State of California

M e m o r a n d u m

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Subject: Capture-mark-recapture at Mossy Pond, Tahoe National Forest, Nevada County
Summary of activities in 2018

INTRODUCTION

The Aquatic Biodiversity Management Plan for the South Yuba River Management Unit (CDFW 2014) identifies sites occupied by the Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) as amphibian resources and prescribes regular monitoring of populations. California Department of Fish and Wildlife (CDFW) began monitoring SNYLF populations in the management unit in 2001. In addition, CDFW halted fish plants in areas with observed SNYLF populations (CDFW 2013). This memorandum addresses SNYLF in the Mossy Pond Complex, south of Fordyce Reservoir (Figure 1).

In 2012, periodic visual encounter surveys (VES) during the previous decade suggested the Mossy Pond SNYLF population could be headed toward extirpation. However, complete VES of wetted habitat during summer 2013 suggested a robust population is present in the area. After assessing all available habitats in the area, CDFW concluded that previous surveys had focused on the wrong habitat: large, deep lakes, instead of streams, smaller ponds, and meadows. Based on this new understanding of the SNLYF population in the Mossy Pond Complex, CDFW initiated a capture-mark-recapture (CMR) study in 2014. Beginning in 2015, U.S. Fish and Wildlife Service (USFWS) awarded CDFW funds for this study through the endangered species recovery grant program (Section 6 of the U.S. Endangered Species Act of 1973; Federal Grant Award #F16AP00042). The most recent funding allowed field work to continue through summer 2018.

ENVIRONMENTAL SETTING

The Mossy Pond Complex is located in Tahoe National Forest, north of Highway 80 in Nevada County (Figure 1). The site is accessible via United States Forest Service (USFS) dirt roads and four-wheel drive trails. The Mossy Pond Complex consists of approximately 60 lakes, ponds, and small streams set on granite benches southeast of Fordyce Lake. Many of the waterbodies in the Mossy Pond Complex support small SNYLF populations. The Mossy Pond Complex ranges in elevation from 6,400 feet (near Fordyce Lake) to 7,100 feet. Various stream channels contain flowing water for brief periods each spring, but the site retains intermittent pools in the stream channels during the rest of summer. United States Geological Survey (USGS) field crews first detected SNYLF in the watershed in 1998 at Mossy Pond and Evelyn Lake; CDFW began monitoring the population in 2001.

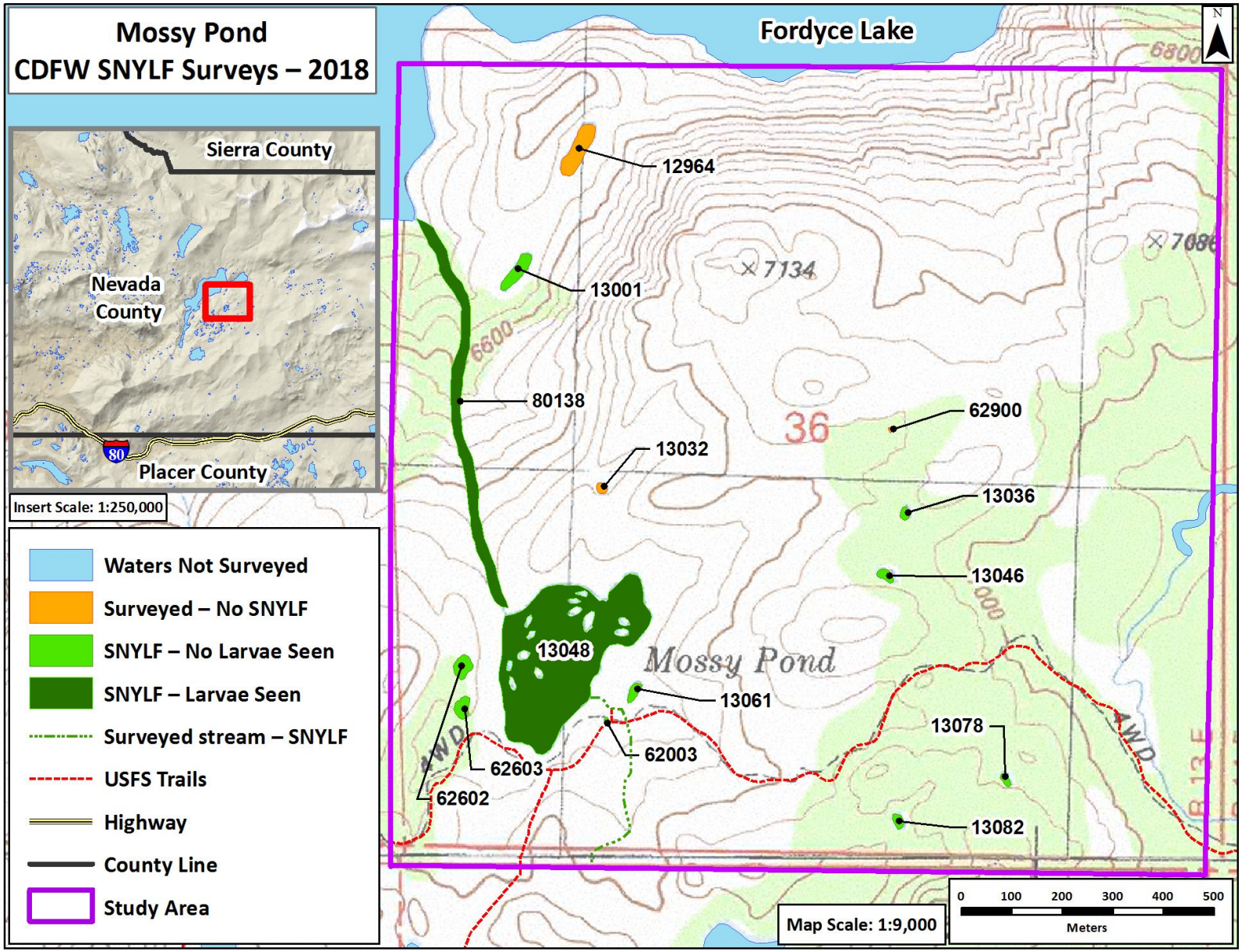


Figure 1: Sierra Nevada Yellow-legged Frog (SNYLF) observations from visual encounter surveys (VES) in the Mossy Pond area in summer 2018. California Department of Fish and Wildlife (CDFW) field crews visited the study area (highlighted in purple) four times (June, July, August, and September) for a capture-mark-recapture (CMR) study that has been underway since 2014. Each visit involved three consecutive days of surveying. Each day, crews surveyed all 14 labeled waterbodies in the study area, plus any other observed aquatic habitat.

THREATS

- **Marginal Habitat** –Mossy Pond has a nearly six hectare surface area and a maximum recorded depth of 2.5 meters, though much of the pond is even shallower. Although there are multiple deep fishless lakes in the vicinity, there is currently no evidence of breeding at these lakes. Field crews regularly observe SNYLF larvae and egg masses at Mossy Pond and its outlet stream, both of which are shallow. Severe winter conditions, extended drought, or anthropogenic habitat disturbances present potential extirpation risks to the population.

- **Disease** – The Mossy Pond SNYLF population is positive for the fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*). To detect *Bd*, field crews collected epithelial swabs in 2010 and 2011. Partner scientists screened the swabs for presence of *Bd* DNA using real-time quantitative polymerase chain reaction (qPCR) analysis. The swab analyses detected very light to moderate *Bd* infection intensity.

- **Introduced Fish** – CDFW formerly stocked Mossy Pond and all named ponds in the vicinity with Brook Trout (*Salvelinus fontinalis*, BK). In 2000, in response to rangewide declines of SNYLF and a departmental reassessment of stocking practices, CDFW halted stocking at ponds in the vicinity. During surveys in 2001, CDFW field crews detected BK at five lakes in the Mossy Pond Complex, including three ponds in which crews observed SNYLF. During follow-up gill net surveys in 2010, field crews did not capture any BK, which suggests that BK did not persist in the absence of stocking. Since 2010, crews have not detected any fish during visual surveys in the Mossy Pond Complex.

  CDFW planted Fordyce Reservoir with Rainbow Trout (*Oncorhynchus mykiss*) through 2013 and Brown Trout (*Salmo trutta*) through 1999, and recent survey data suggest trout will persist in Fordyce without additional fish plants. Crews have detected SNYLF at the downstream end of the outlet stream draining from Mossy Pond into Fordyce Reservoir. Fish do not present an immediate threat to most SNYLF in the Mossy Pond Complex. However, given the close proximity of trout, illegal movement of fish into currently fishless ponds that contain SNYLF presents a low probability risk. The main threat is that trout prevent SNYLF from being able to successfully breed and recruit in the largest aquatic habitat in the area; additionally, Fordyce Reservoir may act as a population sink for migrating subadult SNYLF.

CAPTURE-MARK-RECAPTURE PROJECT

Materials and Methods:

The study area consists of an approximately one square-mile section of Tahoe NF, containing Mossy Pond, its seasonally flowing outlet stream, and 12 ephemeral ponds (Figure 1). CDFW plans to use a robust design model (Pollock 1982) to estimate SNYLF abundance and other population demographic parameters in the study area. Now that the field portion of the study is completed, CDFW staff anticipate using Program MARK to analyze the data, applying analytical methods similar to other amphibian studies using the robust design model (e.g., Bailey et al. 2004, McCaffery and Maxell 2010, Fellers et al. 2013). Under the robust design, three surveys ("primary periods") occurred each summer, beginning in 2014 and proceeding through 2018. Each primary period consisted of three survey days ("secondary periods"), during each of which field crews surveyed all wetted habitat in the study area and attempted to capture every adult frog observed (Table 1).

Field crews captured frogs by hand or dip net, and processed frogs at the point of capture. Crews first scanned each captured frog with a BioMark 601 passive integrated transponder (PIT) tag reader to detect if the frog was marked (i.e., a recapture). Crews then used calipers to measure the snout to urostyle (SUL) length of each captured frog, and released frogs <40 mm SUL (which are considered subadults) without further processing. Crews continued collecting data on larger (>40 mm SUL) frogs, which are considered adults. For new adult captures, crews inserted an 8 X 1.4 mm PIT tag under the dorsal skin using methods recommended by McAllister et al. (2004). Crews collected a GPS point (estimated precision error ~3 m) for each capture using a handheld Garmin GPS unit. Crews weighed each adult frog inside a tared plastic bag to the nearest 0.1 g using a Pesola spring scale. For each captured adult individual, crews only collected length and weight data during the first capture event within a three-day primary period. Afterward, if crews captured the same individual on a subsequent day during

the same primary period, crews only recorded PIT tag, sex, and location data. In the field, crews recorded all data on paper datasheets. CDFW staff then entered the data into Microsoft Excel, which staff imported into Microsoft Access following error checking.

Results:

CDFW crews have completed five seasons of CMR surveys in the Mossy Pond study area. Each season consisted of at least three primary periods, each separated by about one month (Table 1).

Table 1. Survey dates for primary periods (PP) and secondary periods (SP) in the Mossy Pond study area, 2014–2018. On each date shown, CDFW field crews surveyed the entire Mossy Pond study area, which includes Mossy Pond, the Mossy Pond outlet stream, and 12 nearby ponds.

	PP 1			**PP 2**			**PP 3**		
YEAR	*SP 1*	*SP 2*	*SP 3*	*SP 1*	*SP 2*	*SP 3*	*SP 1*	*SP 2*	*SP 3*
2014	10-Jun	11-Jun	12-Jun	15-Jul	16-Jul	17-Jul	9-Sep	10-Sep	11-Sep
2015	9-Jun	11-Jun	12-Jun	14-Jul	15-Jul	16-Jul	9-Sep	10-Sep	11-Sep
2016	6-Jul	7-Jul	8-Jul	2-Aug	3-Aug	4-Aug	30-Aug	31-Aug	1-Sep
2017	18-Jul	19-Jul	20-Jul	15-Aug	16-Aug	17-Aug	12-Sep	13-Sep	14-Sep
2018*	19-Jun	20-Jun	21-Jun	10-Jul	11-Jul	12-Jul	7-Aug	8-Aug	9-Aug

***In 2018, field staff visited the Mossy Pond study area for a fourth PP (4–6 Sept 2018)**

CDFW plans to conduct an initial CMR analysis using the robust design model during winter-spring 2019. Initial results suggest that the Mossy Pond SNYLF population is persisting and healthy, despite the 2012–2015 drought (Robeson 2015) and presence of *Bd*. Crews have observed numerous adult and subadult SNYLF in Mossy Pond and associated stream channels (e.g., 2018 survey results in Tables 2 and 3; Figure 2). VES counts (which provide a general overview of population status) during the past five years have consistently revealed a large population. Since VES do not account for detection probability and other factors, VES nearly always underestimate the number of individuals present in the population (Mazerolle et al. 2007). CMR results will provide a much more accurate population estimate than those provided through traditional count methods like VES (Figure 3).

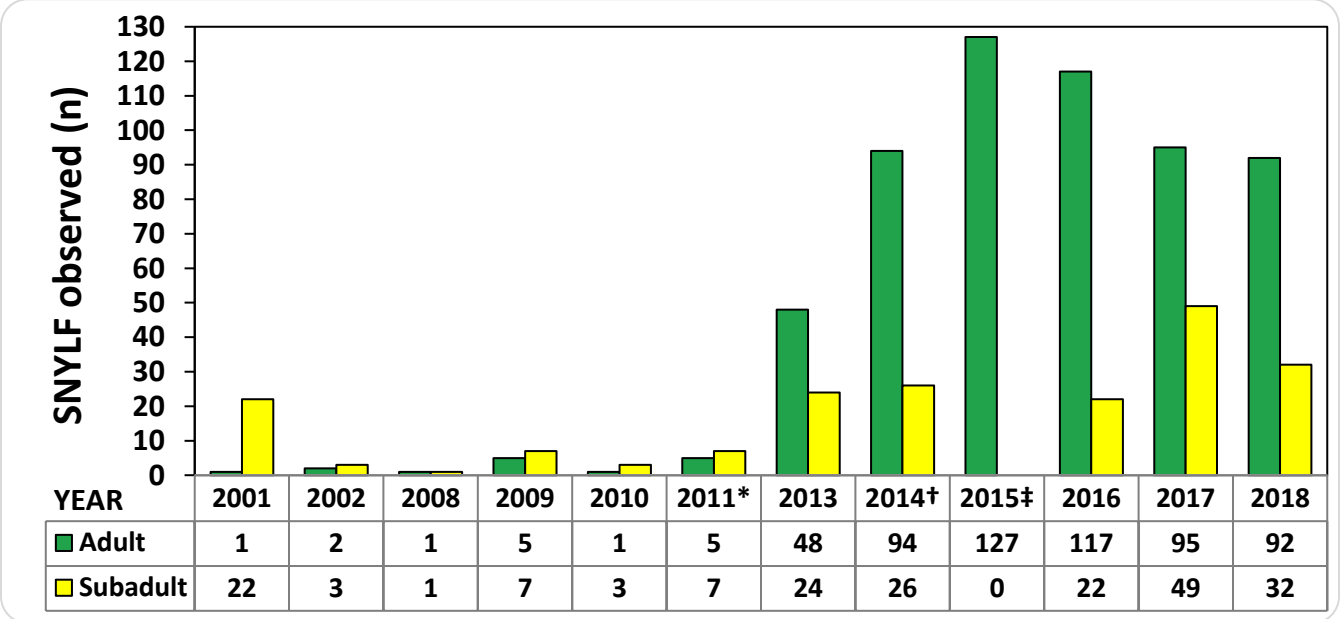
Table 2. Number of adult Sierra Nevada Yellow-legged Frogs (SNYLF) observed on each capture-mark-recapture survey day in 2018. The table does not show surveyed ponds (n=3) in which crews detected zero adult SNYLF in 2018.

Site ID	Site Name	6/19	6/20	6/21	7/10	7/11	7/12	8/7	8/8	8/9	9/4	9/5	9/6
13001		0	0	3	1	0	0	1	3	1	1	1	0
13036		0	0	0	1	0	1	2	2	1	0	1	0
13046		4	2	0	1	2	2	1	0	0	DRY	DRY	DRY
13048	**Mossy Pond**	**6**	**6**	**11**	**5**	**10**	**8**	**21**	**21**	**25**	**12**	**33**	**15**
13061		4	3	1	6	3	5	DRY	DRY	DRY	DRY	DRY	DRY
13078		0	0	0	1	0	1	0	1	0	0	0	0
13082		1	2	1	2	2	1	2	1	2	0	1	1
62003		1	3	1	1	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
62602		9	7	5	3	3	1	7	8	8	DRY	DRY	DRY
62603		3	7	8	10	7	8	16	20	18	DRY	DRY	DRY
80138	**Mossy Outlet**	**45**	**43**	**37**	**42**	**30**	**52**	**43**	**36**	**33**	**36**	**30**	**28**
TOTAL		**73**	**73**	**67**	**73**	**57**	**79**	**93**	**92**	**88**	**49**	**66**	**44**

Table 3. Number of subadult Sierra Nevada Yellow-legged Frogs (SNYLF) observed on each capture-mark-recapture survey day in 2018. The table does not show surveyed ponds (n=10) in which crews detected zero subadult SNYLF in 2018.

Site ID	Site Name	6/19	6/20	6/21	7/10	7/11	7/12	8/7	8/8	8/9	9/4	9/5	9/6
13048	**Mossy Pond**	**0**	**1**	**2**	**0**	**6**	**5**	**6**	**22**	**16**	**20**	**34**	**26**
13061		2	0	0	0	0	0	DRY	DRY	DRY	DRY	DRY	DRY
62603		1	0	0	0	0	0	3	5	0	DRY	DRY	DRY
80138	**Mossy Outlet**	**21**	**12**	**15**	**9**	**7**	**10**	**8**	**5**	**3**	**0**	**0**	**0**
TOTAL		**24**	**13**	**17**	**9**	**13**	**15**	**17**	**32**	**19**	**20**	**34**	**26**

Figure 2. Adult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) basking on a rock ledge above a small plunge pool in the outlet stream of Mossy Pond. (CDFW)



YEAR	2001	2002	2008	2009	2010	2011*	2013	2014†	2015‡	2016	2017	2018
Adult	1	2	1	5	1	5	48	94	127	117	95	92
Subadult	22	3	1	7	3	7	24	26	0	22	49	32

Figure 3: Counts of adult and subadult Sierra Nevada Yellow-legged Frogs (SNYLF) detected during surveys in the Mossy Pond study area, 2001–2018. In years when crews conducted more than one survey, results shown are from the survey day with the largest number of SNYLF detections for the year. ***Surveys before 2011 only included a subset of waterbodies.***

*(2011): First year CDFW field crews surveyed the entire Mossy Pond study area. From 2011 onward, when visiting the area, crews surveyed the entire study site.

†(2014): First year of the Mossy Pond Capture-Mark-Recapture (CMR) study. Results shown are from a separate visual encounter survey (VES) conducted at the site during a CMR trip.

‡(2015): Results shown from 2015 onward are from the CMR survey day with the most detections. Crews did not begin documenting subadult SNYLF during CMR surveys until the final trip of the 2015 season (in September). Results shown for 2015 are from the survey day with the most detections of the summer (July 16, 2015). From September 2015 onward, CDFW field crews consistently recorded subadult detections as part of the CMR survey protocol.

Discussion:

Current CMR work suggests that the Mossy Pond SNYLF population is large enough to provide frogs for translocation to nearby Nevada County sites. Once population analysis using CMR methods is completed, CDFW will have more detailed knowledge of the SNYLF population structure at Mossy Pond. These results will allow CDFW to estimate how many post-metamorphic SNYLF may be removed from the population annually for future translocation efforts to supplement or reestablish nearby populations in Nevada County, per the recommendations of the Interagency Mountain Yellow-legged Frog Conservation Strategy (USFWS 2018).

The CMR methods used in this study will greatly enhance our understanding of SNYLF population dynamics. Traditional VES methods–although useful, fast, and inexpensive–are less informative. Numerous factors reduce the comparability of VES results, including weather conditions, time of year, habitat complexity, and observer bias (Mazerolle et al. 2007). VES are a helpful measure for obtaining a general idea of SNYLF population status, but proper interpretation of the results requires consideration of the numerous assumptions inherent with VES (Heyer et al. 1994). CMR methods provide a more accurate method for estimating population parameters, such as abundance and survivorship, by incorporating detection probability (Williams et al. 2001).

A Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) feeding on an adult dragonfly at Mossy Pond. (CDFW)

A substantial benefit of this study is that the demographic information may be applicable beyond SNYLF at Mossy Pond. The estimate of detection probability may help better inform results from traditional SNYLF VES counts in similar habitats in the northern Sierra Nevada (Davis et al. 2018). Additionally, results from this study could be used in other modeling approaches, such as *N*-mixture models (Zipkin et al. 2014), to estimate demographic parameters in populations for which there is only count data of unmarked animals available. This study will also be useful for comparison with a study in Yosemite National Park that used the same methods to investigate a SNYLF population found in complex wetland habitats at similar elevations (Fellers et al. 2013). Therefore, this study will be incredibly valuable, not only to provide detailed demographic data for this population specifically, but also helping inform the understanding of SNYLF throughout the broader geographic area.

Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) basking on a rock in the Mossy Pond outlet stream. (CDFW)

The abundance of SNYLF in streams has been somewhat surprising, especially the observation that SNYLF seem to use streams preferentially during certain times of year. One reason that these observations were initially unexpected is that many studies of SNYLF (and the closely related *Rana muscosa*) have occurred in the high alpine regions of the central and southern Sierra Nevada. Much of this research has concentrated on lentic habitats in the 10,000–12,000 foot elevation range. Although SNYLF found in high elevation lakes will also disperse into streams for foraging, both species are often concentrated around lentic habitats. Additionally, SNYLF located in high elevation habitats typically require breeding habitats that do not freeze entirely in winter because tadpoles often overwinter 2–3 times before metamorphosis (Bradford 1983). Deeper lakes and ponds (> 3 m deep) are habitats that most often meet these requirements.

Subsequent survey efforts have shown that SNYLF in the northern Sierra Nevada may utilize a broader range of wetland habitat types more frequently when compared with their high-elevation counterparts. In the northern Sierra Nevada, many of the remaining SNYLF populations are relatively abundant in streams, marshes, and shallow ponds. SNYLF use of these habitats may be born out of necessity, either due to a greater availability of these habitat types in the northern Sierra Nevada and/or historic fish stocking, which likely relegated many frog populations to smaller, shallower, fishless habitats (Knapp and Matthews 2000). In part because of the historic dearth of studies investigating SNYLF use of wetlands in the northern Sierra Nevada, CDFW undertook this study, and other researchers have been exploring SNYLF populations in similar habitats. The results of these investigations will help broaden understanding of SNYLF population demographics.

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