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Post-fire survival of the threatened California red-legged frog in the Sierra Nevada following the Mosquito Fire

RESEARCH NOTE

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Fire in the landscape is a natural disturbance factor to which native species have evolved, particularly in the western United States (Pilliod et al. 2003, Jager et al. 2021). Large-scale wildfires can temporarily reduce thatch, directly kill wildlife, change soil chemistry, facilitate immigration and emigration, open otherwise closed habitats, redistribute vegetation communities, reduce, or eliminate some habitat types, and have either positive or negative impacts (Rommo 1982, Pease et al. 1989, Pilliod et al. 2003, Schuster et al. 2005, Rochester et al. 2010). Fire has been used as a management tool for wildlife populations based on an understanding that fire has always been a part of the evolutionary history of wildlife (Leopold 1933). However more recent changes in fire suppression, changes from historical land use, and confounding effects of bark beetle epidemics and climate change have severely altered the intensity and frequency of large-scale wildfires in California (Hessack and Corn 2007, Jager et al. 2021, Wayman and Safford 2021).

The response of wildlife to fire has been and is currently being studied (Leopold 1933, Kramm 1966, Mackey et al. 2002, Hossack and Pilliod 2011, Jager et al. 2021). Slow-moving species or isolated wildlife populations, which would appear to be very vulnerable to large-scale fire, are getting increasing attention by researchers (Pilliod et al. 2003, Keyser et al. 2004, Rochester et al. 2010, Hossack and Pilliod 2011). Amphibians in particular, have been shown to recover from wildfires events, albeit at different levels and among different species (Hossack and Corn 2007, Cook and Hayes 2020). Species in decline may be more vulnerable to high severity fire events due to their isolation and low numbers.

The California red-legged frog (*Rana draytonii*) is a declining species that occurs in patches of appropriate habitat in the southern portion of the North Coast Range, through the northern portion of the south Coast Range, and in isolated populations in the Sierra Nevada mountains (Barry and Fellers 2013, Thompson et al. 2016). We assessed the survival of the threatened California red-legged frog immediately following the high severity Mosquito Fire, which burned the habitat for an isolated population in the central Sierra Nevada.

California red-legged frogs have been known to occur at the Big Gun Mitigation site, Michigan Bluff, California since at least 2007, but certainly occurred there before their documentation, and include a stable population of breeding adult California red-legged frogs within seven ponds on the property (J. Alvarez, unpublished data; Services, unpublished data). Additional ponds were created within the last 10 years on adjacent lands owned by the US Forest Service and the Bureau of Land Management. These off-site ponds have included colonizing individuals, but breeding populations are not currently known. Habitat in the general area includes extensive tracts of coniferous forest that are contiguous for many tens of miles. Interspersed within this forest are small residential houses, small towns, roadways and highways, and the American River.

The mitigation site is the focal point of California red-legged frog monitoring efforts that include counting frogs and differentiating each life stage, along with assessing sympatric species twice annually with up to six additional visits per year. The most recent survey occurred in June 2022 and was conducted by the authors and several associates, who walked the perimeter of all inundated ponds and counted individual frogs.

On 6 September 2022, a fire ignited at Mosquito Road, near Oxbow Reservoir in Placer County, CA, USA approximately 4.2 km south-southwest of the mitigation site. Due to extensive stressed-killed trees, drought conditions, and a northeasterly wind, the mitigation site was burned over within one day of the initial ignition. The fire encompassed an area of approximately 31,200 ha within five days. Although the burn severity maps were not complete at the writing of this report, on-the-ground assessments by the authors on 26 September 2022 suggested high severity burned areas mixed with completely unburned areas (Figs. 1, 2).

Figure 1. Burned area of the mitigation site showing areas of high severity burn north and upslope of pond 6, Big Gun Mitigation site in Michigan Bluff, Placer County, CA, USA, 29 Sep 2022.

Figure 2. Burned area showing mixed severity burn on the mitigation site southeast of pond 4, Big Gun Mitigation site in Michigan Bluff, Placer County, CA, USA, 26 Sep 2022.

The result was a mixed severity burn area over the 21 ha site that included burn patches to mineral soil and other patches of untouched vegetation. Most of the existing inundated ponds experienced fire to the wet edge on 50% or more of the shoreline (Fig. 3).

Figure 3. Burned area showing high severity burn up to the wet edge of pond 4, Big Gun Mitigation site in Michigan Bluff, Placer County, CA, USA, 29 Sep 2022.

We conducted nighttime visual encounter surveys of the ponds, using 400 lumen hand-held lights to collect data on the numbers, life stage, and, when possible, sex of frogs that were encountered. This mimicked surveys that we conducted in June of the same year with the intention of making a generalized comparison of the population structure pre- and post-fire. We acknowledge that our observations were opportunistic and may have included unintended biases. Our access to the site was much easier and with that we may have been able to look at approximately 20% more (estimated) shoreline edge due to vegetation absent post-fire. We are aware that the two timeframes are not equivalent in that life stages of this frog appear at different times of the year. Finally, we acknowledge that two surveys in the same year by a similar group of skilled biologists are likely to see a different suite of individuals and or species composition due to the change in seasonal behavior of the observable species.

In June 2022, we found 22 adult, 2 subadult, and 230 larval California red-legged frogs inhabiting Ponds 1, 3, and 4, (Fig. 4). Numbers of animals detected surveyed by pond (Table 1). During our post-fire surveys in September of 2022, we observed >300 California red-legged frogs in ponds 1, 3, and 4 (Table 1).

Figure 4. Big Gun Mitigation site in Michigan Bluff, Placer County, CA, USA (outlined in dashed yellow), with School Road going north/south along left edge. Individual ponds are labeled.

Table 1. California red-legged frogs observed at all ponds (1, 3, and 4) combined at the Big Gun Mitigation site in Michigan Bluff, Placer County, CA, USA in 2022.

Timing	Adult	Sub-adult	Post-metamorphic	Larvae	Sympatric Species
Pre-fire	22	2	0	230	Pacific treefrog, Sierra garter snake, terrestrial garter snake
Post-fire	62	1	>300	0	none

Our results show that the California red-legged frog population at the Big Gun Mitigation site survived 24 days following the Mosquito Fire. Additionally, more than 300 post-metamorphic frogs, (6 of which were found in a rain-filled pool away from natal ponds), also survived the fire. By using hand-held flashlights to detect frogs we were frequently (>50%) able to observe frogs very closely along the shoreline. During surveys in June and in September we detected both adult and subadult frogs. We did not detect a single injury or potential injury that could be attributed to burns (zero injuries detected).

We noted the adult and post-metamorphic frogs were found up to approximately 3 m from the wet edge of aquatic habitat, which was similar to June survey efforts. This included frogs of all sizes and ages resting on burned soil, in ash piles, and on burned logs, along with resting immediately adjacent to or within aquatic habitat. Although we saw seven snakes of two species, and numerous lizards (N=75 Pacific treefrogs during June surveys, these species typically move away from aquatic sites or retreat later in the season and would not be expected in large numbers in late September (Conant 1938, Oliver 1947, Seigel et al. 1987).

We made no attempt to analyze water or soil chemistry, to tag individual frogs, or to collect systematic data during either survey. Our surveys were opportunistic and designed to determine if an isolated population of California red-legged frogs could survive a late-moving high severity fire in the Sierra Nevada. Many authors suggest that high-intensity fires may increase in frequency due to changes in fire suppression activities, land use changes, and effects of bark beetle epidemics, in conjunction with climate change (Hessack and Corn 2007, Jager et al. 2021, Wayman and Safford 2021). If this is a part of the future faced by declining species, it is critical to know if species can survive such conditions. Cook and Hayes (2020) found that California red-legged frogs, and sympatric species can survive a low and moderate severity fire that was centered around an ephemeral marshland. Neither Cook and Hayes (2020), nor this study can say to what level California red-legged frog mortality may have occurred during the respective fires, but both studies show that populations of this species can survive a single low to severe severity fire in different habitats. Understanding the impacts to individuals (e.g., among a PIT tagged population) could help to elucidate the impacts on populations (loss of individuals) and may better inform management surrounding these types of sites. However, this species and other California amphibians, have evolved with fire as part of their natural history. Knowing that there are behavioral mechanisms that are part of the natural history of this species guild, which contribute to their survival during severe fire events can support better and more resilient management of this declining species.

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