State of California
Department of Fish and Wildlife

Memorandum

Date: 7 March 2023

To: Leslie Alber, Senior Environmental Scientist;
Sierra District Supervisor;
North Central Region Fisheries

From: Isaac Chellman, Environmental Scientist;
High Mountain Lakes;
North Central Region Fisheries

Cc: Region 2 Fish Files

Ec: CDFW Document Library

Subject: Amphibian monitoring in Tahoe National Forest, Nevada County

- ***Rana sierrae* monitoring in the Mossy Pond and Rattlesnake Creek areas**

ENVIRONMENTAL SETTING

The Mossy Pond complex and Rattlesnake Creek are in Tahoe National Forest, north of Highway 80 in Nevada County (**Figure 1**). The sites are accessible via United States Forest Service (USFS) dirt roads and four-wheel drive trails. The Mossy Pond complex is composed of approximately 80 lakes, ponds, and small streams set on granite benches southeast of Fordyce Reservoir (Fordyce). The series of closely associated lakes, small ponds, and ephemeral streams in the Mossy Pond complex support a low density metapopulation of Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF; **Figure 2**). The Mossy Pond complex ranges in elevation from 6,400 feet (ft) (1,951 meters [m]) near Fordyce, to 8,098 ft (2,468 m) at the summit of Buzzard Roost. Various stream channels contain flowing water until early summer, but dwindle to

intermittent pools by mid-summer. United States Geological Survey (USGS) field staff first detected SNYLF in the watershed in 1998 at Mossy Pond and Evelyn Lake; California Department of Fish and Wildlife (CDFW) began monitoring the population in 2001.

Rattlesnake Creek is located approximately 5 kilometers (km) south of the Mossy Pond complex. CDFW monitors a 2-km section of Rattlesnake Creek that flows east to west through USFS-owned land, the lower segment of a small tributary that flows from Magonigal Summit into Rattlesnake Creek, and a small pond approximately 40 m north of the creek (**Figure 1**). The Rattlesnake Creek area ranges in elevation from about 6,700 ft (2,042 m) at the lower end of the monitored segment of Rattlesnake Creek to 8,098 ft (2,468 m) at the summit of Buzzard Roost. The first official records for SNYLF in Rattlesnake Creek are from the 1960's (Brown et al. 2014). USGS field staff also detected SNYLF in 1995 and 1996, Tahoe National Forest (TNF) staff began monitoring the area more regularly in 2003, and CDFW began collaborative monitoring with TNF in 2009.

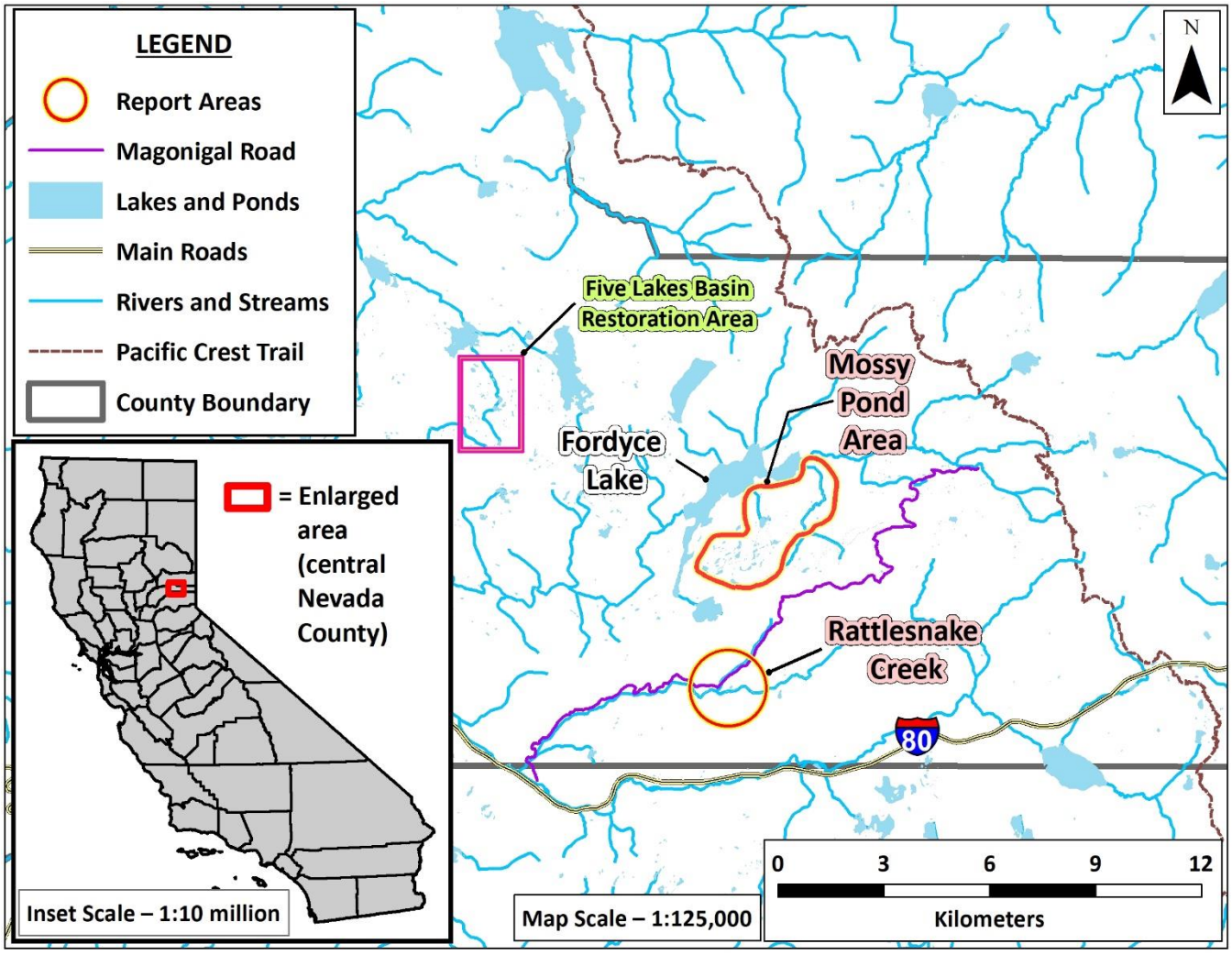


Figure 1. Mossy Pond and Rattlesnake Creek areas, Nevada County, CA. Areas discussed in this memorandum are circled in red and yellow. The Five Lakes Basin restoration area is also identified (see LOOKING AHEAD: 2023 section below).

INTRODUCTION

The Aquatic Biodiversity Management Plan (ABMP) for the South Yuba River Management Unit (CDFW 2014) identifies sites occupied by SNYLF as amphibian resources and prescribes regular population monitoring. Periodic visual encounter surveys (VES) during the early 2000's suggested that the Mossy Pond SNYLF population could be headed toward extirpation. However, USFS surveys of the Mossy Pond outlet stream and surrounding areas, later followed by complete VES of wetted habitat by CDFW during summer 2013, suggested a robust metapopulation still present in the area. After assessing most available habitat, CDFW concluded that previous surveys had focused on areas less often occupied by SNYLF. CDFW and USFS discovered that SNYLF in the Mossy Pond area often occupy streams and ephemeral ponds.

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 CMR field work to continue through summer 2018. In 2019–2022, CDFW field staff returned to the Mossy Pond complex to conduct VES in the Mossy Pond study area and surrounding wetlands. In 2021, CDFW conducted the most extensive survey of the area since 2013; staff surveyed most waterbodies in the Mossy Pond area during eight separate survey days from 30 August to 28 September 2021. However, because CDFW conducted these surveys during late summer and early fall in a dry water year, many of the small ponds and stream segments were either dry or contained very low water levels. In 2022, CDFW and TNF staff surveyed the Mossy Pond area on three occasions, including two surveys earlier in the summer (late June and early July) than those CDFW conducted the year prior, and one occasion in early September, during each of which staff surveyed a subset of the ponds and stream segments in the area.

Figure 2. Two adult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) on a small rock outcrop above a tiny pool in the Mossy Pond outlet stream in late summer 2022.

CDFW has been monitoring Rattlesnake Creek (Site ID 51019) and an unnamed tributary to Rattlesnake Creek (Site ID 51021) since 2009. Staff have consistently observed all SNYLF life stages in Rattlesnake Creek and low numbers of post-metamorphic SNYLF (adults and subadults) in Site ID 51021. Additionally, CDFW has been monitoring a small pond north of Rattlesnake Creek (Site ID 13275) since 2004 (**Figure 12**). In 2021, CDFW and USFS field staff visited Rattlesnake Creek on several occasions in late August and September to conduct monitoring and emergency salvage of SNYLF tadpoles stranded in rapidly drying pools (**Figure 3**). Staff moved approximately 1,100 tadpoles to larger nearby pools on Rattlesnake Creek. Additionally, staff translocated approximately 1,500 SNYLF tadpoles to Evelyn Lake, which is located approximately 4 km north of Rattlesnake Creek, in the Mossy Pond area. These emergency salvage activities are detailed in a separate memorandum, ***Rana sierrae* tadpole rescue at Rattlesnake Creek, Nevada County** (CDFW 2022a). In 2022, CDFW staff revisited Rattlesnake Creek on the one-year anniversary of the emergency salvage effort. Goals of the survey were to examine pool levels in the 2021 collection area to determine whether further emergency salvage and translocation of SNYLF may be necessary.

Figure 3. California Department of Fish and Wildlife (CDFW) and Tahoe National Forest (TNF) staff collecting Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) tadpoles from a tiny, rapidly drying pool in Rattlesnake Creek on 9 September 2021. By September 2021, almost no water remained in most of Rattlesnake Creek. (CDFW)

THREATS

Marginal Habitat

Mossy Pond has an approximately six-hectare surface area and a maximum recorded depth of 2.5 meters, while much of the pond is shallower. Although there are multiple fishless ponds in the vicinity, CDFW has not detected evidence of SNYLF breeding at those other locations. Additionally, many of the fishless ponds are ephemeral, and these habitats desiccate completely by mid-summer during dry water years, which have been the majority during the past decade (CDEC 2023a, b). Field staff occasionally observe SNYLF larvae (and, more rarely, egg masses) at Mossy Pond and its outlet stream (**Figure 4**). Rattlesnake Creek is intermittent, with only a small amount of perennial aquatic habitat present by late summer, particularly during dry water years. Extended drought, severe winter conditions, or anthropogenic habitat disturbances present potential extirpation risks to the SNYLF populations in both areas.

Figure 4. One of only a few locations in the Mossy Pond outlet stream (Site ID 80138) containing water in late summer 2022. This area at the downstream end of the outlet stream appears to be spring fed, retaining a very small amount of water, even during dry years. Fordyce Lake is visible in the upper background. (CDFW)

Disease

The fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*) is present in the Mossy Pond area. *Bd* was initially detected via epithelial swabs collected by field staff 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. In 2021, staff collected an additional six epithelial swabs from adult SNYLF (four from the Mossy Pond outlet stream and two from Site ID 13106). In January 2022, partner scientists at the Sierra Nevada Aquatic Research Laboratory (SNARL) screened the new swabs for presence of *Bd* DNA using real-time qPCR analysis (Knapp and Lindauer 2020). The swab analyses detected very light to moderate infection intensities. These designations of infection intensity are subjective; however, none of the six swabs showed high *Bd* loads (i.e., high enough to suspect increased likelihood of mortality from severe chytridiomycosis, the disease caused by *Bd*).

Introduced Fish

CDFW formerly stocked Mossy Pond—on two occasions, in 1940 and 1966—and all named ponds in the vicinity with Brook Trout (*Salvelinus fontinalis*, BK), including Bigley (Site ID 13135), Evelyn (Site ID 13093), Freeman (Site ID 13153), Sectional Line (Site ID 13132), Talbot (Site ID 13113), Virginia (Site ID 13117), Lower Eastern Brook (Site ID 13140), and Upper Eastern Brook (Site ID 13144) Lakes (**Figure 7**, in the VES OUTSIDE THE MOSSY POND STUDY AREA section). Apart from Mossy Pond, these stocking events occurred consistently from about 1940 to 1999. In 2000, in response to range-wide declines of SNYLF and a departmental reassessment of stocking practices, CDFW halted stocking in the vicinity. During surveys in 2001, CDFW field staff detected BK at five lakes in the Mossy Pond complex (Site IDs 13113, 13117, 13130, 13140, and 13144; **Figure 7**), including one lake in which staff observed SNYLF (Site ID 13113). During follow-up gill net surveys in 2010, field staff did not capture any BK, which suggests that BK did not persist in the absence of stocking. Since 2010, staff have not detected any trout during gill netting and visual surveys in the Mossy Pond complex. However, various minnow species (e.g., Lahontan Redside; *Richardsonius egregius*) are abundant in some lakes and stream segments, including Site IDs 13140, 13144, 13150, and 52594 (**Figure 7**).

CDFW stocked Fordyce with Rainbow Trout (*Oncorhynchus mykiss*) through 2013 and Brown Trout (*Salmo trutta*) through 1999, and gill net survey data from 2014 suggested trout may persist in Fordyce without additional fish plants. Staff have detected SNYLF at the downstream end of the outlet stream draining from Mossy Pond into Fordyce. Fish do not present an immediate threat to most SNYLF in the Mossy Pond complex. However, given the 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 may act as a population sink for migrating subadult SNYLF.

CAPTURE-MARK-RECAPTURE PROJECT

The data collection portion of the Mossy Pond CMR study ended in 2018. CDFW staff may partner with other researchers to analyze data collected during the CMR study, 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). For a complete description of the materials, methods, and initial results of the Mossy Pond CMR study, please consult the memorandum "**Capture-mark-recapture at Mossy Pond, Tahoe National Forest, Nevada County – Summary of activities in 2018**" (CDFW 2019).

VES IN THE MOSSY POND STUDY AREA

The Mossy Pond CMR study area consisted of an approximately one square-mile section of TNF, containing Mossy Pond, its seasonally flowing outlet stream, and 12 ephemeral ponds (**Figure 5**). Prior to 2014, VES effort in the Mossy Pond area varied, both in quantity and quality. During the study, from 2014–2018, surveys were more consistent, during which CDFW field staff visited Mossy Pond at least three times each summer. During each trip, staff surveyed 14 sites each day for three consecutive days, for a total of nine to 12 survey days per year. Therefore, the summary of VES results for years during the CMR study (2014–2018) include the one survey day with the highest number of SNYLF observations for that year (**Figure 6**).

With the CMR study completed, CDFW and TNF staff surveyed the Mossy Pond study area at least once per summer from 2019–2022 using traditional VES methods (Heyer et al. 1994). During VES in 2022, staff used dip nets or their hands to capture and scan all frogs large enough to have been marked with a passive integrated transponder (PIT) tag during the CMR study (i.e., adult frogs ≥50 mm snout-to-urostyle [SUL] length, which is a highly conservative lower end of potential size for SNYLF that are at least 5 years old). If staff detected a tag, they recorded the PIT tag number, sex, and coordinates for the point of capture of each frog. Although the CMR study ended, subsequent data obtained from any marked adult SNYLF will contribute to the understanding of population dynamics in the Mossy Pond area, including SNYLF movement patterns and longevity.

When compared with the CMR study period, both adult and subadult SNYLF detections in 2021 and 2022 were notably lower (**Figure 6**). However, fewer adult SNYLF detections do not necessarily suggest a true decline in the SNYLF population. The CMR study period provided several opportunities to detect SNYLF over the course of the summer. With at least nine surveys of the entire study area each year during the period 2014–2018, staff had a greater chance of any one survey corresponding with good survey conditions, more frogs available for detection, and/or the presence of recently metamorphosed subadults. Therefore, confounding factors that affect SNYLF detectability during VES, including weather conditions, time of year, habitat complexity, and observer bias were likely mitigated between 2014 and 2018 (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).

The aforementioned considerations notwithstanding, the lack of SNYLF detections in the Mossy Pond study area is potential cause for concern. SNYLF detections in 2021 were the lowest seen by CDFW since before the CMR study began, and detections in 2022 were not substantially higher. CDFW does not know the cause for this potential decline, but frequent dry conditions for the past decade may play a role. During myriad trips to the area since 2013, CDFW has found that SNYLF in the Mossy Pond study area often occupy ephemeral stream and pond habitats. These habitats dry earlier in the season and remain desiccated for longer periods during dry water years. Of the water years from 2012–2022, eight have received precipitation well below the 1991–2020 average (2012–2015, 2018, and 2020–2022; CDEC 2023a). These frequent and extended dry periods may be a concern for the long-term persistence of SNYLF populations in some of these locations where frogs are occupying ephemeral habitats. These environmental concerns and other potential causes for reduced SNYLF detections are discussed further in the VES OUTSIDE THE MOSSY POND STUDY AREA section below.

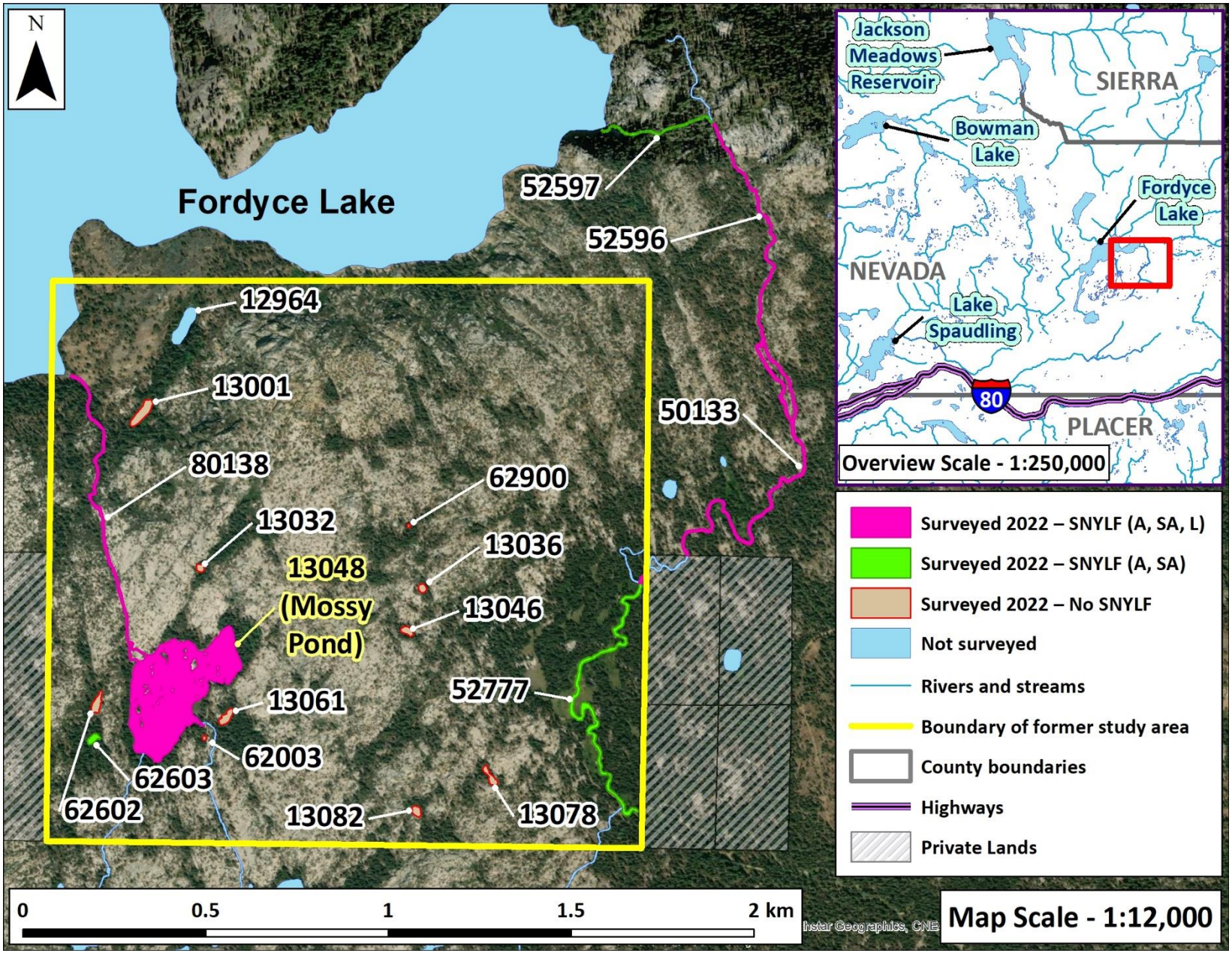
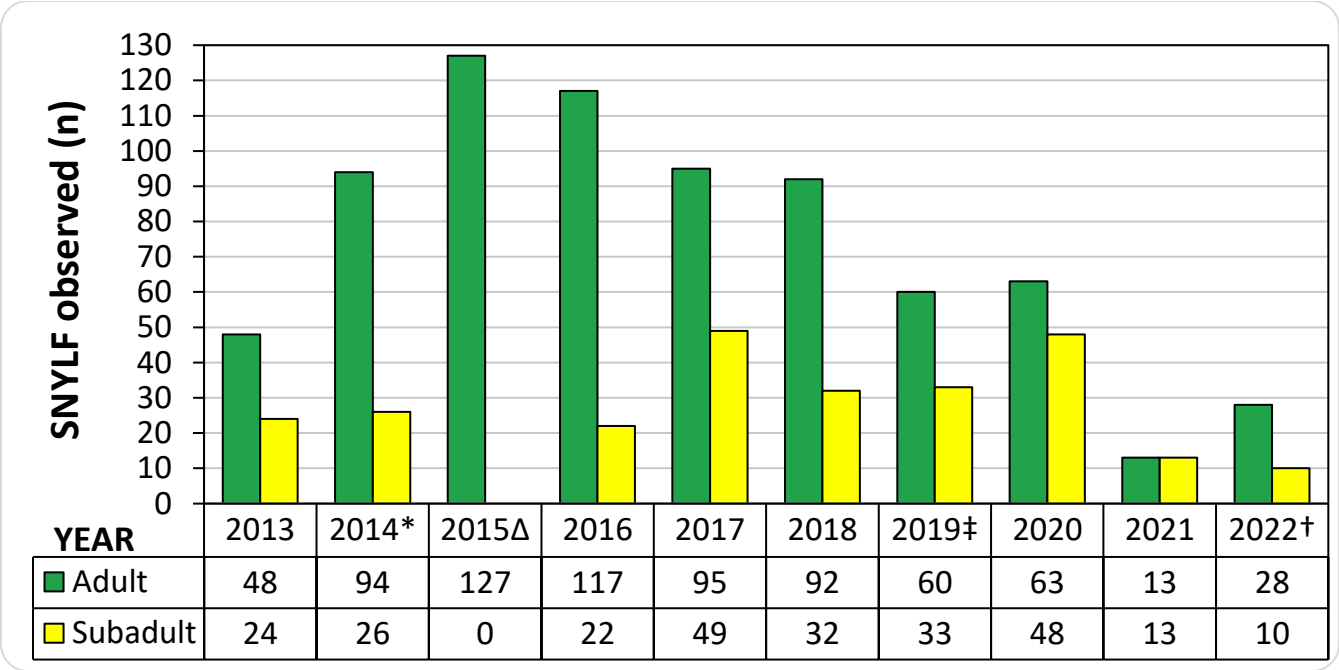


Figure 5. [See figure caption at the beginning of the next page.]

Figure 5 (continued). Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) observations during visual encounter surveys (VES) in the former Mossy Pond capture-mark-recapture (CMR) study area during summer 2022. The CMR study occurred from 2014 to 2018. However, beginning in 2019, CDFW suspended marking any newly captured (i.e., unmarked) adults with PIT tags. During VES, California Department of Fish and Wildlife (CDFW) staff capture all adult frogs observed and scans each older adult (i.e., those individuals ≥50 mm snout-to-urostyle length) for passive integrated transponder (PIT) tags inserted during the study period. The results shown combine data from surveys by CDFW staff in late June (CDFW survey results shown include all small satellite ponds in the former study area, except Site IDs 62602 and 12964), and surveys by Tahoe National Forest (TNF) staff in early July (TNF survey results shown include Mossy Pond, the Mossy Pond outlet stream [Site ID 80138], and Site ID 62602). CDFW staff surveyed the entire study area in late June. However, TNF resurveyed a subset of locations within the former study area in early July 2022, during which TNF staff detected more SNYLF than CDFW staff had observed 10 days earlier. Therefore, CDFW used the SNYLF totals from TNF surveys of Mossy Pond, the Mossy Pond outlet stream, and Site ID 62602 for this figure (note: both CDFW and TNF staff did not detect SNYLF in nearby Site ID 62603 in either late June or early July 2022). Additionally, results shown for Site ID 52777 are from a survey by CDFW staff in early September 2022. SNYLF letter codes in the legend, which indicate the life stages observed during the most recent survey, are as follows: “A” = adults and “SA” = subadults.



YEAR	2013	2014*	2015Δ	2016	2017	2018	2019‡	2020	2021	2022†
Adult	48	94	127	117	95	92	60	63	13	28
Subadult	24	26	0	22	49	32	33	48	13	10

Figure 6. Count of adult and subadult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) detected during surveys in the Mossy Pond study area, 2013–2022. California Department of Fish and Wildlife (CDFW) began surveying some locations in the Mossy Pond area in 2001. However, earlier surveys only included a small subset of waterbodies and, therefore, counts were very low (i.e., ≤5 adults seen during any given survey). Therefore, the histogram only presents results beginning in 2013, which is the first year field staff surveyed the entire Mossy Pond study area. In years when staff conducted more than one survey, results shown are from the one survey day with the largest number of SNYLF detections for the year.

*First year of the Mossy Pond capture-mark-recapture (CMR) study. Results shown are from a visual encounter survey (VES) conducted separately from the CMR work in 2014.

ΔStaff did not begin documenting subadult SNYLF during CMR surveys until the final trip of the 2015 season (in September): from September 2015 onward, CDFW field staff consistently recorded subadult detections as part of the CMR survey protocol. Results shown for 2015 are from the survey day with the most detections of the summer (July 16, 2015), which is why no subadults are shown in the histogram. Results shown from 2015–2018 are from the CMR survey day with the most total SNYLF detections for that year.

‡Following completion of the CMR study in 2018, CDFW only visited the Mossy Pond study area once per year to assess the relative abundance and general status of the SNYLF population. Staff are no longer marking captured frogs but continue to record PIT tag numbers for recaptured frogs. Survey totals from 2019 onward also included a stream segment at the eastern edge of the study area that had not been included in the CMR study (Site ID 52777, see **Figure 5**).

†Survey totals in 2022 combine data from CDFW surveys in late June and Tahoe National Forest surveys in early July (see caption of **Figure 5** for details), with the exception of Site ID 52777, which CDFW staff surveyed in early September 2022. [***End of figure caption***.]

VES OUTSIDE THE MOSSY POND STUDY AREA

There are approximately 67 mapped lakes, ponds, and stream segments in the Mossy Pond complex outside of the CMR study area (most of which are shown in **Figure 7**). Between 2001 and 2022, CDFW staff have observed SNYLF of various life stages in 34 of these waterbodies. Following the 2022 monitoring season, CDFW used high resolution aerial imagery to identify and map 35 additional ephemeral ponds and stream segments in locations adjacent to the former Mossy Pond study area, which staff have added to geographic information system (GIS) layers of waterbodies used for survey planning. CDFW plans to conduct VES at these newly identified stream segments and ephemeral ponds during summer 2023.

Occasional monitoring data from the past 22 years indicate a relatively large SNYLF metapopulation in the greater Mossy Pond area. However, in 2021 and 2022, CDFW staff observed comparatively few post-metamorphic SNYLF outside of the study area, despite surveying 34 and 40 sites with surface water in 2021 and 2022, respectively. In 2022, staff observed more adults when compared with surveys during the exceptionally dry late summer and early fall period in 2021 (**Figure 8**). Despite seeing more SNYLF in 2022 than the year prior, staff still detected fewer post-metamorphic SNYLF when compared with surveys during the period from 2013 to 2019 (**Figure 8**). However, the level of survey effort has varied substantially among survey periods (e.g., 55 sites were surveyed in 2013, the year with the most surveys, and only three sites were surveyed in 2015, the year with the least; **Figure 8**).

[*Main text continues on pg. 16, following Figures 7 and 8.*]

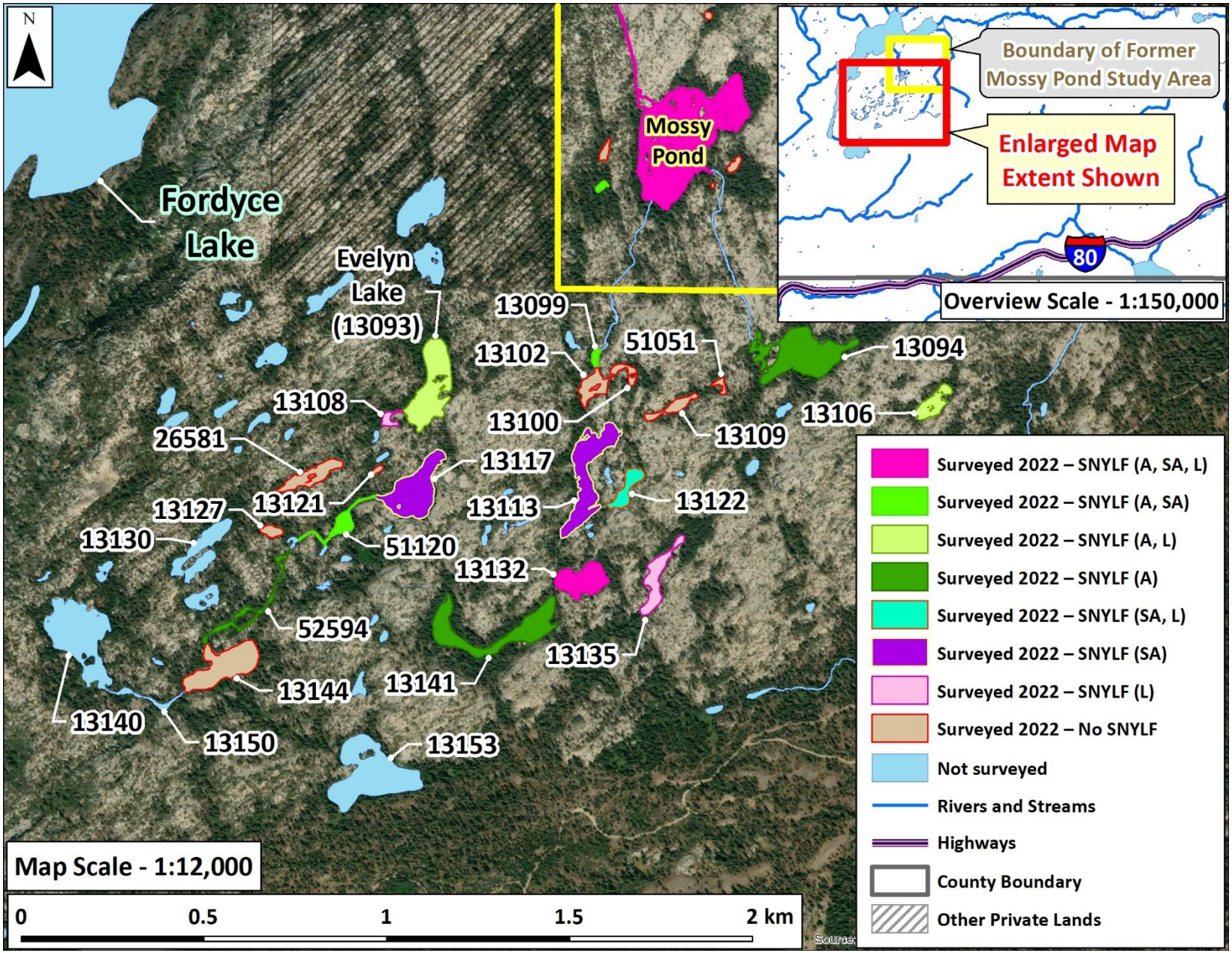
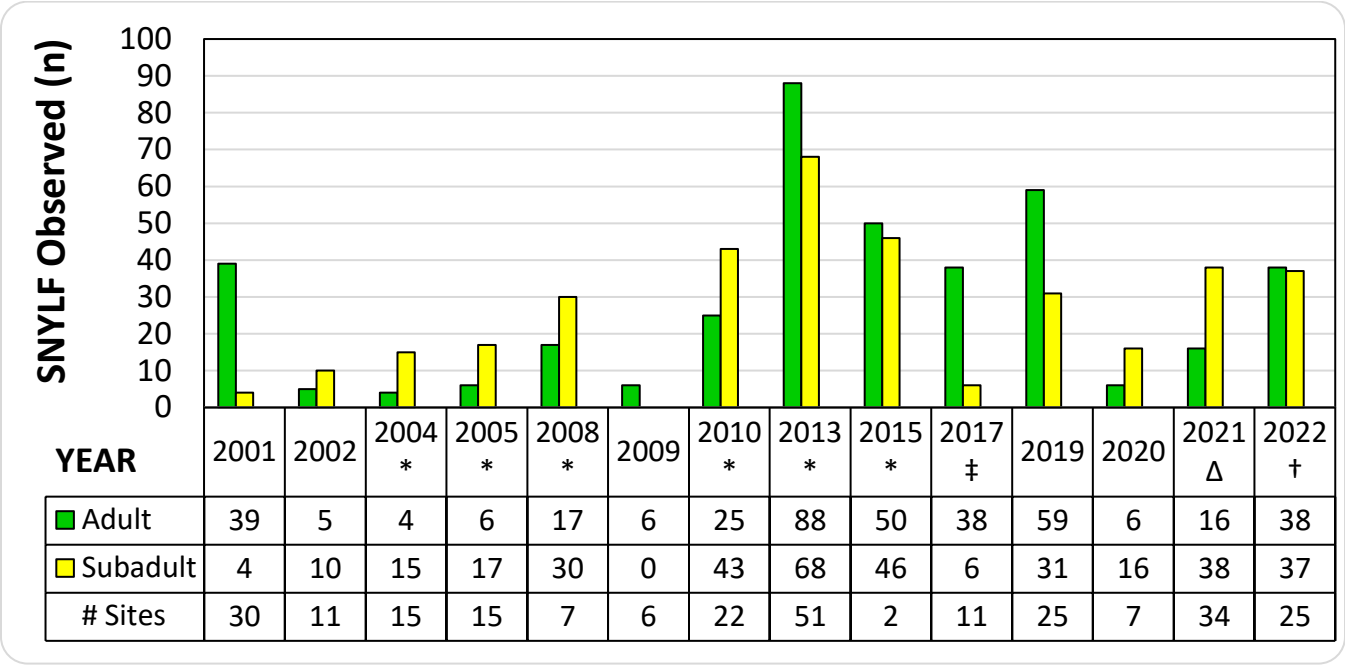


Figure 7. [See figure caption at the beginning of the next page.]

Figure 7 (continued). Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) observations during visual encounter surveys (VES) in the Mossy Pond complex, southwest of the former study area, in summer 2022. SNYLF letter codes in the legend, which indicate the life stages observed during the most recent survey, are as follows: “A” = adults, “SA” = subadults, and “L” = larvae. CDFW conducted surveys in late June and early September 2022. Data shown above include results from 13 waterbodies surveyed by Tahoe National Forest (TNF) partners in early July 2022. All other survey results are from CDFW surveys at other waterbodies approximately 10 days prior, in late June 2022. CDFW returned to the Mossy Pond area in early September to resurvey a subset of waterbodies. However, this map only shows CDFW results from late June, to eliminate the potential for any double-counting of individuals that may have moved between waterbodies between late June and early September.



YEAR	2001	2002	2004 *	2005 *	2008 *	2009	2010 *	2013 *	2015 *	2017 ‡	2019	2020	2021 Δ	2022 †
Adult	39	5	4	6	17	6	25	88	50	38	59	6	16	38
Subadult	4	10	15	17	30	0	43	68	46	6	31	16	38	37
# Sites	30	11	15	15	7	6	22	51	2	11	25	7	34	25

Figure 8. Counts of adult and subadult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) detected during surveys outside of the Mossy Pond capture-mark-recapture (CMR) study area from 2001–2022. These results are derived from a collection of 67 labeled (i.e., locations that have associated Site IDs) lakes, ponds, and streams outside of the Mossy Pond study area that California Department of Fish and Wildlife (CDFW) staff have surveyed at least once (and often several times) during the past 22 years. The last row of the data table displays the number of sites (out of the 67 total identified waterbodies) surveyed each year, excluding sites that were completely dry when visited. Survey effort, as measured by the number of sites surveyed, varies substantially between survey years.

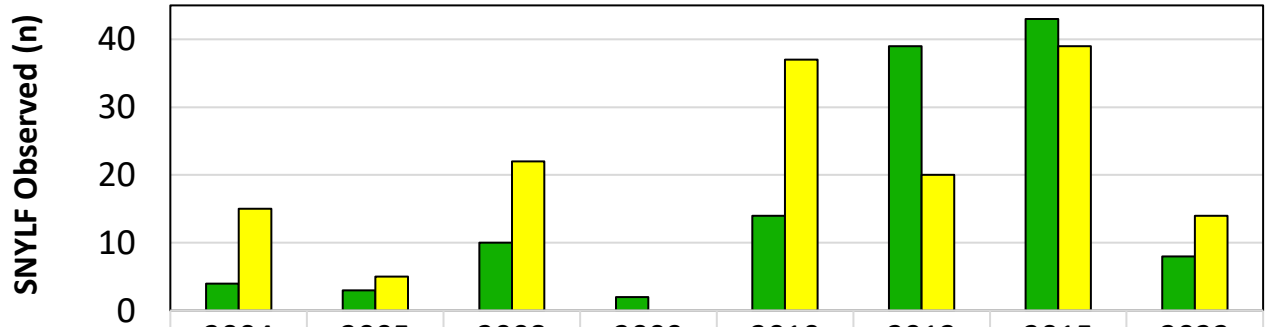
*During these years, one location—Site ID 50133 (a stream segment east of the study area; see **Figure 5**)— accounted for a majority of SNYLF observations.

‡Surveys in 2017 were not traditional visual encounter surveys (VES). CDFW staff were looking for SNYLF marked with passive integrated transponder (PIT) tags (which provide a unique identifier for adult SNYLF captured during the CMR study) that had moved outside of the CMR study area. Surveys in 2017 were confined to ponds closest to the southern and eastern borders of the study area.

ΔThe 2020–2021 water year was exceptionally dry and CDFW conducted surveys late in the monitoring season (staff surveyed 10 of 34 ponds on 1–2 September, and the remaining 24 ponds during four different site visits 14–28 September). Counts of post-metamorphic frogs shown in 2021 do not include dead individuals detected by CDFW. In 2021, staff observed six dead subadults and one dead adult among 34 ponds surveyed in late summer and early fall.

†Survey totals in 2022 combine data from CDFW surveys in late June and Tahoe National Forest surveys in early July, with the exception of three Site IDs (50133, 52596, and 52597; **Figure 5**) along the eastern inlet to Fordyce Lake, which CDFW staff surveyed in early September 2022. [***End of figure caption***.]

Among the survey locations outside the study area, CDFW staff have historically observed most post-metamorphic SNYLF at one site: an ephemeral stream to the east of the Mossy Pond study area that drains into the eastern side of Fordyce Lake (Site IDs 50133, 52596, and 52597; **Figure 5**). CDFW staff have surveyed Site ID 50133 occasionally since 2004. In 2013, CDFW added two additional survey segments along this same stream reach (Site IDs 52596 and 52597), which are located between Fordyce Lake and the downstream end of Site ID 50133. After not having visited this stream for a concerted survey effort since 2015, CDFW conducted VES at this location in late June and early September 2022. Staff did not detect nearly as many SNYLF during 2022 surveys when compared with surveys in 2013 and 2015 (**Figure 9**). During the surveys in 2022, staff detected the following SNYLF numbers and life stages: one adult, one subadult, four recent metamorphs, and 162 larvae on 30 June; and eight adults, 14 subadults, and 19 larvae on 8 September. However, several caveats need to be considered when interpreting the results. In June 2022, during which the stream was still flowing, staff did not survey the upstream 500 meters of Site ID 50133 due to time constraints on the survey day, so areas with higher SNYLF densities may have been overlooked. In September, staff surveyed the entire reach. However, by that time, the stream was no longer flowing and only intermittent pools remained. Additionally, only one staff member conducted the survey in September 2022, and the survey effort (28 minutes of survey time) was notably lower than effort during previous years when staff detected many more post-metamorphic SNYLF. For example, in 2013 and 2015, two CDFW staff conducted the survey, and the survey duration during each year was over two hours. Therefore, the more cursory survey effort in 2022 may have contributed to fewer SNYLF detections when compared with results from surveys in 2013 and 2015.



YEAR	2004	2005	2008	2009	2010	2013	2015	2022
Adult	4	3	10	2	14	39	43	8
Subadult	15	5	22	0	37	20	39	14

Figure 9. Counts of adult and subadult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) detected during surveys of Site ID 50133 (a segment of stream that flows into the eastern side of Fordyce Lake) from 2004–2022. Historically, this one stream segment has accounted for a majority of SNYLF detections among waterbodies surrounding the former Mossy Pond study area. In 2022, CDFW staff surveyed this site twice: on 30 June and 8 September. Results displayed above are from the survey on 8 September.

Another factor to consider when interpreting survey results from the entire Mossy Pond area are environmental conditions, which have varied widely. Of the last five survey periods, two have occurred during far above average water years (2017 and 2019) and three have occurred during exceptionally dry water years (2020–2022; CDEC 2023a, b). Potential effects of the more recent dry years may be compounded, given that a majority of water years since 2012 have resulted in well below average precipitation and snowpack (2012–2015, 2018, and 2020–2022; CDEC 2023a, b). When recent above average water years have occurred (2011, 2017, and 2019), they have been followed by at least one—but more often multiple—dry water years. Winter 2021–2022 was the third year in a row with well below average accumulated snowpack (CDEC 2023b), with the 1 April 2022 northern Sierra Nevada snow water content being only 26% of average (CDEC 2023c), although northern Sierra Nevada 2021–2022 water year precipitation totals were higher than the two prior water years, at approximately 81% of the 1991–2020 average (CDEC 2023a).

Initial amphibian VES in 2022 was timed to avoid exceptionally dry late season conditions, such as those present during VES in September 2021. The core amphibian monitoring season in high elevations of the Sierra Nevada is typically mid-June through mid-September. In 2022, CDFW and TNF staff conducted all VES of the Mossy Pond area within this more typical survey period. CDFW and TNF staff visited the area in late June and early July 2022, with CDFW staff returning for an additional round of VES at a subset of waterbodies in early September 2022. During the early summer surveys, water levels were high in the Mossy Pond area (**Figure 10**). All ponds visited still contained surface water, and stream channels—nearly all of which dry almost completely by late summer—were still flowing in late June and early July (**Figure 11**).

Despite these differences in survey effort and site conditions, even comparing VES results between years during which the same locations are surveyed during similar times of year can be misleading, because VES detections can vary widely due to the factors mentioned above in the VES IN THE MOSSY POND STUDY AREA section. Therefore, evaluating the true SNYLF population status is difficult from VES data alone.

While acknowledging these challenges, CDFW suspects that environmental conditions may be at least partly responsible for the relatively low SNYLF detections that staff have observed in recent years. Although water levels were relatively high during early summer 2022, a majority of water years during the past decade have been very dry. These drought conditions have led to shorter hydroperiods during the active season for SNYLF. When accumulated across multiple years over the past decade, drought may be causing an increase in the frequency of local SNYLF extirpations within the Mossy Pond metapopulation, particularly among populations occupying smaller, more isolated ponds and ephemeral stream channels. The environmental stresses of drought on SNYLF populations are compounded with historic non-native trout stocking in the area, and continued *Bd*-induced mortality.

As discussed in the INTRODUCTION, CDFW has found that SNYLF in this area often occupy small, ephemeral waterbodies, seemingly preferentially over more perennial habitats available nearby. In 2021, CDFW suspected that widespread desiccation of these ephemeral habitats may have caused some SNYLF to seek refuge in locations with more protection from wind and dry atmospheric conditions (e.g., in thick vegetation, debris piles, and loosely consolidated rock within stream channels and pond margins), resulting in fewer frogs being available for detection during surveys that staff conducted in September 2021. Additionally, CDFW suspects that the extremely dry conditions may have led some SNYLF to initiate reduction in seasonal activity earlier than usual, and/or estivate during a time period when they may have otherwise been active during a more average water year.

These potential explanations for reduced SNYLF detections do not apply to the relatively low number of SNYLF that staff observed during early summer surveys in 2022. However, as discussed above, multiple years of dry conditions may have decreased survivorship among SNYLF in the Mossy Pond area, in part through stranding frogs in suboptimal habitats during protracted dry periods. Overwinter mortality during drought conditions, via environmental factors such as direct freezing or increased odds of anoxic conditions in shallow ponds (Bradford 1983, Fellers et al. 2007, Hammond et al. 2021), or periods of *Bd*-induced overwinter mortality (Briggs et al. 2005, Rumschlag and Boone 2018), may have also contributed to the recent decline in SNYLF detections. Finally, the prevalence of dry site conditions during the past decade may have contributed to increased late summer and early fall *Bd*-induced mortality among Mossy Pond area SNYLF, through factors such as increased chances of *Bd* susceptibility among frogs confined to small, isolated, and stagnant stream pools or drying ponds (Tunstall 2012, Kupferberg et al. 2021). More discussion of *Bd* and SNYLF in the Mossy Pond area continues at the bottom of page 19.

Figure 10. Site ID 13102 on 28 June 2022. During spring and early summer, this site connects to Site ID 13099, which drains into Mossy Pond (Site ID 13048) via an ephemeral stream channel. (CDFW)

Figure 11. A large pool at the upstream end of Site ID 52596 on 30 June 2022. CDFW observed Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) tadpoles in this pool during the survey. On 30 June 2022, water was still flowing in this stream segment (flow can be seen entering the pool on the far left of the photograph). (CDFW)

The endemic state of *Bd* in most of the Sierra Nevada (Briggs et al. 2005, Padgett-Flohr and Hopkins 2009, Knapp et al. 2016, Vredenburg et al. 2019) and widespread detections of the pathogen in nearly all extant SNYLF populations sampled during the past 10–15 years (CDFG 2011; CDFW, unpubl. data), suggest that epizootic *Bd*-induced mass mortality events, such as those that often occur in populations newly exposed to the pathogen (Vredenburg et al. 2010), are unlikely among *Bd*-positive SNYLF populations such as the Mossy Pond area, where epithelial swabs have revealed *Bd* presence since at least 2010 (CDFG 2011, plus see *Disease* section above). However, *Bd* may still be an ongoing source of mortality in the Mossy Pond area, despite SNYLF persisting with the disease (Rachowicz et al. 2006, Briggs et al. 2010). Enzootic *Bd* dynamics may be resulting in consistent rates of mortality in the Mossy Pond area SNYLF population, particularly among recent metamorphs and subadults, which are known to be highly susceptible to *Bd*-induced mortality (Rachowicz et al. 2006). In 2021, staff observed

seven dead SNYLF among the 34 sites surveyed outside the study area. Six of the dead individuals were subadults and one was an adult. In 2022, CDFW made similar observations, all at Evelyn Lake (Site ID 13093), where staff detected one dead tadpole on 28 June and seven dead subadults on 8 September. However, the subadults detected on 8 September were all highly decomposed, so staff were not able to definitively determine species ID (i.e., the mortalities may have been Sierran Chorus Frogs). The cause of these mortalities is unknown, but *Bd* may be a factor in at least some of the observed mortalities. The known *Bd* dynamics discussed above correlate with staff finding mostly young frogs among observed mortalities in 2021 and 2022.

In 2017 and 2019–2022, staff captured adult SNYLF in a subset of ponds adjacent to the study area to check for PIT tags and identify any frogs that may have migrated out of the study area. In 2022, staff did not capture any adult SNYLF outside of the former Mossy Pond study area that were marked during the 2014–2018 CMR study period. However, in 2017, 2019, and 2020, staff detected one adult SNYLF at Site ID 13094 that moved out of the Mossy Pond study area. PIT tags revealed that the frog captured in 2017 and 2020 was the same individual, and the frog captured in 2019 was a different individual. The individual captured in 2017 and 2020 was a large adult female. Before 2017, this female had most recently been captured in September 2014, along the eastern shore of Mossy Pond. The individual CDFW staff captured in 2019 was a different adult female, last captured in July 2015 at the base of the Mossy Pond outlet stream (Site ID 80138; **Figure 5**). This frog likely traveled at least 1.75 km horizontal distance (and, more likely, at least 2 km along the closest path of travel via available water courses) and 200 m in vertical elevation gain along steep terrain between observations in 2015 and 2019. During the Mossy Pond CMR study, this frog was recaptured five times between September 2014 and July 2015, each time within a 40-m radius of its original capture location at the downstream end of Site ID 80138.

VES IN THE RATTLESNAKE CREEK AREA

In late August 2021, TNF staff noted critically low water levels throughout Rattlesnake Creek. Several rapidly drying pools contained stranded SNYLF tadpoles in danger of desiccation before the return of autumn rains. On 1 September 2021, TNF staff received permission from CDFW and USFWS to move a subset of tadpoles (n ≈ 700) to a large pool in a nearby section of Rattlesnake Creek. On 9 September 2021, CDFW staff joined TNF to move additional tadpoles (n ≈ 400) to another perennial pool in Rattlesnake Creek (**Figure 12**). CDFW and TNF staff translocated the remaining SNYLF collected from stranded pools in Rattlesnake Creek (n ≈ 1,500) to Evelyn Lake (Site ID 13093; **Figure 7**), which is located approximately 4 km north, in the Mossy Pond area. These emergency translocation activities are detailed in a separate memorandum, ***Rana sierrae* tadpole rescue at Rattlesnake Creek, Nevada County** (CDFW 2022a). Additional details on post-translocation survey efforts in 2021 are included **last year's SNYLF monitoring update from the Mossy Pond and Rattlesnake Creek areas** (CDFW 2022b).

In previous years, CDFW conducted VES throughout Rattlesnake Creek, including Site IDs 13275, 51019, 51021, and 52776. However, in September 2022, staff did not survey the entire creek. Instead, staff only surveyed the reach of Site ID 51019 along which CDFW and TNF had collected and released SNYLF tadpoles during emergency translocation efforts in September 2021 (**Figure 12**). In 2022, CDFW staff visited Rattlesnake Creek on 9 September, exactly one year after emergency translocation efforts. The primary goal of the 2022 visit was to observe late summer site conditions and determine whether any additional emergency SNYLF tadpole translocation may be needed, given that 2021–2022 was another below average water year (CDEC 2023a, b). Additionally, staff revisited Rattlesnake Creek for more general monitoring, to observe relative abundance of SNYLF in the area from which CDFW and TNF staff had collected SNYLF tadpoles in 2021. During the visit, staff surveyed most of Site ID 51019, including all pools from which CDFW and TNF had collected SNYLF tadpoles in 2022 (**Figure 12**).

Fortunately, although most of Rattlesnake Creek was not actively flowing during the visit on 9 September 2022, staff observed notably more water in the remaining pools when compared with water levels in late summer 2021 (**Figures 13–20**). All pools from which staff had collected tadpoles in 2021 were still large and deep enough that no emergency salvage effort was deemed necessary. Other pools, particularly two larger perennial pools into which CDFW and TNF staff had released a subset of SNYLF tadpoles during the emergency translocation, maintained water levels in September 2022 that were similar to water levels staff observed in 2021 (**Figures 21 and 22**).

In 2022, staff observed a quantity of SNYLF larvae comparable to the most recent VES from Rattlesnake Creek in 2020 (**Figure 23**). This result was encouraging, given the extremely low water levels during 2021. Additionally, pre-translocation VES in 2021, which were followed soon thereafter by direct collection using aquarium nets, proved that the number of SNYLF tadpoles actually present in Rattlesnake Creek is much greater than the number of tadpoles

that can be detected during standard VES (CDFW 2022a). SNYLF tadpoles are skittish, and most individuals will rapidly seek cover if they see an observer approaching. SNYLF tadpoles also have cryptic coloration and patterns. Given these attributes, individuals can be difficult to detect, particularly when hiding within and beneath substrate. Therefore, although a portion of individuals may be in the open and available for detection during VES, particularly if observers approach cautiously, many other individuals may be unavailable for detection. Net collection in September 2021 allowed staff to locate most individuals in every pool, which resulted in a nearly complete census of SNYLF tadpoles within the collection pools (**Figure 23**).

CDFW staff observed fewer post-metamorphic SNYLF in 2022 when compared with VES during many previous years (**Figure 24**). However, although CDFW has historically detected most SNYLF of all life stages in Site ID 51019, staff did not survey the entire reach, and staff also did not survey other sites, including 52776 and 51021, in both of which CDFW will occasionally detect SNYLF. Therefore, lower post-metamorphic SNYLF observations in 2022 may simply be due to more spatially limited sampling of the Rattlesnake Creek area, since the primary focus was investigating pools within the emergency translocation area (**Figure 12**).

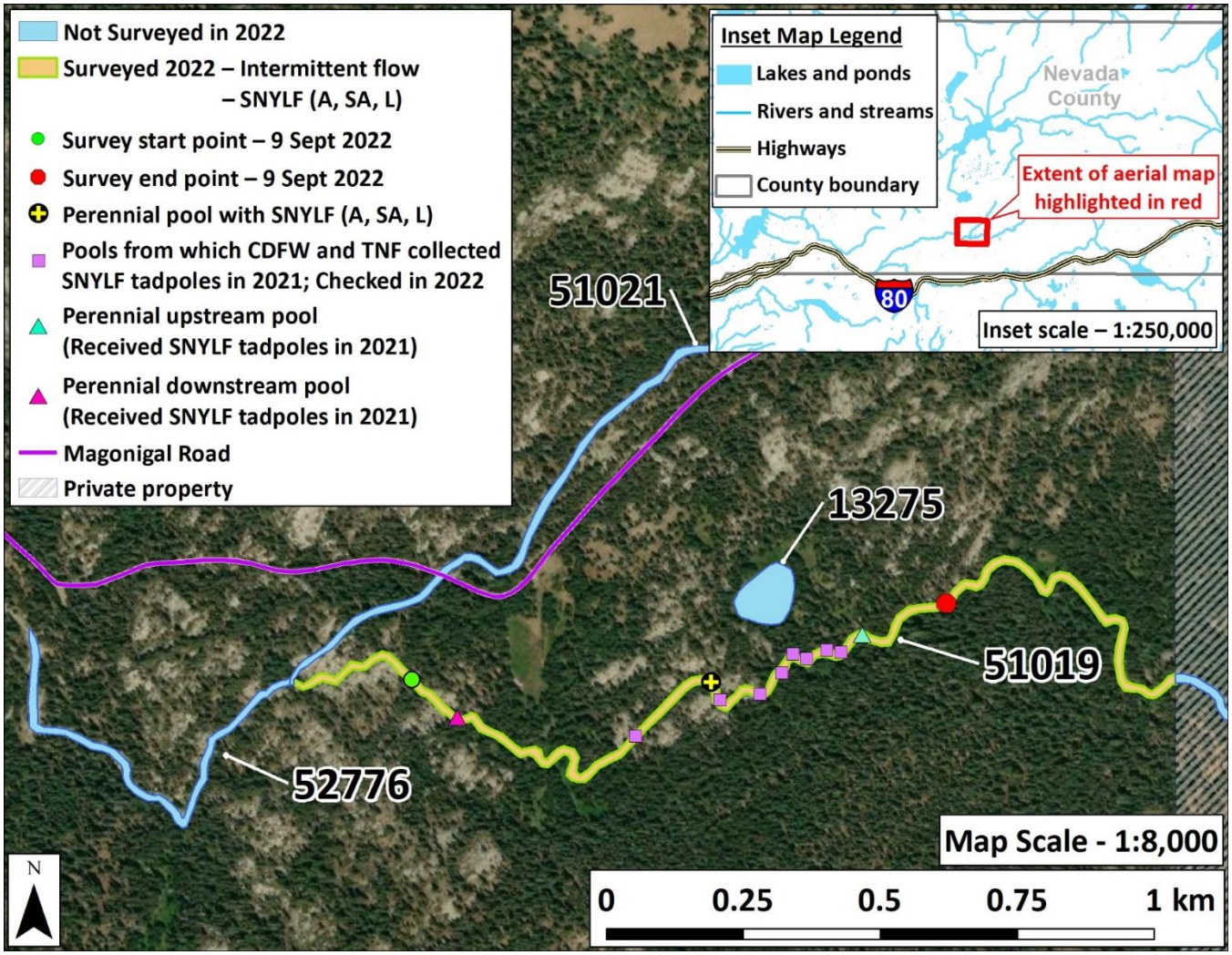


Figure 12. Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) observations, survey start/end locations, and key stream pool locations associated with the SNYLF emergency translocation in early September 2021 and visual encounter surveys (VES) in the Rattlesnake Creek area in September 2021 and 2022. SNYLF letter codes in the legend, which indicate the life stages observed during the most recent survey, are as follows: "A" = adults, "SA" = subadults, and "L" = larvae.

Figure 13. A small pool along Rattlesnake Creek (Site ID 51019) in early September 2021. This pool was a location from which California Department of Fish and Wildlife (CDFW) and Tahoe National Forest (TNF) staff collected Sierra Nevada Yellow-legged Frog (*Rana sierrae*) tadpoles for an emergency translocation in early September 2021. (TNF Photo)

Figure 14. The same pool along Rattlesnake Creek (Site ID 51019) as shown above (in **Figure 13**), in early September 2022. (CDFW)

Figure 15. A nearly dry pool along Rattlesnake Creek (Site ID 51019) in early September 2021. This pool was a location from which California Department of Fish and Wildlife (CDFW) and Tahoe National Forest (TNF) staff collected Sierra Nevada Yellow-legged Frog (*Rana sierrae*) tadpoles for an emergency translocation in early September 2021. (CDFW)

Figure 16. The same pool along Rattlesnake Creek (Site ID 51019) as shown above (in **Figure 15**), in early September 2022. (CDFW)

Figure 17. Two tiny pools (one of which is barely visible in front of the large piece of exposed bedrock on the left) along Rattlesnake Creek (Site ID 51019) in early September 2021. These pools were in a location from which California Department of Fish and Wildlife (CDFW) and Tahoe National Forest (TNF) staff collected Sierra Nevada Yellow-legged Frog (*Rana sierrae*) tadpoles for an emergency translocation in early September 2021. (TNF Photo)

Figure 18. The same two pools (now connected) along Rattlesnake Creek (Site ID 51019) as shown above (in **Figure 17**), in early September 2022. (CDFW)

Figure 19. A small pool along Rattlesnake Creek (Site ID 51019) in mid-September 2021. This pool was a location from which California Department of Fish and Wildlife (CDFW) and Tahoe National Forest (TNF) staff collected Sierra Nevada Yellow-legged Frog (*Rana sierrae*) tadpoles for an emergency translocation in early September 2021. (CDFW)

Figure 20. The same pool along Rattlesnake Creek (Site ID 51019) as shown above (in **Figure 19**), in early September 2022. (CDFW)

Figure 21. A perennial pool along Rattlesnake Creek (Site ID 51019) in mid-September 2021. This pool is identified by the blue triangle in **Figure 12**. This pool was a location into which California Department of Fish and Wildlife (CDFW) and Tahoe National Forest (TNF) staff released a subset of Sierra Nevada Yellow-legged Frog (*Rana sierrae*) tadpoles collected during an emergency translocation in early September 2021. This pool retains water late in the season, even during dry water years. (CDFW)

Figure 22. The same pool along Rattlesnake Creek (Site ID 51019) as shown above (in **Figure 21**), in early September 2022. (CDFW)

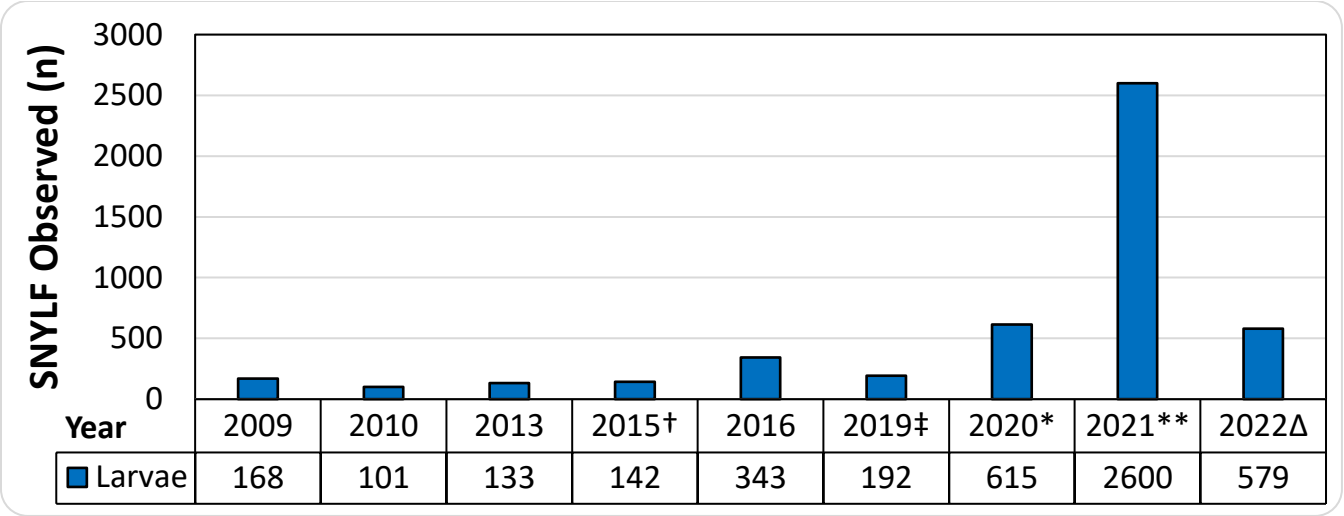


Figure 23. Counts of larval Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) detected during surveys in the Rattlesnake Creek area from 2009–2021. The histogram includes observations from Sites IDs 51019, 51021, and 52776. California Department of Fish and Wildlife (CDFW) staff have not observed any SNYLF at Site ID 13275 since 2004, during which CDFW staff observed eight adults, 200 recently metamorphosed frogs, 220 larvae, and four egg masses.

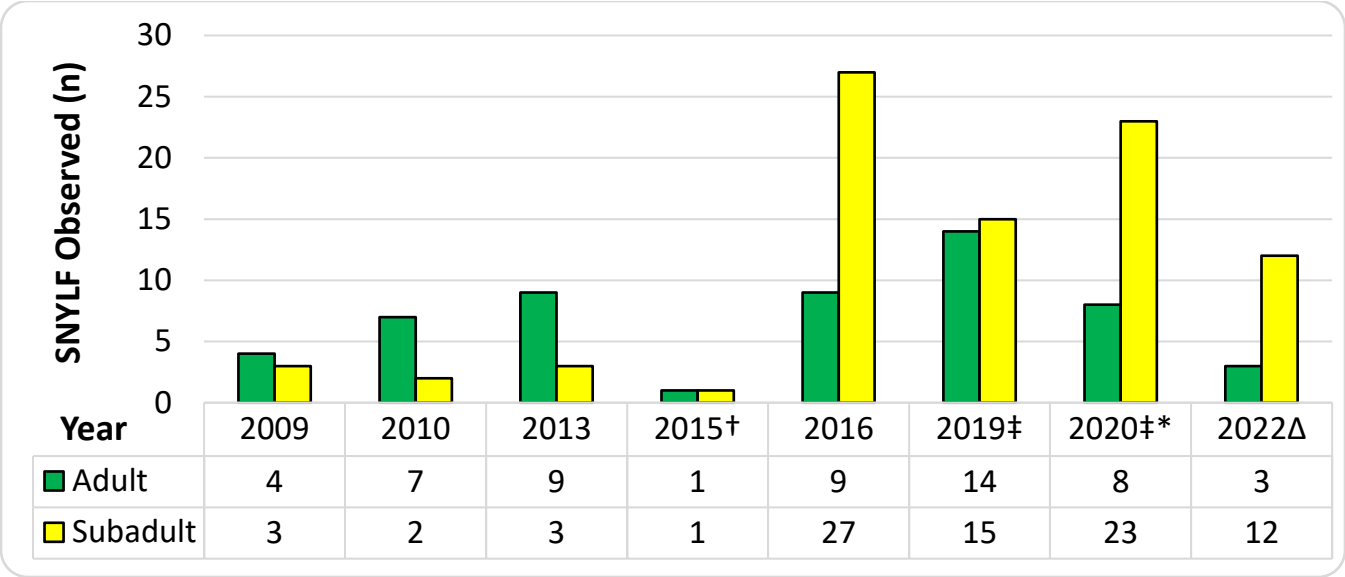
†In 2015, surveys occurred in mid-September, and weather conditions were poor, including overcast with occasional hail. Additionally, 2015 was an exceptionally dry year, following the lowest snowpack since weather records began (CDEC 2023b). Therefore, apart from occasional pools, little water remained in Rattlesnake Creek. Although little water was available compared with other years, the low water likely concentrated SNYLF larvae into small pools with undisturbed surfaces, in which CDFW staff could easily observe larvae. These conditions may partially explain why larval SNYLF detections in 2015 were more comparable with other survey years, whereas post-metamorphic SNYLF detections were substantially lower.

‡From 2019 onward, the histogram includes SNYLF observations from Site ID 52776. Site ID 52776 was first surveyed and assigned a Site ID number in 2019.

*CDFW field staff did not survey Site ID 50121 in 2020.

Surveys in 2021 were not traditional, single pass visual encounter surveys (VES). Instead, CDFW and Tahoe National Forest (TNF) staff conducted an emergency translocation effort, where staff collected tadpoles from small, rapidly drying pools using aquarium dip nets and translocated the tadpoles to more perennial aquatic habitat. ***These methods resulted in a near census of tadpoles within the small pools sampled, which greatly increased detections when compared with traditional VES.*

ΔIn 2022, results shown only include traditional VES results from within the portion of Site ID 51019 identified in **Figure 12.** This is the reach of Rattlesnake Creek from which CDFW and TNF staff had collected and released SNYLF as part of the emergency translocation effort in September 2021. [***End of figure caption***.]



Year	2009	2010	2013	2015†	2016	2019‡	2020‡*	2022Δ
Adult	4	7	9	1	9	14	8	3
Subadult	3	2	3	1	27	15	23	12

Figure 24. Counts of adult and subadult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) detected during surveys in the Rattlesnake Creek area from 2009–2022. The histogram includes observations from Sites IDs 51019, 51021, and 52776 (see below for specifics). CDFW staff have not observed any SNYLF at Site ID 13275 since 2004, during which CDFW staff observed eight adults, 200 recently metamorphosed frogs, 220 larvae, and four egg masses.

†In 2015, surveys occurred in mid-September, and weather conditions were poor, including overcast with occasional hail. Additionally, 2015 was an exceptionally dry year, following the lowest snowpack since weather records began (CDEC 2023b). Therefore, apart from occasional pools, little water remaining in Rattlesnake Creek. These conditions likely explain the very low post-metamorphic SNYLF detections in 2015.

‡In 2019 and 2020, the histogram includes SNYLF observations from Site ID 52776. Site ID 52776 was first surveyed and assigned a Site ID number in 2019.

*CDFW field staff did not survey Site ID 50121 in 2020.

ΔIn 2022, results shown only include traditional VES results from within the section of Site ID 51019 identified in **Figure 12.** This is the reach of Rattlesnake Creek from which CDFW and TNF staff had collected and released SNYLF as part of the emergency translocation effort in September 2021.

LOOKING AHEAD: 2023

In fall 2022, CDFW completed non-native trout removal from Five Lakes Basin, which is a location into which CDFW originally planned to reestablish SNYLF using individuals translocated from the Mossy Pond area (CDFW 2023). Five Lakes Basin is located approximately 8 km west of Mossy Pond, directly north of the Black Buttes (**Figure 1**). In 2013, the Mountain Yellow-legged Frog Interagency Technical Team (MYLF ITT) discussed using the Mossy Pond SNYLF population as a source for translocations to the Five Lakes Basin area. The following year, the project was formally proposed in the ABMP for the South Yuba River Management Unit, which highlighted Five Lakes Basin as a priority area for non-native fish removal to help reestablish a SNYLF population on TNF (CDFW 2014). Subsequently, the MYLF ITT finalized the "**Interagency Conservation Strategy for Mountain Yellow-legged Frogs in the Sierra Nevada**" (Strategy; MYLF ITT 2018), which lists non-native fish removal and translocations into Five Lakes Basin as part of the species conservation action plan (MYLF ITT 2018; Attachment 1, pg. 30; Attachment 2, pg. 4).

Under original terms of the endangered species recovery grant (Federal Grant Award #F19AP00750) for the Five Lakes Basin non-native trout removal and SNYLF reintroduction, CDFW planned to translocate SNYLF back into Five Lakes Basin during summer 2022, using adult frogs collected from the Mossy Pond area. Translocation is a well-established method to attempt supplementing or reestablishing SNYLF populations in the Sierra Nevada, and one of the primary recovery techniques recommended by the MYLF ITT (2018). However, VES in the Mossy Pond area in late summer and fall 2021, early summer 2022, and late summer 2022 revealed fewer adult SNYLF than anticipated (see results detailed in the VES IN THE MOSSY POND STUDY AREA and VES OUTSIDE THE MOSSY POND STUDY AREA earlier in this memorandum). CDFW and TNF staff detected <70 total adult SNYLF during VES. Since CDFW plans to collect at least 20 adult SNYLF to undertake the translocation effort, and the grant terms dictate that no more than 20% of adults observed during VES will be collected, CDFW needs to detect at least 100 adult SNYLF in the Mossy Pond area, during a single round of surveys soon before the planned translocation, in order to collect adults for translocation to Five Lakes Basin. Therefore, given these recent survey results, CDFW may not be able to collect adult SNYLF without the potential for unacceptable risk to the persistence and health of the Mossy Pond source population.

Given these recent VES results and need to limit unnecessary risk to the source population, CDFW may pursue an alternative option for reintroducing SNYLF to Five Lakes Basin. After discussion with the CDFW Statewide Amphibian and Reptile Conservation coordinator, supervisory staff in the Region 2 Fisheries Program, TNF partners, and USFWS, CDFW may collect early life stage SNYLF (tadpoles and/or recent metamorphs) from Rattlesnake Creek. Rattlesnake Creek would be a preferred alternative to Mossy Pond for collecting early life stage SNYLF because CDFW and TNF staff have detected comparatively far fewer tadpoles in the

Mossy Pond area, most of which have been observed at Site IDs 50133, 52596, and 52597 (**Figure 5**). Given consistent SNYLF breeding at Rattlesnake Creek and ability to more easily collect early life stages from shallow pools during late summer, CDFW would plan to collect a subset (≤20% of tadpoles through recent metamorphs seen during VES conducted soon before to collection) for translocation to Five Lakes Basin. However, collecting early life stage SNYLF from Rattlesnake Creek would still be an alternative, with the preferred option being moving older, post-metamorphic individuals.

Given that recent VES findings resulted in the need to postpone SNYLF translocation from the Mossy Pond and Rattlesnake Creek areas to Five Lakes Basin, CDFW applied for an official extension to continue the grant through the end of 2023. CDFW anticipates receiving this approval by spring 2023, which will allow funding of additional surveys in the Mossy Pond and Rattlesnake Creek areas during mid-summer 2023, plus a translocation in late summer 2023.

In summer 2023, CDFW will resurvey most waterbodies in the Mossy Pond area within a one-week period to obtain a current relative abundance estimate of SNYLF in the Mossy Pond metapopulation. CDFW will plan to time surveys to correspond with quality survey conditions during mid-summer. As of early February 2023, the 2022–2023 water year is on a trajectory to be a far above average water year, with particularly impressive mountain snow water content accrued between mid-December 2022 and mid-January 2023 (CDEC 2023a). If the Sierra Nevada continues to receive occasional winter storms that contribute to the snowpack, there is a chance the 2022–2023 water year will result in one of the largest snowpacks (if not the largest) on record. These current conditions may result in more ideal late summer survey conditions than occur in the Mossy Pond area during an average or dry water year. Therefore, depending on conditions in the field, CDFW may consider surveying the Mossy Pond later in the summer (e.g., late August or early September). If staff detect at least 100 adult SNYLF within the Mossy Pond area during the one-week survey period, CDFW will plan to consult with USFWS and USFS partners to consider proceeding with translocating adult SNYLF to Five Lakes Basin. Otherwise, CDFW will plan to instead coordinate with agency partners to pursue collecting SNYLF tadpoles and/or recent metamorphs from Rattlesnake Creek.

LITERATURE CITED

Bailey, L.L., W.L. Kendall, D.R. Church, and H.M. Wilbur. 2004. Estimating survival and breeding probability for pond-breeding amphibians: a modified robust design. Ecology 85:2456–2466. Available from: https://www.jstor.org/stable/pdf/3450244.pdf

Bradford, D.F. 1983. Winterkill, oxygen relations, and energy metabolism of a submerged dormant amphibian, *Rana muscosa.* Ecology 64:1171–1183. Available from: https://www.jstor.org/stable/pdf/1937827.pdf

Briggs, C.J. V.T. Vredenburg, R.A. Knapp, and L.J. Rachowicz. 2005. Investigating the population-level effects of chytridiomycosis: an emerging infectious disease in amphibians. Ecology 86:3149–3159. Available from: https://esajournals.onlinelibrary.wiley.com/doi/pdfdirect/10.1890/04-1428

Briggs, C.J., R.A. Knapp, and V.T. Vredenburg. 2010. Enzootic and epizootic dynamics of the chytrid fungal pathogen of amphibians. Proceedings of the National Academy of Sciences, USA 107:9695–9700. Available from: https://www.pnas.org/content/pnas/107/21/9695.full.pdf

Brown, C., M.P. Hayes, G.A. Green, and D.C. Macfarlane. 2014. Mountain yellow-legged frog conservation assessment for the Sierra Nevada mountains of California, USA. USDA Forest Service. Interagency technical report R5-TP-038. Available from: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3811864.pdf

California Data Exchange Center (CDEC). Department of Water Resources. 2023a. Northern Sierra precipitation 8-station index – interactive plot. Accessed January 2023. Available from: https://cdec.water.ca.gov/precipapp/get8SIPrecipIndex.action

CDEC. Department of Water Resources. 2023b. Daily regional snowpack plots from snow sensors – interactive plot. Accessed January 2023. Available from: https://cdec.water.ca.gov/snowapp/swcchart.action

CDEC. Department of Water Resources. 2023c. Daily regional snow water content data query for the northern Sierra Nevada. Accessed January 2023. Available from: https://cdec.water.ca.gov/dynamicapp/querySWC?reg=NORTH

California Department of Fish and Game (CDFG). 2011. A status review of the Mountain Yellow-legged Frog (*Rana sierrae* and *Rana muscosa*). Report to the Fish and Game Commission. Available from: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=40357

California Department of Fish and Wildlife (CDFW). 2014. Aquatic biodiversity management plan for the South Yuba River Management Unit. Available from: http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=85427

CDFW. 2019. Capture-mark-recapture at Mossy Pond, Tahoe National Forest, Nevada County – A summary of activities in 2018. Available from: http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=165860

CDFW. 2022a. *Rana sierrae* tadpole rescue at Rattlesnake Creek, Nevada County. Available from: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=198563

CDFW. 2022b. Amphibian monitoring in Tahoe National Forest, Nevada County – *Rana sierrae* monitoring in the Mossy Pond and Rattlesnake Creek areas. Available from: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=199214

CDFW. 2023. Native amphibian restoration in Five Lakes Basin (Grouse Ridge Non-motorized Area, Tahoe National Forest, Nevada Country) – Five Lakes Basin fish removal. Available from: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=210888

Fellers, G.M., D.F. Bradford, D. Pratt, and L.L. Wood. 2007. Demise of repatriated populations of Mountain Yellow-legged Frogs (*Rana muscosa*) in the Sierra Nevada of California. Herpetological Conservation and Biology 2:5–21. Available from: https://www.herpconbio.org/Volume_2/Issue_1/Fellers_etal_2007.pdf

Fellers, G.M., P.M. Kleeman, D.W. Miller, B.J. Halstead, and W.A. Link. 2013. Population size, survival, growth, and movements of *Rana sierrae*. Herpetologica 69:147–162. Available from: https://www.jstor.org/stable/pdf/24634280.pdf

Hammond, T.T., M.J. Curtis, L.E. Jacobs, P.M. Gaffney, M.M. Clancy, R.R. Swaisgood, and D.M. Shier. 2021. Overwinter behavior, movement, and survival in a recently introduced, endangered amphibian, *Rana muscosa*. Journal for Nature Conservation 64:e126086. Available from: https://par.nsf.gov/servlets/purl/10312253

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.-A.C. Hayek, and M.S. Foster (eds.). 1994. Measuring and monitoring biological diversity: standard methods for amphibians. Smithsonian Institution Press, Washington, D.C., USA.

Knapp, R.A., G.M. Fellers, P.M. Kleeman, D.A.W. Miller, V.T. Vredenburg, E.B. Rosenblum, and C.J. Briggs. 2016. Large-scale recovery of an endangered amphibian despite ongoing exposure to multiple stressors. Proceedings of the National Academy of Sciences 113:11889–11894. Available from: https://www.pnas.org/content/pnas/113/42/11889.full.pdf

Knapp, R., and A. Lindauer. 2020. Collection and analysis of amphibian skin swabs for qPCR analysis and Bd load. Protocol available from: http://mountainlakesresearch.com/wp-content/uploads/Protocol_SkinSwabbing_forclients-1.pdf

Kupferberg, S.J., H. Moidu, A.J. Adams, A. Catenazzi, M. Grefsrud, S. Bobzien, R. Leidy, and S.M. Carlson. 2021. Seasonal drought and its effect on frog population dynamics and amphibian disease in intermittent streams. Ecohydrology 15:e2395. Available from: https://onlinelibrary.wiley.com/doi/epdf/10.1002/eco.2395

Mazerolle, M.J., L.L. Bailey, W.L. Kendall, J.A. Royle, S.J. Converse, and J.D. Nichols. 2007. Making great leaps forward: accounting for detectability in herpetological field studies. Journal of Herpetology 41:672–689. Available from: https://www.jstor.org/stable/pdf/40060463.pdf

McCaffery, R.M., and B.A. Maxell. 2010. Decreased winter severity increases viability of a montane frog population. Proceedings of the National Academy of Sciences 107:8644–8649. Available from: https://www.jstor.org/stable/pdf/3536474.pdf

Mountain Yellow-legged Frog Interagency Technical Team (MYLF ITT). 2018. Interagency conservation strategy for mountain yellow-legged frogs in the Sierra Nevada (*Rana sierrae* and *Rana muscosa*). California Department of Fish and Wildlife, National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service. Version 1.0. Available from: https://www.fws.gov/sacramento/es_species/Accounts/Amphibians-Reptiles/sn_yellow_legged_frog/documents/Mountain-Yellow-Legged-Frog-Conservation-Strategy-Signed-508.pdf

Padgett-Flohr, G.E., and R.L. Hopkins II. 2009. *Batrachochytrium dendrobatidis*, a novel pathogen approaching endemism in central California. Diseases of Aquatic Organisms 83:1–9. Available from: https://www.int-res.com/articles/dao2008/83/d083p001.pdf

Rachowicz, L.J., R.A. Knapp, J.A.T. Morgan, M.J. Stice, V.T. Vredenburg, J.M. Parker, and C.J. Briggs. 2006. Emerging infectious disease as a proximate cause of amphibian mass mortality. Ecology 87:1671–1683. Available from: https://www.jstor.org/stable/pdf/20069125.pdf

Rumschlag, S.L., and M.D. Boone. 2018. High juvenile mortality in amphibians during overwintering related to fungal pathogen exposure. Diseases of Aquatic Organisms 131:13–28. Available from: https://www.int-res.com/articles/dao2018/131/d131p013.pdf

Tunstall, T.S. 2012. Characteristics of the emergent disease *Batrachochytrium dendrobatidis* in the *Rana muscosa* and *Rana sierrae* species complex. Ph.D. dissertation, University of California, Berkeley, CA. Available from: https://escholarship.org/content/qt0w45b27v/qt0w45b27v.pdf

Vredenburg, V.T., R.A. Knapp, T.S. Tunstall, and C.J. Briggs. 2010. Dynamics of an emerging disease drive large-scale amphibian population extinctions. Proceedings of the National Academy of Sciences, USA 107:9689–9694. Available from: https://www.pnas.org/doi/epdf/10.1073/pnas.0914111107

Vredenburg, V.T., S.V.G. McNally, H. Sulaeman, H.M. Butler, T. Yap, M.S. Ko, D.S. Schmeller, C. Dodge, T. Cheng, G. Lau, and C.J. Briggs. 2019. Pathogen invasion history elucidates contemporary host pathogen dynamics. PLoS ONE 14:e0219981. Available from: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0219981&type=printable

Williams, B.K., J.D. Nichols, and M.J. Conroy. 2001. Analysis and management of animal populations. Academic Press, San Diego, CA, USA.