Research Note

Diurnal Versus Nocturnal Surveys for California Red-Legged Frogs

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Key words

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The United States Fish and Wildlife Service (USFWS) federally listed the California red-legged frog (*Rana draytonii*; Shaffer et al. 2004) as a threatened species in June 1996 (USFWS 1996). The listing justification stated that a variety of human activities, including urban encroachment, construction of reservoirs and water diversions, introduction of exotic predators and competitors, livestock grazing, and habitat fragmentation, had extirpated red-legged frogs from 70% of their former range and continue to be a threat (see also Fellers 2005). Because the Endangered Species Act of 1973 now protects this frog, biologists must conduct surveys prior to any federally permitted habitat modifications or any activity on federal lands that has the potential to affect this species.

In February 1997, USFWS provided guidelines for conducting red-legged frog surveys, including general guidelines for conducting both diurnal and nocturnal surveys (USFWS 1997). The USFWS updated these guidelines in 2005 (USFWS 2005) and gave detailed requirements for both the qualifications of biologists conducting surveys and the techniques for carrying out field surveys. The goal of our study was to compare diurnal and nocturnal surveys for California red-legged frogs to determine whether there was a difference in detections. We conducted paired diurnal and nocturnal surveys for adult and subadult California red-legged frogs at sites in the California Coast Range and Sierra Nevada foothills.

Study Area

Our 17 survey sites were located in 5 counties and 8 habitat types in California, USA (Table 1). Two sites were located in the Sierra Nevada foothills (P-393, P-494), with the rest located near San Francisco Bay (Fig. 1). Land movement along the San Andreas Fault formed the 2 natural ponds in Marin County. The pond vegetation was predominantly cattails (*Typha* sp.), rushes (*Juncus* sp.), and pennywort (*Hydrocotyle ranunculoides*). The stock ponds were located in grasslands with similar vegetation to the natural ponds. Old mine tailings formed the Yuba County pond, which had a combination of blackberries (*Rubus ursinus*), willow (*Salix* sp.), and alder (*Alnus* sp.). The abandoned millpond in Butte County had white alder (*Alnus rhombifolia*) and willows around the perimeter.

Ranchers previously used the abandoned waste ponds to accumulate livestock waste on a dairy ranch. All dairy activities ceased in 1998 and the ponds had recovered and looked similar to the stock ponds. The largest abandoned waste pond supported a dense growth of algae that made the water opaque. The cement cistern had a water depth of >2 m, and vertical sides that precluded frogs from leaving during the drier times of the year when the water level dropped. There was a dense growth of pennywort on the surface that the frogs used for cover and resting. The marsh was a natural wetland and had cattails and some willows.

The former estuary was a large horseshoe-shaped pond with occasional saltwater intrusions from the ocean, located 100 m away. A dam, built about 50 years ago, excluded salt water and allowed the marsh to become a shallow freshwater pond. There was little aquatic vegetation, but some coyote brush (*Baccharis pilularis*) was present around the perimeter. One stream site (P-576) had relatively little vegetation aside from a few rushes and Mediterranean grasses. The pool at this site was >1 m deep and held water when the perennial stream dried in the fall. The other stream site (P-408) was permanent and bounded by willows, California bay (*Umbellularia californica*), blackberries, and nettles (*Urtica dioica*).

In addition to California red-legged frogs, we found Pacific treefrogs (*Pseudacris* [=*Hyla*] *regilla*) at 12 of the 17 survey sites and we found bullfrogs (*Rana catesbeiana*) at four sites. Pacific treefrogs are common, but readily distinguished from California red-legged frogs based on size alone. Bullfrogs are difficult to distinguish from California red-legged frogs during nocturnal surveys, but they were rarely present at our study sites, and we were able to approach the frogs sufficiently closely to allow observation of the diagnostic features of each frog. Bullfrogs could be problematic in areas where frogs could not be closely approached or where less experienced observers conducted surveys.

Methods

We conducted 29 paired diurnal and nocturnal surveys from October 1999 to September 2004 (Table 1). We conducted

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Table 1. Site characteristics for California red-legged frog diurnal and nocturnal surveys conducted in northern California, USA from Oct 1999–Sep 2004.

Site	County	Habitat	Size (m)
P-100	Marin	Natural pond	80 × 40
P-122	Marin	Natural pond	188 × 28
P-494	Yuba	Natural pond	23 × 9
P-072	Marin	Stock pond	82 × 18
P-084	Marin	Stock pond	67 × 18
P-090	Marin	Stock pond	31 × 21
P-393	Butte	Abandoned mill pond	43 × 20
P-037	Marin	Abandoned mill pond	85 × 25
P-541	Marin	Abandoned dairy waste pond	43 × 17
P-542	Marin	Abandoned dairy waste pond	22 × 4
P-543	Marin	Abandoned dairy waste pond	5 × 3
P-540	Marin	Cement cistern	6 × 4
P-143A	Marin	Marsh	60 × 10
P-310	Marin	Former estuary[a]	1250 × 125
P-411	Contra Costa	Stream pool	3 × 2
P-408	Santa Clara	Stream	350 × 1
P-576	Contra Costa	Stream	190 × 1

[a] Former estuary that was dammed about 50 years ago to create a large, shallow pond adjacent to the ocean.

surveys throughout most of the year, not just from 1 May–1 November (USFWS 1997) or 1 January–30 September (USFWS 2005), because many of the surveys were part of other research projects that required us to work during other times of the year. This variation in sampling time is unlikely to affect the diurnal and nocturnal comparisons reported here. We reduced the potential of disturbing frogs, eggs, or tadpoles while conducting surveys because we did not wade in the water. We surveyed one site entirely by boat (P-310), and we surveyed all other sites by walking along the bank.

We were careful to reduce variation caused by weather, season, or observer. At each site, we conducted diurnal and nocturnal surveys on the same day and by the same observer (one of the authors). Both of us have >12 years of experience conducting surveys for frogs, including more than 600 surveys for California red-legged frogs. To maximize detections, we conducted surveys when 1) wind speed was <15 km/hour, 2) fog or rain did not reduce visibility below 100 m, and 3) air temperature exceeded 14° C during the day and did not fall below 5° C at night. We recorded frogs as subadults if they appeared to be <6 cm in snout–vent length.

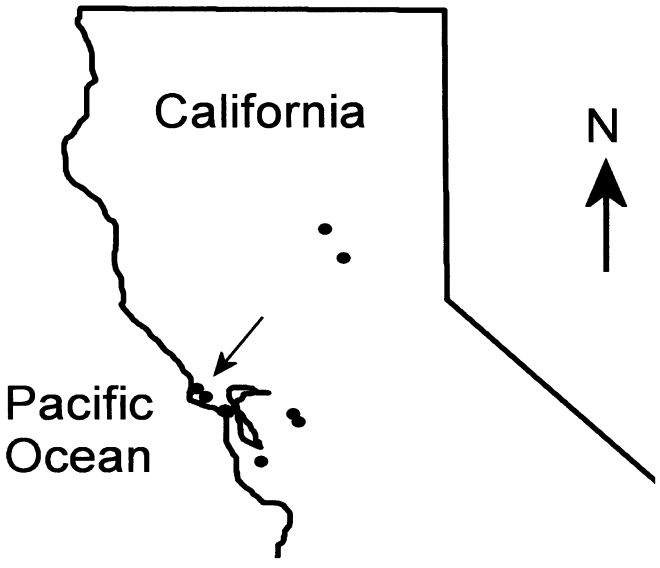

Figure 1. Distribution of California red-legged frog sites in northern California, USA, where we conducted diurnal and nocturnal surveys from Oct 1999–Sep 2004. Arrow highlights sites in Marin County, where we conducted the majority of the surveys.

We conducted diurnal surveys by slowly walking the perimeter of each site while searching the bank and open water for frogs with 8 or 10× binoculars (Fellers and Freel 1995). We classified frogs to species and age (adult or subadult [<6 cm snout–vent length]). We slowly approached frogs not readily identified until we could make a positive identification. We recorded frogs that jumped into the water before we identified them as unidentified and excluded them from statistical analysis. We did not include any diurnal surveys where our primary goal was to count California red-legged frogs egg masses, because we detected notably fewer adult and subadult California red-legged frogs when searching for eggs.

Nocturnal surveys were similar to diurnal surveys except that we used a 30-W sealed beam light (358 lux at 5 m) and binoculars to look for frog eye shine (Corben and Fellers 2001). We placed the binoculars on the light and moved the two in unison to scan the bank, open water, and emergent or floating vegetation up to about 20 m away. Nocturnal surveys began 1 hour after sundown (complete darkness) and we completed them within 3 hours of darkness, with one exception (site P-393, Table 1). We did not conduct surveys within 5 days of a full moon (with 2 exceptions) because frogs are less active and more skittish on nights with increased ambient light (Table 1).

We analyzed data with the use of Statistix (*t*-tests, version 8.0, Analytical Software, Tallahassee, Florida). We used $\alpha = 0.05$ to evaluate statistical significance.

Results

We detected significantly more California red-legged frogs during nocturnal surveys than diurnal surveys (387 vs. 46 ad

Table 2. California red-legged frog counts during diurnal and nocturnal surveys conducted Oct 1999–Sep 2004 in northern California, USA.

Site	Day			Night			No. of surveys[a]
	Ad	Subadults	Total	Ad	Subadults	Total	
P-100	0	5	5	6	19	25	1
P-122	1	1	2	27	9	36	1
P-494	0	0	0	1	0	1	1
P-072	1	7	8	22	19	41	2
P-084	1	1	2	13	4	17	3
P-090	0	0	0	5	16	21	2
P-393	2	2	4	10	3	13	2
P-037	0	0	0	27	1	28	1
P-541	0	0	0	45	88	133	3
P-542	0	5	5	1	7	8	2
P-543	0	4	4	9	5	14	2
P-540	1	5	6	3	5	8	2
P-143A	0	0	0	1	0	1	1
P-310	0	0	0	2	0	2	1
P-411	1	1	2	1	1	2	1
P-408	2	0	2	5	0	5	1
P-576	3	3	6	22	11	33	1
Totals	12	34	46	200	188	388	27

[a] Number of surveys refers to the number of paired day and night counts at that site. Hence, one survey consists of one diurnal and one nocturnal survey conducted on the same day.

and subadult frogs, $t = 2.89$, df $= 46$, $P < 0.001$; Table 2), and we detected 89.4% of the California red-legged frogs at night. We detected California red-legged frogs during 52% of the diurnal surveys, compared with 100% of nocturnal surveys ($Z = 4.62$, $P < 0.001$; Table 2). Furthermore, there was not a site at which we detected frogs during the day but not during that same night. The results remain significant when we analyzed adult and subadult frogs separately (ad, $P = 0.008$; subadults, $P = 0.003$).

During diurnal surveys, we classified more frogs as unknown (34.5% vs. 6.3% of all frog sightings) or as *Rana* sp. (12.6% vs. 3.3% of frogs), but these differences were not statistically significant due to large variability between sites. We found unidentified frogs, or frogs referred to as *Rana* sp., at 5 of 27 sites, with 87.8% of these frogs at only 3 sites where dense vegetation affected detections.

Discussion

We compared diurnal and nocturnal surveys for adult and subadult California red-legged frogs occupying a variety of habitats (Table 1). Our results indicate that nocturnal surveys were more likely to detect the presence of California red-legged frogs and they detected significantly more frogs of this species than did diurnal surveys. These findings support the provision of the USFWS protocol for conducting California red-legged frog surveys (U.S. Fish and Wildlife Service 2005) that requires nocturnal surveys if California red-legged frogs are not detected during the day.

We found large differences between the numbers of unidentified frogs observed during the day versus night, but the differences were not significant. Nonetheless, it was often easier to observe frogs closely at night. During the day, frogs were more skittish, jumping into the water or sinking out of sight. Hence, nocturnal surveys are advisable not only because they result in higher detection of California red-legged frogs but also because it is easier to identify frogs reliably.

Although nocturnal surveys are more effective than diurnal surveys for detecting and counting California red-legged frogs, we believe diurnal surveys are an important part of the survey protocol. A diurnal visit to the site gives the biologist a chance to evaluate how to conduct the nocturnal survey effectively, including evaluating potential obstacles (e.g., thickets, downed trees, steep banks) and noting prime habitat to survey carefully at night. Diurnal visits also allow the biologist to assess habitat quality and conduct surveys for eggs, tadpoles, and recent metamorphs; however, it is important to recognize that it is not possible to survey effectively for all 3 of these life history stages simultaneously. Each stage requires different techniques and a different search image; trying to search simultaneously for multiple life history stages can reduce the likelihood of finding any one of them (Dukas and Kamil 2001, Clark and Dukas 2003).

Management Implications

Nocturnal surveys are the most efficacious method to determine the presence of adult and subadult California red-legged frogs. However, biologists doing surveys for California red-legged frogs must be skilled at finding and identifying amphibians, and they must use appropriate survey techniques and equipment.

If California red-legged frogs are not detected at a site during surveys conducted in accordance with the USFWS protocol (USFWS 2005), USFWS has the option of allowing development of the area without further fieldwork. Hence, it is important that the protocol results in a high likelihood of detecting California red-legged frogs if they are present. Our study supports the recent improvements in the USFWS protocol (USFWS 2005) that require both

diurnal and nocturnal surveys to evaluate the presence of California red-legged frogs.

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