State of California
Department of Fish and Wildlife

Memorandum

Date: 16 March 2022

To: Angie Montalvo,
Senior Environmental Scientist;
Acting Sierra District Supervisor;
North Central Region Fisheries

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

Cc: Region 2 Fish Files

Ec: CDFW Document Library

Subject: Amphibian monitoring in Desolation Wilderness, El Dorado County

- **Capture-mark-recapture (CMR) on Lake Tahoe Basin Management Unit (LTBMU)**
- ***Rana sierrae* visual encounter surveys (VES) in Desolation Valley (Eldorado National Forest) and Tamarack Lake area (LTBMU)**

ENVIRONMENTAL SETTING

Desolation Valley is located in the Desolation Wilderness, El Dorado County (**Figure 1**). This memorandum includes capture-mark-recapture (CMR) surveys in the southeastern portion of Desolation Valley, including Jabu, Margery, and Lucille Lakes, plus visual encounter surveys (VES) in the Tamarack Lake area and portions of Desolation Valley. Desolation Valley is a large granite basin, with elevations ranging from approximately 7,400 feet (ft; 2,255 meters [m]) at the top of Horsetail Falls to 9,983 ft (3,043 m) at the summit of Pyramid Peak. Eldorado National Forest (ENF) and the Lake Tahoe Basin Management Unit (LTBMU) manage the surrounding land. The site is predominately accessed via the Pacific Crest Trail from the Echo Lakes trailhead, which is located at the eastern end of Lower Echo Lake.

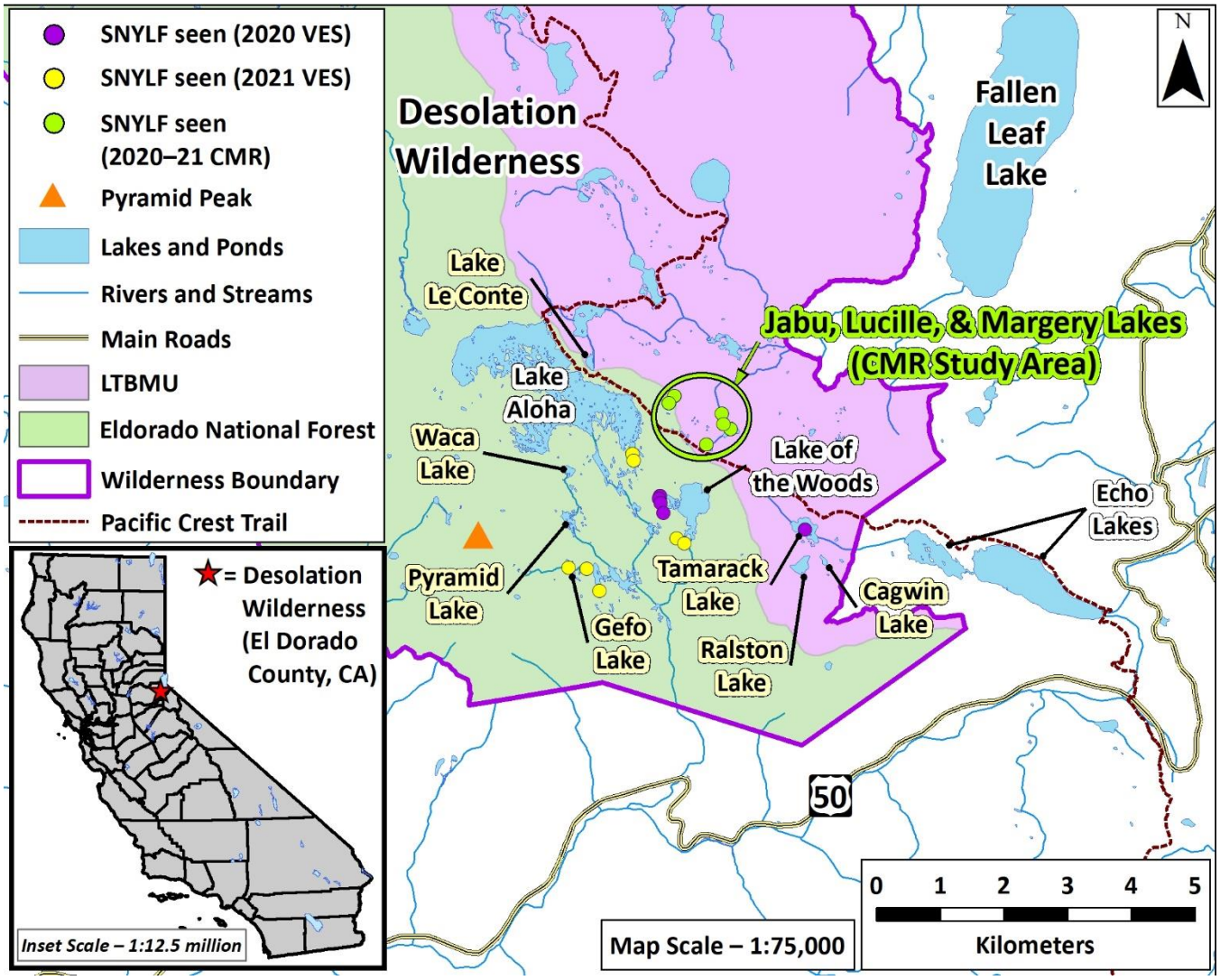


Figure 1. Locations of Sierra Nevada yellow-legged Frog (*Rana sierrae*; SNYLF) capture-mark-recapture (CMR) and visual encounter surveys (VES) in Desolation Valley, El Dorado County, CA. Purple dots and yellow dots show locations with SNYLF detections during VES conducted by California Department of Fish and Wildlife (CDFW) staff in 2020 and 2021, respectively. Light green dots indicate lakes with SNYLF detections during CMR in 2020 and 2021. Lakes from which Lake Tahoe Basin Management Unit (LTBMU), Eldorado National Forest (ENF), and CDFW staff removed fish from 2006 to 2012 include Le Conte, Waca, Pyramid, Gefo, Tamarack, Ralston, Cagwin, Jabu, Lucille, and Margery Lakes.

INTRODUCTION

The Aquatic Biodiversity Management Plan (ABMP) for the Desolation Wilderness Management Unit (CDFG 2012) identifies sites occupied by Sierra Nevada yellow-legged Frogs (*Rana sierrae*; SNYLF) as amphibian resources and prescribes regular population monitoring.

Periodic VES during the early 2000's revealed that very few SNYLF remained in the waterbodies on the LTBMU lands of the Desolation Valley area. Only one small pond—in the vicinity of Cagwin, Ralston, and Tamarack Lakes—contained a small breeding population of SNYLF. The

ABMP discussed that reintroductions may be needed to assist SNYLF recolonization and reduce the potential for genetic bottlenecking in this small population (CDFG 2012, pg. 48). Additionally, the ABMP identified several waterbodies on the LTBMU lands of Desolation Valley as priority fish removal sites, into which SNYLF could subsequently be translocated from extant populations on the ENF side of Desolation Valley (CDFG 2012, pg. 49). Concurrently, an interagency team, composed of CDFW, the U.S. Forest Service, U.S. Fish and Wildlife Service, researchers, and zoo partners, began implementing these efforts, which are also discussed in the Interagency Conservation Strategy for Mountain Yellow-legged Frogs in the Sierra Nevada (MYLF ITT 2018, pg. 35).

Beginning in 2008, LTBMU, with assistance from CDFW, started mechanically removing fish from Cagwin, Ralston, and Tamarack Lakes using monofilament gill nets and backpack electrofishers (USFS 2011). In 2009, LTBMU and CDFW started mechanically removing fish from Le Conte, Lucille, and Margery Lakes (USFS 2011; **Figure 1**). LTBMU completed fish by 2012. Non-native fish eradication allowed subsequent SNYLF reintroduction efforts to proceed.

In 2013, the Mountain Lakes Research Group (MLRG; based at the Sierra Nevada Aquatic Research Laboratory in Mammoth Lakes, and affiliated with University of California, Santa Barbara) began the process of collecting early life stage SNYLF from robust populations on the ENF side of Desolation Valley for captive-rearing at the San Francisco Zoo (Zoo). Zoo staff raised SNYLF to adulthood and MLRG subsequently released the captive-reared adult frogs into Jabu and Lucille Lakes. Additionally, in 2014, MLRG began direct translocations of adult frogs and egg masses from Desolation Valley to Jabu and Lucille Lakes. MLRG conducted direct translocations in 2014, 2015, 2017, and 2018; and release of captive-reared frogs in 2014, 2015, 2016, and 2019. Additionally, MLRG conducted direct translocation of adult SNYLF (2017 and 2018) and release of Zoo-reared frogs (2015, 2016, and 2019) into Tamarack Lake. The most recent SNYLF to be translocated into the LTBMU were the final group of 18 captive-reared adult frogs, which CDFW staff released into Lake Lucille in June 2020. No additional SNYLF from Desolation Valley are currently held at the Zoo.

MLRG is the lead organization conducting CMR analysis of the translocated SNYLF on LTBMU lands. To provide additional data on the fate of translocated frogs at these locations, CDFW agreed to conduct additional CMR monitoring in 2020 and 2021. Therefore, this memorandum focuses on presenting data from the CDFW-led efforts. CMR monitoring discussed in this memorandum does not include the Tamarack Lake area (see **CAPTURE-MARK-RECAPTURE** section below).

THREATS

Marginal Habitat

Under current climate conditions, there is ample fishless habitat to accommodate healthy SNYLF populations in Desolation Valley. However, many fishless waterbodies with extant SNYLF

in Desolation Valley are relatively small and shallow, which could reduce the long-term viability of SNYLF populations under climate change scenarios of hotter and drier summers, more winter precipitation falling as rain, and loss of snowpack (Dettinger et al. 2018, Sun et al. 2019, Coats et al. 2021). Therefore, extended drought, severe winter conditions (i.e., scenarios of low snowpack and freezing temperatures leading to complete freezing of small waterbodies; Bradford 1983), or anthropogenic habitat disturbances present potential extirpation risks to SNYLF populations in Desolation Valley.

Disease

The fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*), which has been implicated in amphibian declines worldwide (Rachowicz et al. 2006, Skerratt et al. 2007, Rosenblum et al. 2010, Lambert et al. 2020), has been detected in all SNYLF populations in the Desolation Valley area tested by CDFW. To detect *Bd*, field staff collected epithelial swabs at numerous waterbodies in Desolation Valley between 2008 and 2021. Partner scientists screened the swabs for presence of *Bd* DNA using real-time quantitative polymerase chain reaction (qPCR) analysis. The swab analyses detected varying levels of infection intensity, from very light to moderate.

Introduced Fish

Most fish stocking in Desolation Wilderness conducted by the Division of Fish and Game (the predecessor organization to CDFW; Leitritz 1970) began in the early 1930's (CDFG 2012). Although various individuals and entities—including the Fish and Game Commission, Sierra Club, Mount Ralston Fishing Club, and mountaineers—informally stocked high elevation lakes in prior years, records from those earlier time periods (i.e., approximately early 1870's through the 1930's) are, at best, inconsistent, and often nonexistent (Dill and Cordone 1997, Pister 2001). Record-keeping of authorized backcountry fish stocking became more consistent following implementation of aerial stocking, which began in 1946 (Leitritz 1970). From about 1950 until 2000, CDFW stocked many waterbodies in Desolation Valley with trout, predominantly Brook Trout (*Salvelinus fontinalis*, BK) and Rainbow Trout (*Oncorhynchus mykiss*, RT). During that 50-year period, CDFW aerially stocked BK into most larger lakes and ponds in and around Desolation Valley on nearly an annual basis, including Aloha, American, Cagwin, Channel, Desolation, Jabu, Le Conte, Lucille, Margery, Pyramid, Ralston, Ropi, Tamarack, and Waca Lakes, plus Lake of the Woods. CDFW also intermittently stocked RT into most of the aforementioned lakes, although far less frequently than BK.

In 2000, in response to range-wide declines of SNYLF and a departmental reassessment of stocking practices, CDFW halted aerial stocking at lakes and ponds in Desolation Wilderness (CDFG 2012). Subsequently, LTBMU, ENF, and CDFW mechanically removed fish from a subset of introduced trout-containing waterbodies (discussed in the **INTRODUCTION** above). However, introduced trout are still widespread in Desolation Wilderness, including in Lake Aloha and all lakes connected to the Pyramid Creek drainage (American, Channel, Desolation,

Ropi, Pitt, and Avalanche Lakes, plus all unnamed ponds connected to the main channel). CDFW has not sampled Lake of the Woods via gill net in over a decade. However, during an overnight set of three gill nets in July 2008, CDFW caught six large RT. Therefore, Lake of the Woods may still contain a low density, trophy RT fishery (CDFG 2012).

Fish do not present an immediate threat to all SNYLF populations in Desolation Valley (i.e., some waterbodies with SNYLF are hydrologically separated from waterbodies with extant trout, including areas like Waca, Pyramid, and Gefo Lakes). However, there are some locations where SNYLF and trout overlap (e.g., Lake Aloha and, potentially, Lake of the Woods). There are also more areas where waterbodies with trout are found in very close proximity to those containing SNYLF. In these areas, seasonal flooding, or illegal movement of fish into currently fishless ponds, presents some risk to SNYLF. The more consistent threat is that Lake Aloha and the Pyramid Creek drainage may act as population sinks for migrating SNYLF, and that fish-containing habitat in Desolation Valley prevents SNYLF from being able to successfully breed and recruit in the largest aquatic habitats in the area. However, there are no currently feasible methods available to eradicate introduced trout from the large, complex, and highly interconnected aquatic habitats of Lake Aloha and the Pyramid Creek drainage (CDFG 2012). Additionally, Desolation Wilderness is one of the most visited wilderness areas in the country (USDA 1998), and Desolation Valley is a popular recreational fishing destination for many backcountry users. Therefore, there is benefit in maintaining a mix of fishless areas for SNYLF and other native aquatic species, and fish-containing waterbodies for backcountry anglers.

CAPTURE-MARK-RECAPTURE PROJECT

CMR Materials and Methods:

The study area consists of three distinct areas: Jabu (one named lake and one unnamed pond), Lucille (two named lakes and three unnamed ponds), and Tamarack (one named lake and four unnamed ponds)—plus any connected (mostly ephemeral) streams within each basin—on the LTBMU side of the Desolation Valley area, Desolation Wilderness, CA (**Figure 1**). The MLRG conducted CMR surveys from 2015–2019 and CDFW staff took over surveys beginning in 2020. In 2015 and 2017–2019, the MLRG included all three basins in each CMR trip. Survey effort in 2016 was more limited and only included a single visit to the Jabu and Lucille basins (**Table 1**). CDFW staff did not include Tamarack Basin in 2020 and 2021 CMR surveys. When compared with the MLRG, CDFW had a smaller crew available, and the Tamarack Lake area is further removed from Lucille and Jabu Lakes. Therefore, MLRG and CDFW determined it was more productive to forego CMR in the Tamarack Lake area, and instead focus efforts on the Jabu and Lucille Lake areas.

The study design was developed using the traditional robust design framework (Williams et al. 2001), wherein one to four surveys ("primary periods") occurred each summer, beginning in 2015. Each primary period consists of three consecutive survey days ("secondary periods"), during each of which field crews survey all wetted habitat in the study area and attempt to

capture every adult frog observed (**Table 1**). Data analyses, which will be conducted by the MLRG, may use a robust design model (Pollock 1982) to estimate SNYLF abundance and other population demographic parameters in the study area. The analytical methods may be similar to other amphibian studies using the robust design model (e.g., Bailey et al. 2004, McCaffery and Maxell 2010, Fellers et al. 2013). Regardless of the ultimate methods chosen to analyze the data, MLRG plans to report results of the full study (T.C. Smith, MLRG, pers. comm.).

Table 1. Number of capture-mark-recapture (CMR) trips ("primary periods") to each waterbody among the Desolation Valley translocated Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) recipient sites, from 2015 to 2021. During each trip, biologists surveyed each site on three successive days ("secondary periods"). From 2015 to 2019, the Mountain Lakes Research Group (MLRG), affiliated with University of California at Santa Barbara (UCSB), conducted CMR surveys. California Department of Fish and Wildlife (CDFW) staff took over CMR efforts in 2020. *****In 2020 and 2021, CDFW did not include the Tamarack Lake area in CMR surveys.

Basin	**Jabu**		**Lucille**					**Tamarack**
Site	*52682*	*14218*	*14226*	*14235*	*14237*	*14255*	*14266*	*(5 Sites)*
2015	3	4	3	3	3	4	3	3–4 (depending on waterbody)
2016	1	1	0	0	0	1	1	0
2017	1	2	2	2	2	2	2	2
2018	2	3	2	2	1	2	2	1–3 (depending on waterbody)
2019	2	2	2	2	2	2	2	2
***2020**	2	2	2	2	2	2	2	0
***2021**	1	1	1	1	1	1	1	0

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 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 ~4–12 m, depending on the waypoint) for each capture using a handheld GPS unit or GPS app on a smartphone (see **APPENDIX**). Crews weighed each adult frog inside a tared plastic bag to the nearest 0.1 g using a Pesola® spring scale. Finally, during each primary period and within each CMR focal area, staff collected up to approximately 20 skin swabs from post-metamorphic frogs to provide a current snapshot of *Bd* status in each focal area. For each captured adult frog, crews 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 using data apps on smartphones (e.g., Pendragon Forms or Fulcrum App), or into paper notebooks, which were then transferred to data apps (2020 and 2021 only). In 2020 and 2021, CDFW staff uploaded data collected within the apps to a cloud-based storage system, and then shared those data with the MLRG, who error checked and stored the data for later analyses.

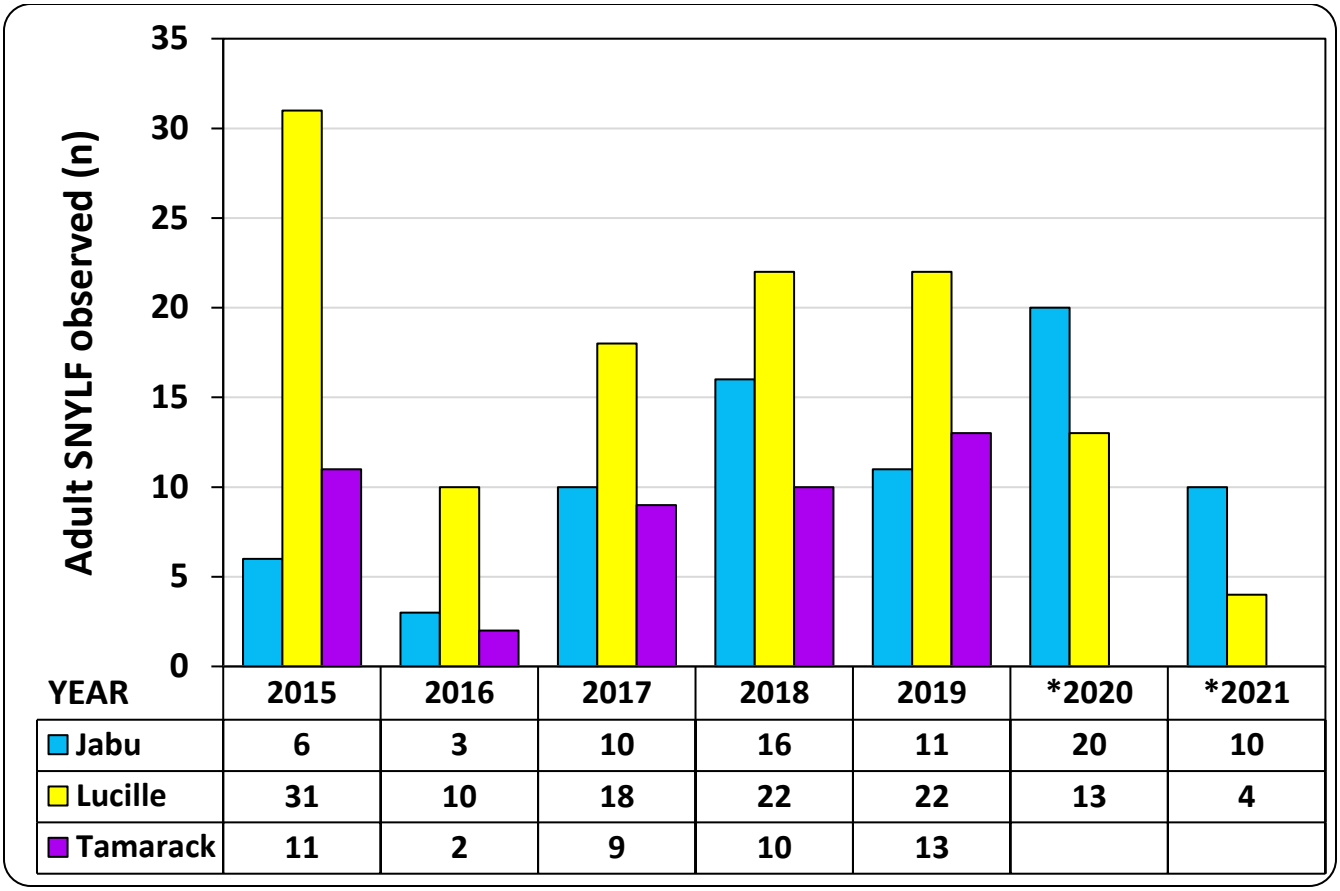
CMR Results:

MLRG and CDFW field staff have completed seven years of CMR surveys in the Desolation Valley study area. Each CMR visit involved at least one primary period, which were separated by at least one month in cases where more than one primary period occurred within one season (in this case, a "season" means the warmer months, during which high elevation lakes are free of ice, sites are accessible, and SNYLF are most active; ~June–September; **Table 1**). Although we provide some summary results from efforts led by MLRG, most results presented below are from CDFW-led efforts in 2020 and 2021.

CDFW visited the Jabu and Lucille areas twice in 2020 (mid-July and early September), and once in 2021 (mid-July). CDFW staff planned to return for a second CMR primary period in late August or early September 2021. However, the Caldor Fire forced the closure of ENF and LTBMU through September, so CDFW was forced to cancel the second CMR trip.

CMR techniques allowed MLRG and CDFW to determine the total number of individual adult SNYLF detected by staff at each waterbody in the CMR study area each season (**Figure 2**). Although adult SNYLF detections have varied in the Jabu Lake area (include Jabu Lake and Site ID 52682; **Figures 2 and 3**), adult SNYLF numbers have remained relatively consistent since 2017. However, adult SNYLF detections have declined in the Lake Lucille area (including Site IDs 14226, 14237, and 14266; **Figures 2 and 3**) for the past two years. Below are the detailed breakdowns of adult SNYLF detections at each Site ID on each survey day in 2020 (**Table 2**) and 2021 (**Table 3**).

CDFW staff noted observations of earlier SNYLF life stages (subadults and tadpoles) in 2020 and 2021, but such observations were incidental because staff did not mark early life stages with unique identifiers in this study. Therefore, staff focused survey effort on capturing as many marked adult SNYLF as possible (or tagging unmarked adults). However, staff noted early SNYLF life stages, which staff detected almost exclusively at Jabu Lake in 2020 and 2021. Additionally, staff have occasionally detected a small number of early SNYLF life stages at Lake Lucille and Site ID 52682. The highest number of subadult SNYLF detected by CDFW staff during any single circumnavigation of Jabu Lake during the two seasons was 130 (seen on 2 September 2020) and 10 (seen on 20 July 2021), respectively. The highest number of SNYLF tadpoles detected by CDFW staff at Jabu Lake was 70 (seen on 14 July 2020) and one (seen on 22 July 2021), respectively. Staff only observed a few early life stage SNYLF at Lake Lucille in 2020 (e.g., staff observed two SNYLF tadpoles on 14 July 2020 and two SNYLF subadults on 1 September 2020), and staff detected no early life stage SNYLF at Lake Lucille in July 2021.



YEAR	2015	2016	2017	2018	2019	*2020	*2021
Jabu	6	3	10	16	11	20	10
Lucille	31	10	18	22	22	13	4
Tamarack	11	2	9	10	13		

Figure 2. Number of unique adult Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) individuals observed during capture-mark-recapture (CMR) surveys in each area during each year. Unique individual totals are only valid within the same year (i.e., some of the captures below include the same individuals caught on successive years). *****In 2020 and 2021, CDFW did not include the Tamarack Lake area in CMR surveys. However, staff surveyed Tamarack Lake once in both 2020 and 2021, using traditional visual encounter survey (VES) techniques (i.e., staff conducted a single pass of Tamarack on a single day in both 2020 and 2021). During VES at Tamarack in 2020, CDFW detected one adult SNYLF in the western inlet. During VES in 2021, CDFW detected no SNYLF at Tamarack.

Table 2. Number of adult Sierra Nevada Yellow-legged Frogs (SNYLF) observed on each capture-mark-recapture survey day in 2020. The number shown for each site on each day is the number of individual adults observed that day.

Site ID	Site Name	7/13	7/14	7/15	9/1	9/2	9/3	**Total unique individuals seen at waterbody in 2020***
14218	Jabu Lake	4	6	7	6	4	4	**14**
14226		1	0	0	1	1	0	**2**
14235	Lake Lucille	5	5	1	7	2	1	**10**
14237		1	1	0	DRY	DRY	DRY	**1**
14255	Lake Margery	0	0	0	0	0	1	**1**
14266		0	0	0	0	0	0	**0**
52682		2	1	2	7	6	4	**8**
TOTAL UNIQUE ADULTS BY DATE		**13**	**13**	**10**	**21**	**13**	**10**	**TOTAL UNIQUE ADULTS CAPTURED IN 2020: 33***

*The sum of adult individuals from each waterbody adds to 36, whereas the total number of observed adults sums to 33, because three individuals moved from one site to another. The one adult from Site ID 14237 in July had moved into Lake Lucille by September. Between site visits in July and September, two individuals moved from Jabu Lake into Site ID 52682.

Table 3. Number of adult Sierra Nevada Yellow-legged Frogs (SNYLF) observed on each capture-mark-recapture survey day in 2021. The number shown for each site on each day is the number of individual adults observed that day.

Site ID	Site Name	7/20	7/21	7/22	**Total unique individuals seen at waterbody in 2021**
14218	Jabu Lake	1	0	0	**1**
14226		0	0	0	**0**
14235	Lake Lucille	3	1	1	**3**
14237		0	0	0	**0**
14255	Lake Margery	0	0	1	**1**
14266		0	0	0	**0**
52682		9	8	8	**9**
TOTAL UNIQUE ADULTS BY DATE		**13**	**9**	**10**	**TOTAL UNIQUE ADULTS CAPTURED IN 2021: 14**

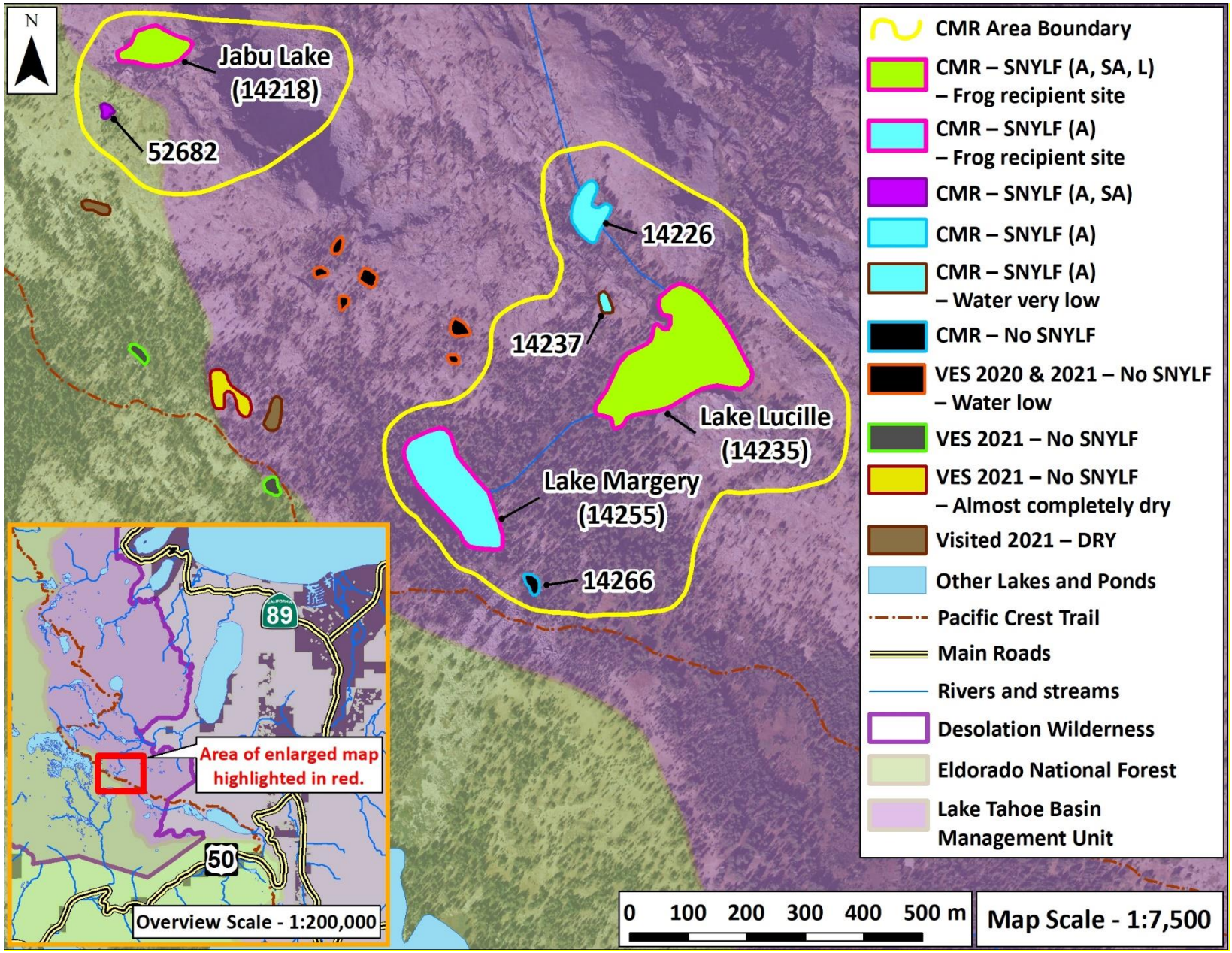


Figure 3. [See figure caption at the beginning of the next page.]

Figure 3 (continued). Spatial summary of Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) detections during capture-mark-recapture (CMR) surveys conducted by California Department of Fish and Wildlife (CDFW) staff in 2020 and 2021. In 2020, CDFW visited the CMR area twice, in July and September. In 2021, CDFW visited the CMR area once (in July): a second visit was not possible due to the Caldor Fire. CMR surveys involved searching the entire area (areas encircled in yellow) for SNYLF each day for three days in a row. During each day, staff surveyed the perimeter of each pond at least once, and often two or three times for waterbodies in which SNYLF are more consistently detected (e.g., Jabu, Site ID 52682, and Lucille). SNYLF letter codes in the legend, which indicate the life stages observed during CMR, are as follows: "A" = adults, "SA" = subadults, and "L" = larvae. During the two-year period, CDFW staff observed SNYLF at least once (and often repeatedly) in six of the seven waterbodies included in the daily surveys. The figure also shows summary results from visual encounter surveys (VES; i.e., one-time surveys not included in the CMR effort) in ponds close to the CMR area. CDFW staff did not detect SNYLF in any of these nearby ponds during VES in 2020 or 2021.

CMR Discussion

Analyses and discussion of the full data set, only part of which are presented in summary form in this memorandum, are planned in a future publication by MLRG. However, this section includes discussion of results and observations from CDFW surveys in 2020 and 2021.

In 2020, adult SNYLF detections in the Jabu Lake area were similar to those during earlier surveys by MLRG. However, in 2021, CDFW staff observed about half the number of SNYLF adults in the Jabu area when compared with 2020. CDFW staff observed an even more striking decline in SNYLF observations in the Lake Lucille area. CDFW staff only observed four adult SNYLF in the entire area during the three-day survey period (three in Lake Lucille and one in Lake Margery; **Table 3**), and no early life stage individuals. This is the lowest SNYLF count observed in the Lake Lucille area since the CMR study began in 2015 and part of a recent downward trend in SNYLF observation in the Lake Lucille area (**Figure 2**).

We do not know the cause(s) for this reduction in SNYLF observations, but there are several plausible explanations. During the one CMR primary period in 2021, winds were often strong during all three survey days. In the CMR area, Jabu Lake (the highest elevation, and most exposed, site) appeared to receive the strongest wind, which often prevented visibility into the water. These weather conditions may have been partly responsible for the limited tadpole detections. Windy conditions may have also limited basking of post-metamorphic SNYLF in more exposed areas and prevented observers from detecting individuals seeking refuge on the lake bottom.

Emigration from the study area is another possible reason for fewer adult SNYLF observations in 2021. Based on observations during 2020 and 2021, adult SNYLF may prefer occupying the small, shallow pond (Site ID 52682) located approximately 60 m south of Jabu Lake. Based on PIT tag data, CDFW staff documented two adult individuals that moved from Jabu Lake to Site

ID 52682 between the two primary periods in 2020 (see **APPENDIX**). Some adults may choose to overwinter and breed in Jabu Lake, but then seek out other aquatic habitats during the summer. In both areas (Jabu and Lucille Lakes), post-metamorphic SNYLF may use late spring snowmelt streams and ephemeral ponds as steppingstone aquatic habitat to emigrate to other locations in Desolation Valley. Such movement is within the abilities of post-metamorphic SNYLF. For example, Lake Aloha is only about 500 m west of Jabu Lake, and SNYLF are known to travel farther distances, including several hundred meters overland during favorable conditions (e.g., during wet, early season; following rainstorms; overnight) (Pope and Matthews 2001, Fellers et al. 2007, Matthews and Preisler 2010, Brown et al. 2019, CDFW 2020, Keung et al. 2021).

Another potential reason for fewer adult detections in 2021, when compared with 2020, is that CDFW only conducted one survey trip, which reduced opportunities for detecting frogs when compared with most other years of CMR in the study area. The other CMR survey year with very few SNYLF detections was 2016, during which MLRG also visited sites during only one primary period (**Table 1**; **Figure 2**). However, this comparison is confounded by the fact that MLRG translocated additional adult SNYLF into Jabu and Lucille Lakes following the 2016 primary period surveys (additional releases of adult SNYLF occurred in 2017– 2019 at Jabu Lake, and 2017–2020 at Lake Lucille). Therefore, the limited detections in 2016 may have been largely due to fewer SNYLF being present at the sites. Despite this complication in comparing observations between years, additional surveys at other times of year may have resulted in more SNYLF individuals being detected in 2021. For example, in 2020, CDFW staff detected more SNYLF adults during the second primary period in early September when compared with the first primary period in mid-July (**Table 2**). Had CDFW been able to return to the study area for a second visit, staff may have detected additional SNYLF that were not available for detection in July.

Finally, the reduction in SNYLF detections may have been in part due to mortalities through various causes, including predation, *Bd*, and overwintering conditions (e.g., a subset of frogs remaining in small ponds like Site ID 52682 may have died from overwinter oxygen depletion, since small and shallow sites can freeze to the bottom and become anoxic; Bradford 1983). CDFW did not observe evidence of any *Bd*-induced die-offs in the study area in 2020 and 2021. Although *Bd*-related die-offs can occur rapidly, such catastrophic population loss is mainly known from large, Bd-naïve SNYLF populations (e.g., Vredenburg et al. 2010). However, in areas where *Bd* is endemic (i.e., where the disease has been present for longer periods), losses may occur more insidiously over time (Briggs et al. 2010), and such smaller-scale losses may be additive to other sources of mortality, thus increasing the probability of long-term decline, particularly in small populations. Additionally, gartersnake (*Thamnophis* spp.) predation is common in SNYLF populations (T.C. Smith, unpubl. data). CDFW staff and researchers have directly observed gartersnakes preying on SNYLF in Desolation Wilderness, including within the CMR study area (I. Chellman, S. DeCurtis, J. Imperato, R. Knapp, and T.C. Smith; pers. obs.).

In one notable example, CDFW staff observed an adult Sierra Gartersnake (*Thamnophis couchii*) preying on a young adult SNYLF at Lake Lucille on 1 September 2020. Staff extracted the frog, which was still alive, to collect PIT tag data and morphological measurements (the frog turned out to be one of the Zoo-reared cohort released at Lake Lucille in June 2020). Staff released the frog at the point of capture, at which time the gartersnake was no longer visible. During the next circumnavigation of Lake Lucille later that same afternoon, staff observed an adult Mountain Gartersnake (*Thamnophis elegans elegans*) consuming the same frog, which was by that time deceased.

VES IN DESOLATION VALLEY AREA

There are approximately 170 lakes, ponds, and stream segments in Desolation Valley area (which, in this memorandum, includes the Tamarack, Ralston, and Cagwin Lakes area) outside of the CMR study area. Between 2003 and 2021, CDFW staff have observed SNYLF of various life stages in 53 of these waterbodies. Among the 53 waterbodies in which CDFW has detected SNYLF, staff have observed evidence of SNYLF breeding in 29 (i.e., staff have observed egg masses, tadpoles, and/or recent metamorphs during at least one survey of the site). Monitoring data from the past 19 years indicate a relatively large SNYLF metapopulation, with the highest SNYLF densities occurring in the fishless headwater areas of western Desolation Valley (**Figure 4**).

In 2020 and 2021, CDFW staff conducted VES in a subset of fishless waterbodies in Desolation Valley outside the CMR study area. CDFW surveyed fewer sites in Desolation Valley than expected, due to time constraints from also conducting CMR, and lack of access caused by the Caldor Fire. However, despite limited time for VES, staff conducted over 30 surveys outside of the CMR area and detected SNYLF at 12 sites (**Figure 5**). Beginning in summer 2022, CDFW plans to conduct more widespread amphibian surveys in Desolation Valley, including Pyramid Valley (Waca and Pyramid Lakes, plus the connected stream and surrounding unnamed ponds), Lake Aloha, and other sites at the western edge of Desolation Valley. Further details on historic amphibian detections can be found in the Aquatic Biodiversity Management Plan for the Desolation Wilderness Management Unit (CDFG 2012). Additionally, CDFW plans to set overnight gill nets in Lake of the Woods, to obtain more current information on whether the lake may have become fishless since the last overnight gill net sampling in 2008.

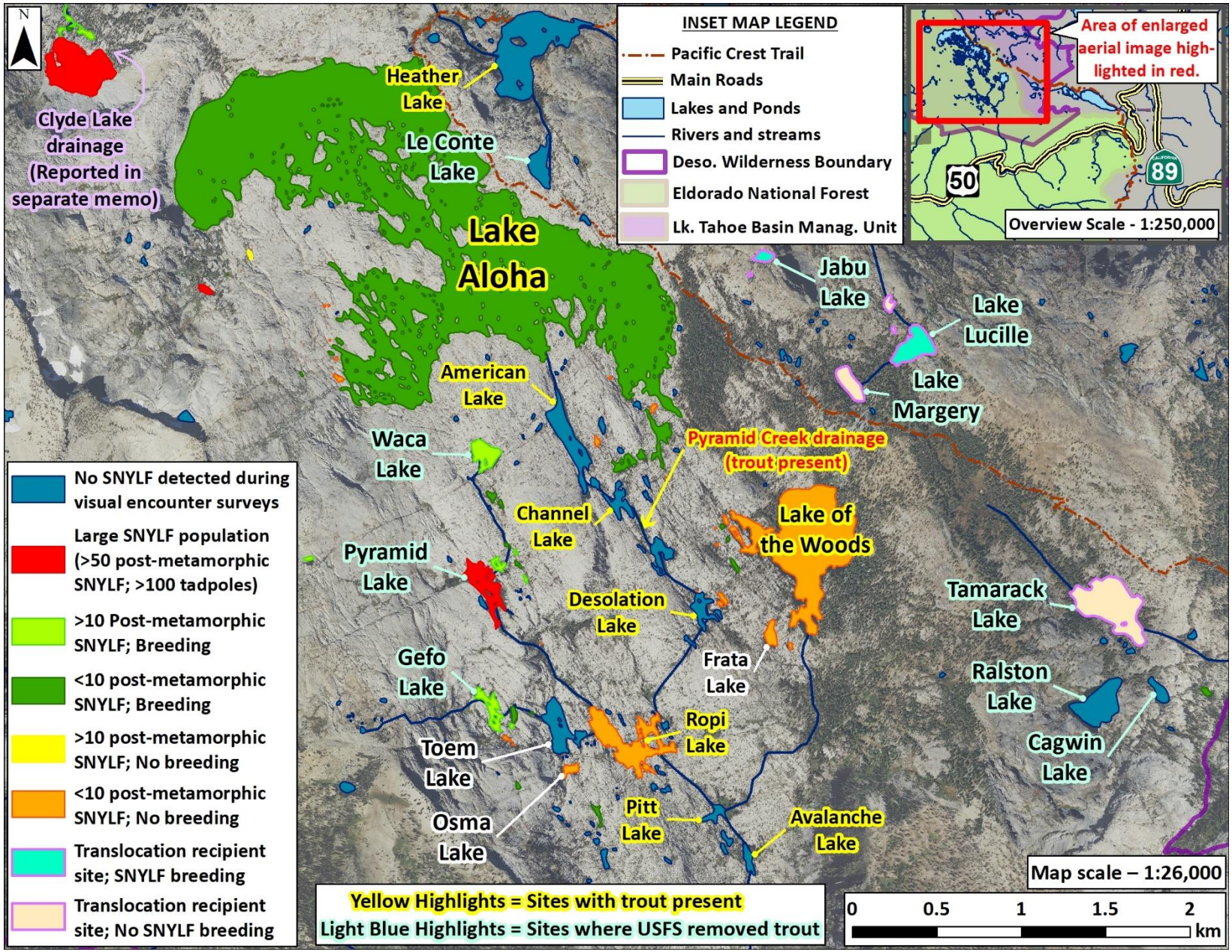


Figure 4. [See figure caption at the beginning of the next page.]

Figure 4 (continued). Summary of historic Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) and trout occupancy in the Desolation Valley area, El Dorado County, CA. Trout populations in Desolation Valley are composed primarily of Brook Trout (*Salvelinus fontinalis*; BK) and, to a lesser extent, Rainbow Trout (*Oncorhynchus mykiss*). Site names with yellow highlights are those in which introduced trout are still present. Although an unmaintained streamflow maintenance dam impedes some fish movement from Ropi Lake, California Department of Fish and Wildlife (CDFW) suspects that Toem Lake may have a small BK population present. However, gill net surveys in 2003 and 2008 resulted in no fish captures (CDFG 2012). Between 2006 and 2012, U.S. Forest Service (USFS) staff from the Lake Tahoe Basin Management Unit (LTBMU) and Eldorado National Forest (ENF) began mechanically removing introduced trout from a subset of waterbodies in the area using monofilament gill nets and backpack electrofishing units. Site names at which USFS (with occasional assistance from CDFW) removed fish are highlighted in light blue. Since 2003, CDFW staff have occasionally surveyed the Desolation Valley area and observed a robust SNYLF metapopulation, the largest subpopulations of which are found in fishless habitat at the western edge of the basin. The map displays sites where CDFW staff have observed SNYLF at least once during the period between 2003 and 2021. Symbology is further broken down to designate sites where staff have observed 1) SNYLF breeding (recent metamorphs, tadpoles, or egg masses detected), 2) a small number of post-metamorphic SNYLF (<10 during any one survey), and 3) a larger number of post-metamorphic SNYLF (>10 during any one survey). Sites with the largest subpopulations (>50 post-metamorphic SNYLF and >100 tadpoles detected during any single survey) are displayed in red. The map also displays translocation recipient sites, all of which are located on LTBMU land, and whether CDFW has observed evidence of SNYLF breeding at those sites in 2020 or 2021. The donor subpopulations are those SNYLF sites with the largest number of post-metamorphic detections on the western side of Desolation Valley, which is managed by ENF. Given the large extent of sites in Desolation Valley, SNYLF detections in the Clyde Lake drainage appear on this map. However, Clyde Lake is in a completely separate drainage, which flows north and forms the headwaters of the Rubicon River. Therefore, the Clyde Lake drainage SNYLF population is detailed in a separate memorandum (CDFW 2022).

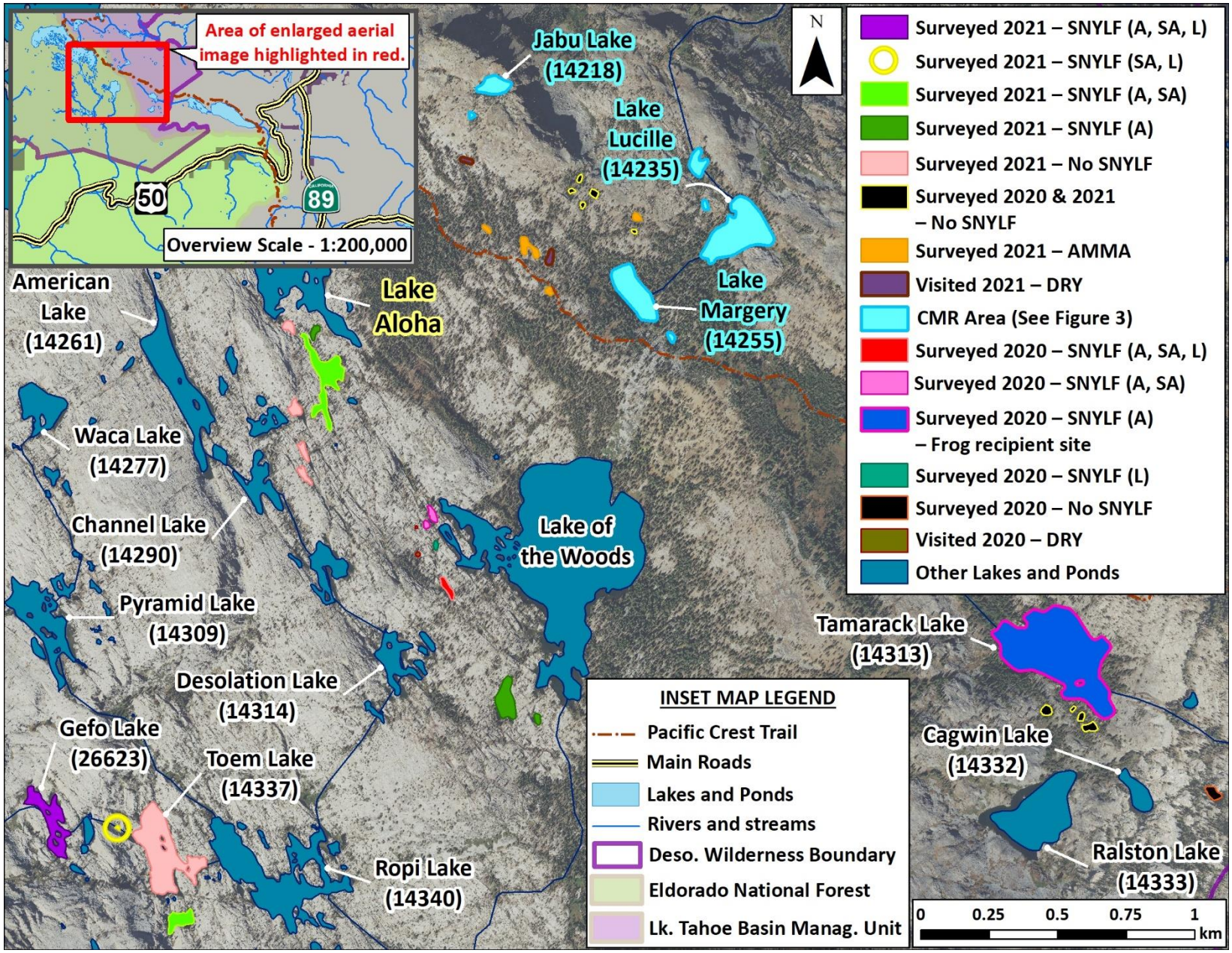


Figure 5. [See figure caption at the beginning of the next page.]

Figure 5 (continued). Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) detections during visual encounter surveys (VES) in the Desolation Valley area (El Dorado County, CA) by CDFW staff in 2020 and 2021. Observed SNYLF life stages are denoted by letter codes in the legend: "A" = adults, "SA" = subadults, and "L" = larvae. VES were limited due to time restrictions from also conducting capture-mark-recapture (CMR) in the Jabu and Lucille Lake areas. However, CDFW plans to return to the Desolation Valley area for additional amphibian surveys beginning in summer 2022. Planned surveys will include Pyramid Valley (including Waca and Pyramid Lakes), Lake Aloha, and other sites at the western edge of Desolation Valley. Waters in Desolation Valley drain south, via Pyramid Creek, into the South Fork American River. Jabu, Lucille, and Margery Lakes drain north into the Glen Alpine drainage, which flows into Fallen Leaf Lake and then Lake Tahoe. Tamarack, Cagwin, and Ralston Lakes drain east into Echo Lakes, which flow into the Upper Truckee River and then into Lake Tahoe. Displayed five-digit numbers are Site IDs, which CDFW uses to partition waterbodies for data collection.

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., 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., L. Wilkinson, K.K. Wilkinson, T. Tunstall, R. Foote, B.D. Todd, and V. Vredenburg. 2019. Demography, habitat, and movements of the Sierra Nevada Yellow-legged Frog (*Rana sierrae*) in steams. Copeia 107:661–675. Available from: http://toddlab.ucdavis.edu/publications/brown%20et%20al.%202019.pdf

California Department of Fish and Game (CDFG). 2012. Aquatic Biodiversity Management Plan for the Desolation Wilderness Management Unit. Available from: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=59961

California Department of Fish and Wildlife (CDFW). 2020. Amphibian monitoring in Tahoe National Forest, Nevada County; *Rana sierrae* monitoring in the Mossy Pond area; *Rana sierrae* monitoring in the Rattlesnake Creek area. Available from: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=179239

California Department of Fish and Wildlife (CDFW). 2022. Native amphibian monitoring in Desolation Wilderness; Rana sierrae monitoring in the Clyde Lake drainage: 2021 update. Available from: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=199309

Coats, R., J. Lewis, and G. Schladow. 2021. Projected climate change impacts in the Tahoe Basin: recent findings from global climate models. Quaternary International; *In Press* (Corrected Proof). Available from: https://tahoe.ucdavis.edu/sites/g/files/dgvnsk4286/files/inline-files/Projected-climate-change-impacts-in-the-Tahoe-Basin--Rec_2021_Quaternary-Int.pdf

Dettinger, M., H. Alpert, J. Battles, J. Kusel, H. Safford, D. Fougeres, C. Knight, L. Miller, and S. Sawyer. 2018. Sierra Nevada Summary Report. California's Fourth Climate Change Assessment. Publication number: SUM-CCCA4-2018-004. Available from: https://www.energy.ca.gov/sites/default/files/2019-11/Reg_Report-SUM-CCCA4-2018-004_SierraNevada_ADA.pdf

Dill, W.A., and A.J. Cordone. 1997. History and status of introduced fishes in California, 1871–1996. CA Department of Fish and Game, Fish Bulletin 178. Available from: https://escholarship.org/uc/item/5rm0h8qg

Fellers, G.M., D.F. Bradford, D. Platt, 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.

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

Keung, N.C., S.P. Lawler, S.M. Yarnell, B.D. Todd, and C. Brown. 2021. Movement ecology study of stream-dwelling Sierra Nevada Yellow-legged Frogs (*Rana sierrae*) to inform reintroductions. Herpetological Conservation and Biology 16:72–85. Available from: http://www.herpconbio.org/Volume_16/Issue_1/Keung_etal_2001.pdf

Lambert, M.R., M.C. Womack, A.Q. Byrne, O. Hernández-Gómez, C.F. Noss, A.P. Rothstein, D.C. Blackburn, J.P. Collins, M.L. Crump, M.S. Koo, P. Nanjappa, L. Rollins-Smith, V.T. Vredenburg, and E.B. Rosenblum. 2020. Comment on "Amphibian fungal panzootic causes catastrophic and ongoing loss of biodiversity." Science 367:aay1838. Available from: https://www.science.org/doi/epdf/10.1126/science.aay1838

Leitritz, E. 1970. A history of California's fish hatcheries, 1870–1960. CA Department of Fish and Game, Fish Bulletin 150. Available from: https://escholarship.org/uc/item/2z8648k3

Matthews, K.R. and H.K. Preisler. 2010. Site fidelity of the declining amphibian *Rana sierrae* (Sierra Nevada Yellow-legged Frog). Canadian Journal of Fisheries and Aquatic Sciences 67:243–255. Available from: https://www.fs.fed.us/psw/publications/matthews/psw_2010_matthews001.pdf

McAllister, K.R., J.W. Watson, K. Risenhoover, and T. McBride. 2004. Marking and radiotelemetry of Oregon spotted frogs (*Rana pretiosa*). Northwestern Naturalist 85:20–25. Available from: https://www.jstor.org/stable/pdf/3536474.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

Pister, E.P. 2001. Wilderness fish stocking: history and perspective. Ecosystems 4:279–286. Available from: https://www.jstor.org/stable/pdf/3658925.pdf

Pollock, K.H. 1982. A capture-recapture design robust to unequal probability of capture. Journal of Wildlife Management 46:752–757. Available from: https://www.jstor.org/stable/pdf/3808568.pdf

Pope, K.L. and K.R. Matthews. 2001. Movement ecology and seasonal distribution of Mountain Yellow-legged Frogs, *Rana muscosa*, in a high-elevation Sierra Nevada basin. Copeia 2001:787–793. Available from: https://www.fs.fed.us/psw/publications/documents/other/KM_copeia.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

Rosenblum, E.B., J. Voyles, T.J. Poorten, and J.E. Stajich. 2010. The deadly chytrid fungus: a story of an emerging pathogen. PLoS Pathogens 6:e1000550. Available from: https://journals.plos.org/plospathogens/article/file?id=10.1371/journal.ppat.1000550&type=printable

Skerratt, L.F., L. Berger, R. Speare, S. Cashins, K.R. McDonald, A.D. Phillott, H.B. Hines, and N. Kenyon. 2007. Spread of chytridiomycosis has caused the rapid global decline and extinction of frogs. EcoHealth 4:125–134. Available from: https://link.springer.com/content/pdf/10.1007/s10393-007-0093-5.pdf

Sun, F., N. Berg, A. Hall, M. Schwartz, and D. Walton. 2019. Understanding end-of-century snowpack changes over California's Sierra Nevada. Geophysical Research Letters 46:933–943. Available from: https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018GL080362

U.S. Department of Agriculture (USDA). 1998. Desolation Wilderness Management Guidelines – Land Management Plan Amendment. Available from: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd528601.pdf

U.S. Forest Service (USFS). 2011. Sierra Nevada Yellow-legged Frog habitat restoration project in the Desolation Wilderness. 2011 Annual Report. USFS Lake Tahoe Basin Management Unit. Available from: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5363180.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 107:9689–9694. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2906868/pdf/pnas.200914111.pdf

Williams, B.K., J.D. Nichols, and M.J. Conroy. 2001. Combining closed and open mark-recapture models: the robust design. Chapter 19 *In* Analysis and management of animal populations. Academic Press, San Diego, CA, USA.

APPENDIX

Below are figures showing waypoints for all PIT-tagged SNYLF detections during CDFW-led CMR surveys in the Jabu and Lucille Lake areas in 2020 and 2021 (**Figures 1A and 2A**). The map legends highlight those SNYLF adults that were captured on more than one CMR trip (i.e., adult frogs caught on more than one primary period). The map also displays waypoints for other adult SNYLF detections (frogs captured only once, or only during a single primary period). However, all such "one-trip" detections are displayed by a white circle with an "x" and, therefore, unique individuals are not distinguishable. All other frogs (those tagged adults captured on more than one primary period) are highlighted in the legend, with every primary period receiving a unique color. For these "multiple-trip" frogs, the map displays a waypoint for every day the frog was detected (i.e., many frogs were captured on more than one day of each CMR trip—that is, unique adult individuals were caught during multiple secondary periods—so many unique shape/color combinations are displayed on the map more than once, which indicates different days of capture). For example, the frog with PIT tag ID ending in 117281 was captured in the western outlet of Lake Lucille on all three secondary periods during the July 2020 primary period (**Figure 1A**). Therefore, the map shows three separate light green squares in the outlet to show the points of detection of all three observations.

Given the small size of some waterbodies and often limited movement of SNYLF within a given season, many of the displayed waypoints are closely clustered together and/or overlapping. Additionally, limited satellite availability, topography, or equipment problems would occasionally result in waypoint precision error, which was particularly significant at small waterbodies such as Site ID 52682 (**Figure 2A**). Therefore, displayed waypoints are not the precise capture location, and often have between four and 12 m of precision error. However, these maps are mainly provided to show a general view of adult SNYLF distribution observed by CDFW staff during CMR in 2020 and 2021.

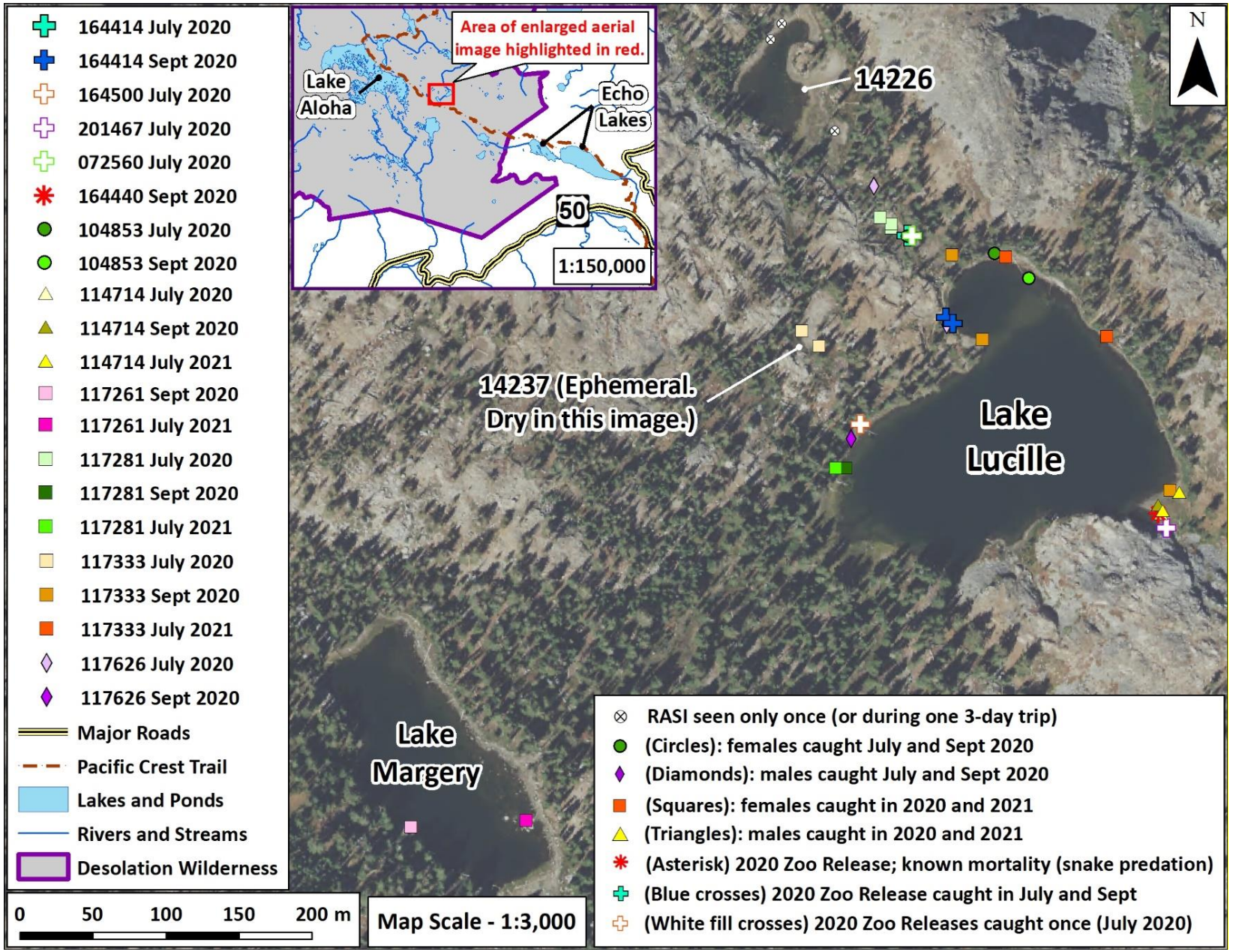


Figure 1A. [See figure caption at the beginning of the next page.]

Figure 1A (continued). Adult Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) capture locations during capture-mark-recapture (CMR) surveys conducted by California Department of Fish and Wildlife (CDFW) staff in the Lake Lucille area of Desolation Wilderness in summers 2020 and 2021. The displayed SNYLF detections only include adults (i.e., those individuals >40 mm snout-to-urostyle length) that received passive integrated transponder (PIT) tags. Those individuals captured on more than one survey trip (known as a "primary period;" which included three consecutive days of surveying the entire area, each day of which is known as a "secondary period") are highlighted in the legend, with the last six digits of the PIT tag identification code displayed, and a unique color for each primary period during which the individual was detected. Circles indicate females caught during the July and September primary periods in 2020 and diamonds indicate males caught during the same periods. Squares indicate females caught during both years of CMR surveys, and triangles indicate males caught during both years. The red asterisk shows the location of a Zoo-reared adults that CDFW staff found preyed on by adult gartersnakes. The cross icons indicate locations of other detections of Zoo-reared frogs released in June 2020.

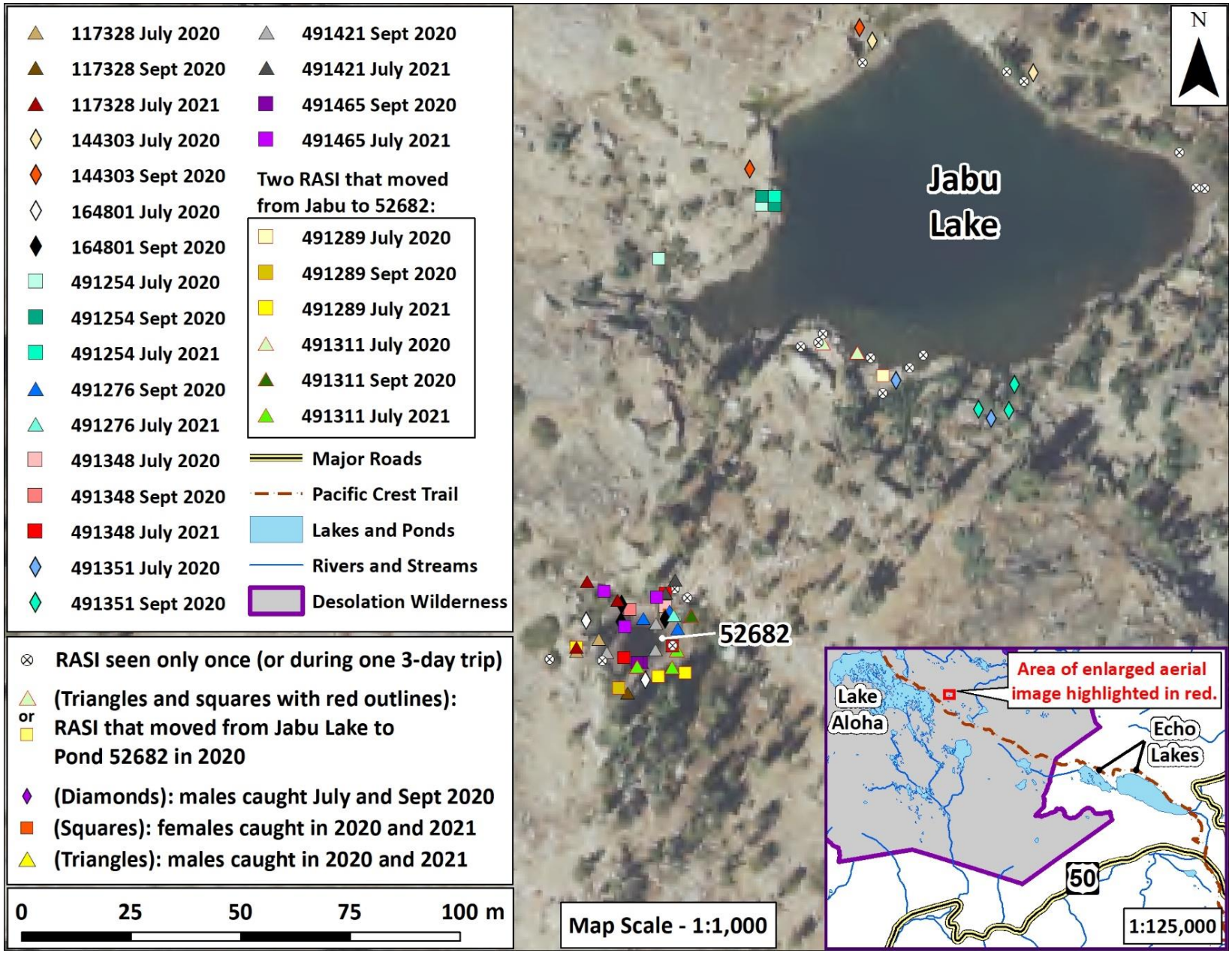


Figure 2A. [See figure caption at the beginning of the next page.]

Figure 2A (continued). Adult Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) capture locations during capture-mark-recapture (CMR) surveys conducted by California Department of Fish and Wildlife (CDFW) staff in the Jabu Lake area of Desolation Wilderness in summers 2020 and 2021. The displayed SNYLF detections only include adults (i.e., those individuals >40 mm snout-to-urostyle length) that received passive integrated transponder (PIT) tags. Those individuals captured on more than one survey trip (known as a "primary period;" which included three consecutive days of surveying the entire area, each day of which is known as a "secondary period") are highlighted in the legend, with the last six digits of the PIT tag identification code displayed, and a unique color for each primary period during which the individual was detected. Diamonds indicate males caught during the July and September primary periods in 2020. Squares indicate females caught during both years of CMR surveys, and triangles indicate males caught during both years. Triangles or squares highlighted in red show two individuals that moved from Jabu Lake to Site ID 52682 between July and September 2020.