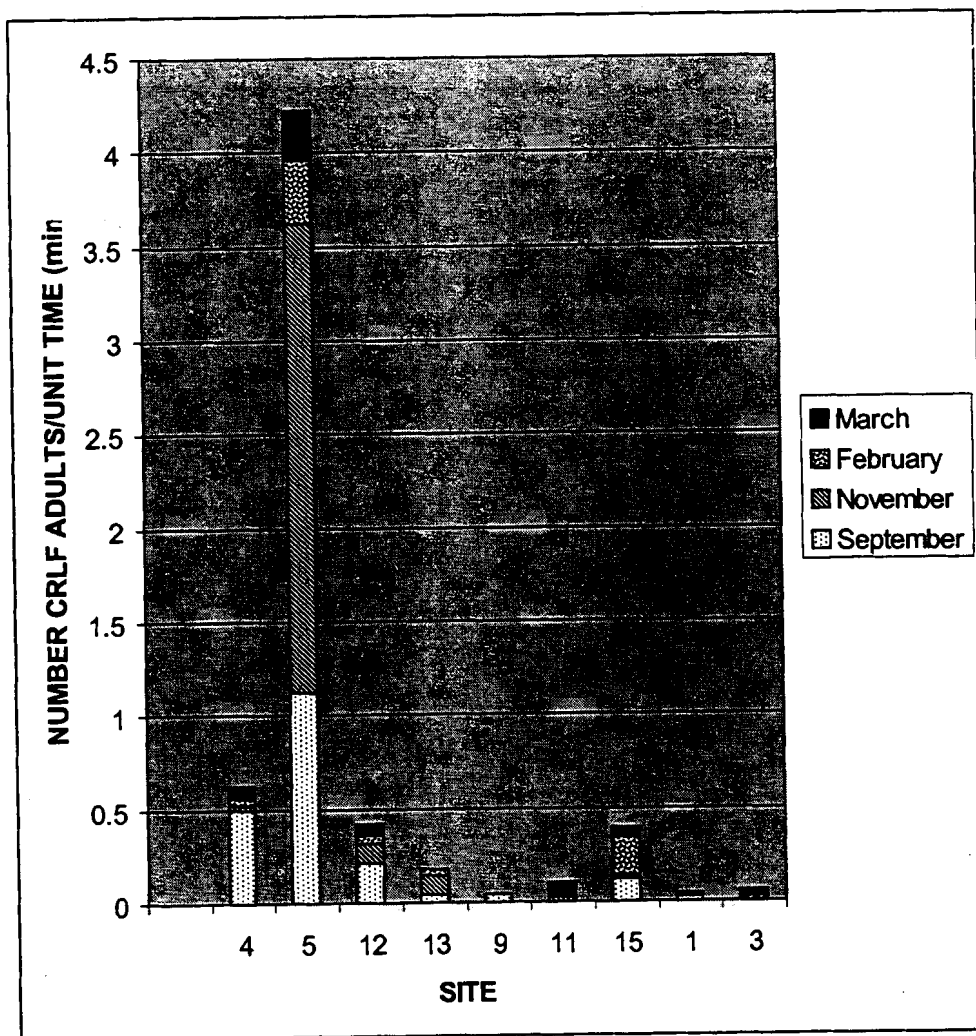


Figure 2. California red-legged frog adults observed per unit search effort at Concord Naval Weapons Station September 1998, November 1998, February 1999, and March 1999.

DISCUSSION

California red-legged frog

Amphibian populations are subject to extreme variation in numbers from year to year (Tyler 1991), but at present the California red-legged frog is widely distributed across the Inland area of CNWS. Past survey efforts have documented the California red-legged frog at CNWS, but in limited distribution relative to our findings. A prior station-wide survey effort in 1982 reported red-legged frogs from only one location, our site 15 (Jones and Stokes, unpublished report). The California red-legged frog was introduced in May, 1982 to site 15 by the California Department of Fish and Game (CDFG) (Jones and Stokes, unpublished report). At the time, the California red-legged frog population at site 15 was considered "an introduced population of marginal viability" that is "unlikely to establish there" because of the current "healthy" bullfrog population. In 1994, Kuenzi and Morrison (unpublished report) found the California red-legged frog at two locations, our site 15, and adjacent to an ephemeral pond (site 5). Because methodology and survey effort varied between these studies and ours, it is difficult to make valid quantitative comparisons. We were, however, able to document the presence and distribution of California red-legged frogs through time at CNWS.

California red-legged frogs were not observed in the Tidal area, even though seemingly suitable aquatic habitat exists at an ephemeral pond (site 18), a perennial freshwater marsh (site 19), and at two intermittent drainages (sites 16 and 17). Past surveys also showed absence of this species in the Tidal area. Diablo Creek represents the only hydrological connection between the Inland and Tidal areas, but upon reaching the Tidal area, Diablo Creek drains into salt marsh. Upland environments are contiguous between the Tidal and Inland areas, although the extent of migration by amphibian species within this area is unknown. California red-legged frogs are known to travel overland up to 1.6 km when appropriate weather conditions exist, such as overcast skies or precipitation (USFWS 1997).

California tiger salamander

California tiger salamanders are also widely distributed across the Inland area at CNWS. In 1982, Jones and Stokes (unpublished report) recorded this species in four localities (our sites 2, 7, 8, 15). Later surveys conducted by Kuenzi and Morrison (unpublished report) did not record the presence of California tiger salamanders at CNWS. The species was found to breed in four ponds at CNWS in 1991-1994 (Loredo and Van Vuren 1996). Based on the use of drift fences, abundance of captured adults at one ephemeral pond (our site 12) were 0 in 1992, 146 in 1993, and 135 in 1994, and the number of juveniles found

were 1,248 in 1992 and 3 in 1994 (Loredo and Van Vuren 1996).

Factors affecting native amphibian populations at CNWS

The apparent decline in bullfrog abundance from 1982 to the present is worthy of notice. Our single bullfrog sighting occurred at a small (2.0 m²) plunge-pool at the end of a densely vegetated drainage (site 15). Past surveys at CNWS resulted in bullfrog sightings at two sites (sites 9 and 15) in 1982 and 14 sightings dispersed across the base during nighttime driving surveys in 1994. The temporal and spatial extent of surveys we conducted in 1998-99 was significantly greater than past studies. Thus, we would expect to find more bullfrogs if they occurred at similar past levels. Thus, combined results suggest a decline in bullfrog abundance at CNWS. Because complete surveys of native amphibian populations have not been conducted between 1982 and the present, we can only speculate as to when or how bullfrog populations fluctuated. However, we think one variable that generally favors native amphibian species is the seasonality of waters on CNWS. Fifteen of the 19 (79%) water features we surveyed are ephemeral. In addition, rainfall in the early 1990's may have been less than sufficient to keep the usually perennial ponds and other waters inundated through the bullfrog's breeding season at CNWS (sites 13, 14, 15, and 19). Prolonged dry periods may favor California red-legged frogs and California tiger salamanders over bullfrogs, because bullfrog tadpoles mature later in the year, and may overwinter in aquatic habitat (Bury and Whelan 1984, Stebbins 1985). Because California red-legged frogs have earlier-developing larvae (Storer 1925), they may have been able to gain an advantage over the introduced bullfrog at this time. Cook (1997) found that the later breeding season and physiological traits of the bullfrog are a "strong disadvantage" in comparison with the California red-legged frog in an ephemeral aquatic environment in northern California.

The spatial distribution of aquatic features is another factor that likely affects the success of native amphibian populations at CNWS, particularly California red-legged frogs. Connectivity exists between several of our survey sites (e.g., 4, 5, and 11; 8, 12, and 15; 1, 2, 3, 13) in the form of small, seasonal drainages, channelized canals, or by water flows during heavy rainfall. At a larger scale, connectivity exists between Mount Diablo State Park and CNWS via Diablo Creek. We think these drainages act as dispersal corridors. Scientists have conjectured that western ranid frogs exhibit metapopulation dynamics, and may exist as small demes (Storm 1960, Brown 1975, Hayes and Jennings 1986), which we believe to be the case at CNWS. As small ponds form or disappear over the landscape,

the local distribution of California red-legged frogs follows suit, with connectivity allowing for immigration of individuals between more permanent bodies of water. Bullfrogs may also use these corridors for dispersal, but we think the ephemeral nature of these corridors, combined with the seasonal nature of most water bodies, present conditions inhospitable for use by bullfrogs.

The low occurrence of migration barriers and abundance of California ground squirrel burrows in upland areas are two additional factors that likely contribute to the continued presence of California red-legged frog and California tiger salamanders at CNWS. Valley annual grassland is the primary environment that occurs between aquatic sites at CNWS. A single road traverses the Inland area, separating Diablo Creek from all other sites. This road receives little use, especially during evening hours. Thus, seasonal movements by California red-legged frogs and California tiger salamanders among most aquatic sites at CNWS are not likely inhibited. Further, nightly foraging activities of the California red-legged frog are likely not inhibited.

Presence of upland habitat may also have a positive effect on native amphibian populations at CNWS. California ground squirrel burrows were present at 89.5% of aquatic sites surveyed. Loredó et al. (1996) found burrows were consistently used by California tiger salamanders, and we observed California red-legged frogs likewise use burrows as cover and foraging habitat. To the best of our knowledge, studies on the importance of small mammal burrows to California red-legged frogs are lacking.

MANAGEMENT IMPLICATIONS

During winter of 1998-1999, California red-legged frog egg masses were observed at water sources accessible to cattle at CNWS. Disruption of red-legged frog egg masses and subsequent scattering of individual eggs as a result of cattle activity was observed. These observations suggest a negative impact on California red-legged frog populations, although this species, along with California tiger salamanders, have co-occurred with cattle for several decades at CNWS. Livestock grazing has been implicated in contributing to population declines in California by decreasing suitability of aquatic habitat (Behnke and Raleigh 1978). Alternatively, cattle grazing may provide habitat for California red-legged frogs through creation of aquatic habitats (stock ponds) and control of emergent vegetation (USFWS 2000). To this point the effect of cattle activity on red-legged frog reproductive success at CNWS is uncertain and needs further study.

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