State of California
Department of Fish and Wildlife

Memorandum

Date: 22 April 2024

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

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Subject: Native amphibian restoration and monitoring in Desolation Wilderness;

- ***Rana sierrae* monitoring in the Highland Lake drainage: update.**
- ***Rana sierrae* translocation from Highland Lake to 4-Q Lakes: 2018–2023 summary.**

Sierra Nevada Yellow-legged Frog (*Rana sierrae*) basking at the edge of Highland Lake. (CDFW)

SUMMARY
The Highland Lake drainage is an area from which California Department of Fish and Wildlife (CDFW) staff removed Rainbow Trout (*Oncorhynchus mykiss*, RT) from 2012–2015 to benefit Sierra Nevada Yellow-legged Frogs (*Rana sierrae*, SNYLF). Amphibian monitoring data from 2003 through 2023 indicate that the Highland Lake drainage continues to support one of the largest known SNYLF populations in the northern Sierra Nevada.

Since at least 2015, annual visual encounter surveys (VES) have revealed that the Highland Lake drainage contains a sufficient adult SNYLF population to provide a source for translocations to nearby suitable fishless habitats. The Interagency Conservation Strategy for Mountain Yellow-legged Frogs in the Sierra Nevada (hereafter "Strategy"; MYLF ITT 2018) highlights translocations as a principal method for SNYLF recovery. In 2016, CDFW applied for funding through the U.S. Fish and Wildlife Service (USFWS) endangered species recovery grant program (Section 6 of the U.S. Endangered Species Act of 1973) to translocate SNYLF from the Highland Lake drainage to 4-Q Lakes, a nearby fishless drainage, where VES conducted by CDFW in 2003, 2015, and 2018 suggested SNYLF were not present. The grant was awarded by the USFWS in November 2016 (Federal Grant Award #F17AP00001) and allowed staff from CDFW and Eldorado National Forest (ENF) to undertake two translocations from Highland Lake to 4-Q Lakes, one in July 2018 (60 adult frogs) and another in August 2019 (40 adult frogs).

After initial success of the first two translocations—as evidenced by many adults surviving overwinter, rapid growth of recaptured adults, and observations of early life stage SNYLF at 4-Q Lakes in June 2020—CDFW applied for another round of funding through Section 6 to conduct two additional translocations in 2021 and 2022. USFWS awarded the grant in mid-January 2021 (Federal Grant Award #F21AP00483). As a result, in July 2021 and 2022, CDFW and ENF staff biologists translocated an additional 51 and 26 adult SNYLF, respectively. In total, CDFW and ENF staff have translocated 177 adult SNYLF (98 females and 79 males) from the Highland Lake drainage to 4-Q Lakes.

Each year from 2018–2023, CDFW field staff revisited 4-Q Lakes two–three times per summer to monitor the new SNYLF population. During those visits, CDFW has recaptured 86 of the 177 translocated SNYLF (49%) at least once since release at 4-Q Lakes. In 2020, CDFW observed the first signs of SNYLF breeding, including observing a recently hatched egg mass, tadpoles, and subadults. From 2021–2023, CDFW staff observed additional egg masses, tadpoles, subadults, and new young adults, the latter of which were unmarked with passive integrated transponder (PIT) tags and, therefore, born at 4-Q Lakes. In 2023, CDFW staff tagged 20 new young adult SNYLF born at 4-Q Lakes. All recaptured SNYLF originally translocated to 4-Q Lakes from Highland Lake had grown noticeably and appeared healthy. CDFW plans to continue monitoring in the Highland Lake drainage and 4-Q Lakes basin during summer 2024 and beyond.

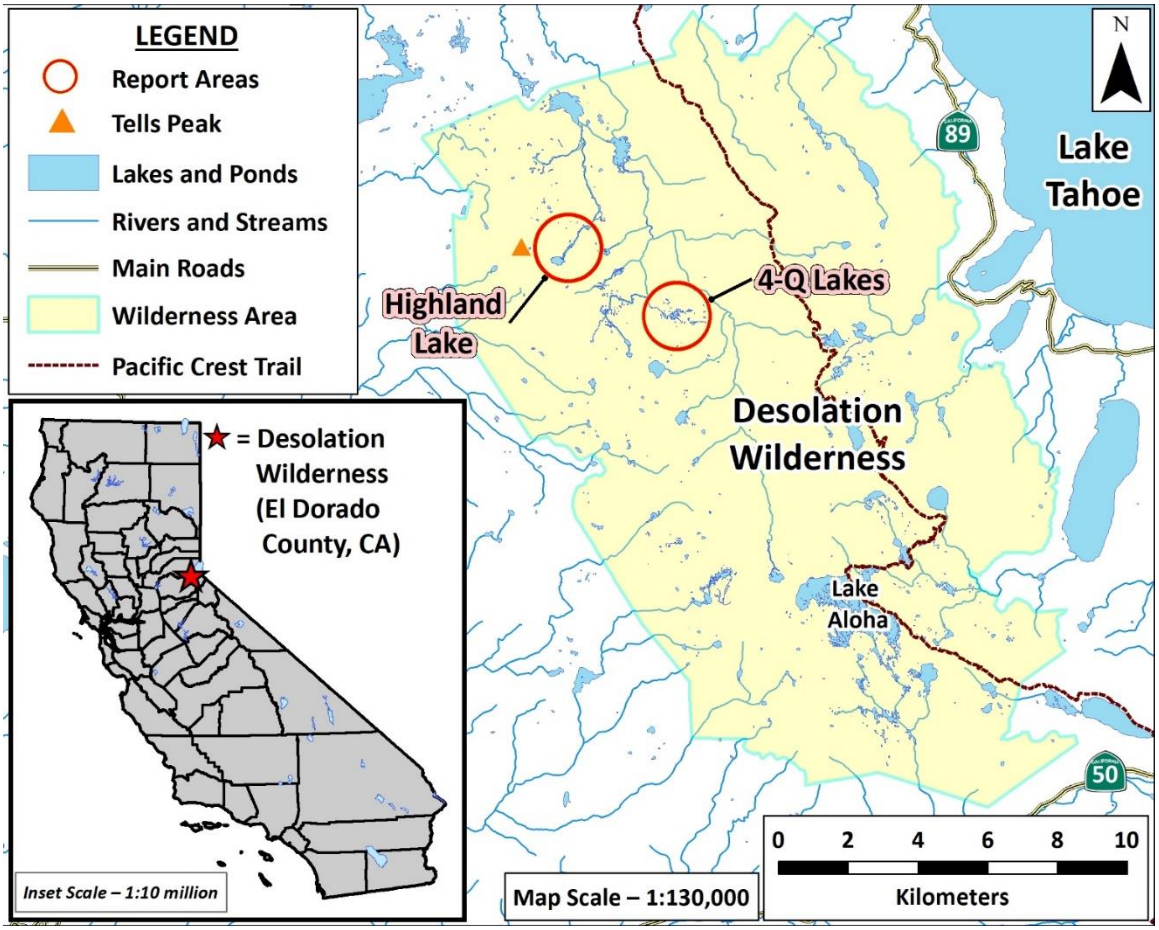


Figure 1. Desolation Wilderness, El Dorado County, CA. The areas discussed in this memorandum are circled.

ENVIRONMENTAL SETTING

Highland Lake and 4-Q Lakes are in Desolation Wilderness, northeast El Dorado County (**Figure 1**). Highland Lake sits in a granite cirque at approximately 7,800 feet in elevation and drains northeast into Rockbound Lake (**Figure 2**). No official trails access Highland Lake, but a use trail from nearby Forni Lake, which proceeds over a saddle just south of Tells Peak, indicates regular visitation by hikers. 4-Q Lakes are located approximately 3.5 km southeast of Highland Lake drainage. 4-Q Lakes sit in a granite basin at approximately 7,500 feet in elevation and drain north into Rubicon Lake. The McConnell Lake Trail provides access to the site from the Leland/McConnell/Horseshoe Lakes drainage (to the west) and Camper Flat (to the east). ENF manages this section of Desolation Wilderness and the surrounding land.

INTRODUCTION

The Aquatic Biodiversity Management Plan (ABMP) for the Desolation Wilderness Management Unit (CDFG 2012) identifies Highland Lake (Site ID 13904; **Figure 2**) and the surrounding habitat, approximately one kilometer (km) of outlet stream (Site IDs 52648, 52649, 52650, 52670, and 52671), and three associated ponds (Site IDs 13892, 13896, and 13903) as a Native Species Reserve (NSR; **Figure 3**) for SNYLF (**Figure 4**).

Figure 2. Highland Lake, center frame, on 16 August 2023, looking east from the saddle south of Tells Peak. Rubicon Reservoir is visible in the distance at left, just above the tip of the tallest conifer in the image foreground. Lake Tahoe is also visible in the far left distance, just below the furthest ridgeline, which is the Carson Range. (CDFW)

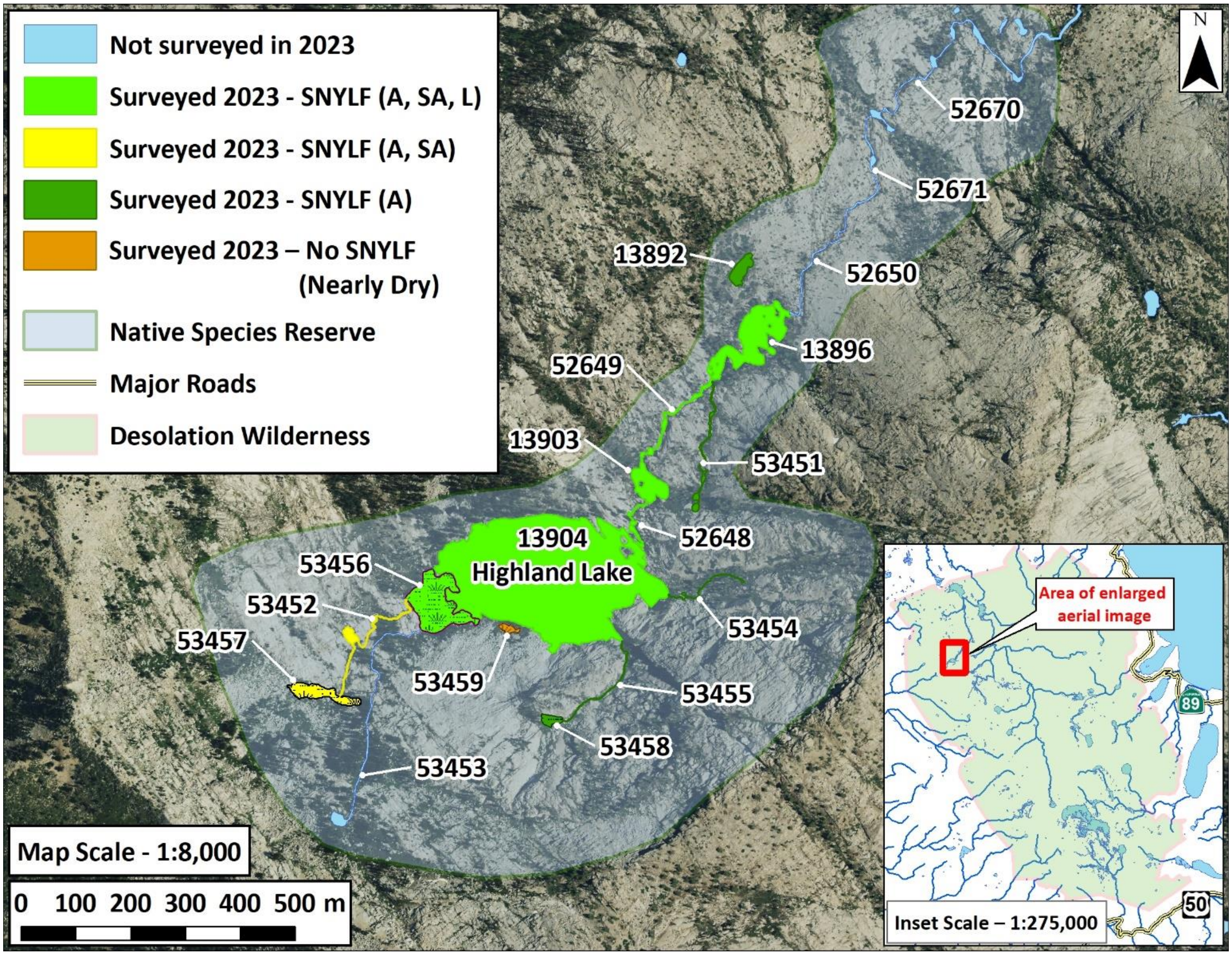


Figure 3. Highland Lake Native Species Reserve (NSR). California Department of Fish and Wildlife (CDFW) staff have observed Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) throughout the drainage. Following surveys in 2022, CDFW added new geographic information system (GIS) site polygons to the drainage to allow for additional spatial detail in presenting survey results. In previous years, CDFW staff surveyed inlets to Highland Lake and associated marsh/meadow habitat. However, these locations were not shown in earlier maps. The addition of new polygons allows more accurate visualization of SNYLF distribution in the Highland Lake area. 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. Number labels shown are unique site identification codes that CDFW uses for data collection. All flowing waters drain northeast into Rockbound Lake.

Figure 4. An adult Sierra Nevada Yellow-legged Frog (*Rana sierrae*) at the edge the Highland Lake on the evening of 15 August 2023. (CDFW)

CDFW stocked Highland Lake with RT from 1935 until 2000. The lake contains limited spawning habitat and RT exhibited little natural reproduction. In 1955, CDFW constructed a stonemasonry streamflow maintenance dam at the outlet (USFS 1955, CDFG 1980). The dam forms an effective barrier to fish moving from the outlet stream into the lake, thereby further reducing spawning potential. In 1993, ENF biologists observed a very small SNYLF population in the Highland Lake outlet stream (USFS 1993). Staff also detected RT in Highland Lake and the outlet stream. Gill net surveys in 2003 and 2010 indicated that RT were persisting at low density in the absence of stocking. In the 2000's, CDFW managers, in partnership with ENF, determined that eradicating the low-density RT population using gill nets and backpack electrofishers would be feasible, and provide an opportunity to recover the SNYLF population in the Highland Lake drainage (CDFG 2012). As a result, in 2012, CDFW and ENF personnel began removing RT from Highland Lake NSR to benefit SNYLF. In 2017, CDFW and ENF determined that the NSR was fishless, following two years without any fish captures or observations. Although field staff have not seen or captured any fish since 2015, CDFW will continue monitoring the site for presence of any latent non-native trout. Those interested in learning more details about fish removal in the Highland Lake drainage may consult the **2017 Highland Lake survey memorandum** (CDFW 2018).

Now that fish removal is complete in the Highland Lake drainage, the SNYLF population has grown substantially, from only a handful of post-metamorphic frog detections in the 1990's, to an average of 475 adults, 288 subadults, and 1,058 larvae detected during VES from 2014 to 2023 (**Figures 5 and 6**). The large SNYLF population allows for translocating a subset of adult frogs to establish new SNYLF populations nearby. The Desolation Wilderness ABMP identifies 4-Q Lakes (located 3.5 km to the southeast; **Figure 1**) as a site to receive SNYLF translocated from the Highland Lake drainage (CDFG 2012). 4-Q Lakes provide an interconnected, fishless aquatic basin that may provide the foundation for establishing another healthy SNYLF population in the Upper Rubicon drainage.

From at least 1931 until 2000, CDFW regularly stocked the three largest 4-Q Lakes with Brook Trout (*Salvelinus fontinalis*; BK). During overnight gill net surveys in 2003, CDFW field staff captured six BK in the basin. However, subsequent gill net surveys in 2010 (one-night net set) and 2016 (one-month net set) returned zero fish, confirming that BK were not self-sustaining and the lakes were fishless.

In addition to gill net surveys, CDFW completed VES of the entire 4-Q Lakes basin to check for potential occupancy by fish, SNYLF, or other special status herpetofauna. VES conducted by CDFW in 2003, 2015, and 2018 resulted in no SNYLF observations, although field staff did observe other amphibian and reptile species. Therefore, CDFW and ENF personnel had not observed SNYLF in 4-Q Lakes basin during any surveys prior to translocations in 2018. Given the habitat composition and relative nearness of extant populations, SNYLF likely occupied 4-Q Lakes before fish stocking began in 1931. However, CDFW is not aware of any museum or earlier survey records to confirm former SNYLF occupancy in 4-Q Lakes basin.

THREATS

Disease

All SNYLF populations in El Dorado County are positive for chytrid fungus (*Batrachochytrium dendrobatidis*; *Bd*). CDFW sampled Site IDs 13903 and 13896 in 2009 and 2010 using epithelial swabs and had the swabs screened for the presence of *Bd* DNA using real-time quantitative polymerase chain reaction (qPCR) analysis. Staff collected eight swabs and results from both years detected very light to moderate *Bd* infection intensity. In 2019, CDFW staff collected an additional 26 SNYLF epithelial swabs at Highland Lake (Site ID 13904). In fall 2020, 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 either no *Bd* (n = 6), or very light (n = 8), light (n = 9), to moderate infection (n = 3). These designations of infection intensity are subjective; however, no swabs collected from SNYLF at Highland Lake in 2019 had high *Bd* loads (i.e., *Bd* loads high enough to suspect increased likelihood of mortality from severe chytridiomycosis).

Loss of Genetic Diversity

VES data suggest that the Highland Lake drainage SNYLF population was very small and only recently expanded. This potential population bottleneck may have resulted in negative genetic consequences for the population, including loss of genetic diversity, inbreeding depression, and fixation of deleterious alleles (Frankham et al. 2009). However, the true size of the Highland Lake drainage population, during the time-period when it was smallest, is unknown. Population genetic analyses are necessary to estimate the level of inbreeding, effective population size, and degree of genetic bottlenecking, if any.

Isolation

Geographic isolation can limit potential for gene flow between populations and increases risk of local extirpation. Isolated populations and small populations can suffer from similar negative genetic effects. Fortunately, the Highland Lake drainage population is not completely isolated. There are a few SNYLF populations relatively close to Highland Lake (including Lake Zitella, McConnell Lake, and Leland Lakes). Lake Zitella is the only location SNYLF could conceivably immigrate from in the near term, but the other populations are close enough to allow for rare instances of gene flow. This arrangement contrasts with SNYLF populations at the northern extent of the species' range, most of which are greatly isolated from one another.

Introduced Fish

Highland Lake, its outlet, and two small ponds along the outlet stream formerly supported a small RT population. The main lakes in 4-Q Lakes basin also formerly contained BK, although the populations were not self-sustaining. Trout prey on SNYLF and are a potential source of competition for food (e.g., benthic macroinvertebrates). Additionally, RT may have been limiting successful SNYLF breeding and recruitment in Highland Lake and the ponds below, which supply the only deep-water habitat in the basin. In the absence of stocking, RT abundance declined, but sufficient natural reproduction was occurring in the inlet to Highland Lake and the upper segment of outlet stream to sustain a small trout population. Barriers to upstream fish movement (e.g., the Highland Lake dam and natural waterfalls) impeded or excluded trout living in stream segments and ponds from moving into Highland Lake. Trout are still present below the natural barrier that demarcates the downstream end of the NSR. Illegal movement of trout into the stream channel above the barrier, the NSR ponds, or Highland Lake presents a potential extirpation risk for SNYLF. However, CDFW has mitigated the immediate threat from trout predation through fish removal efforts.

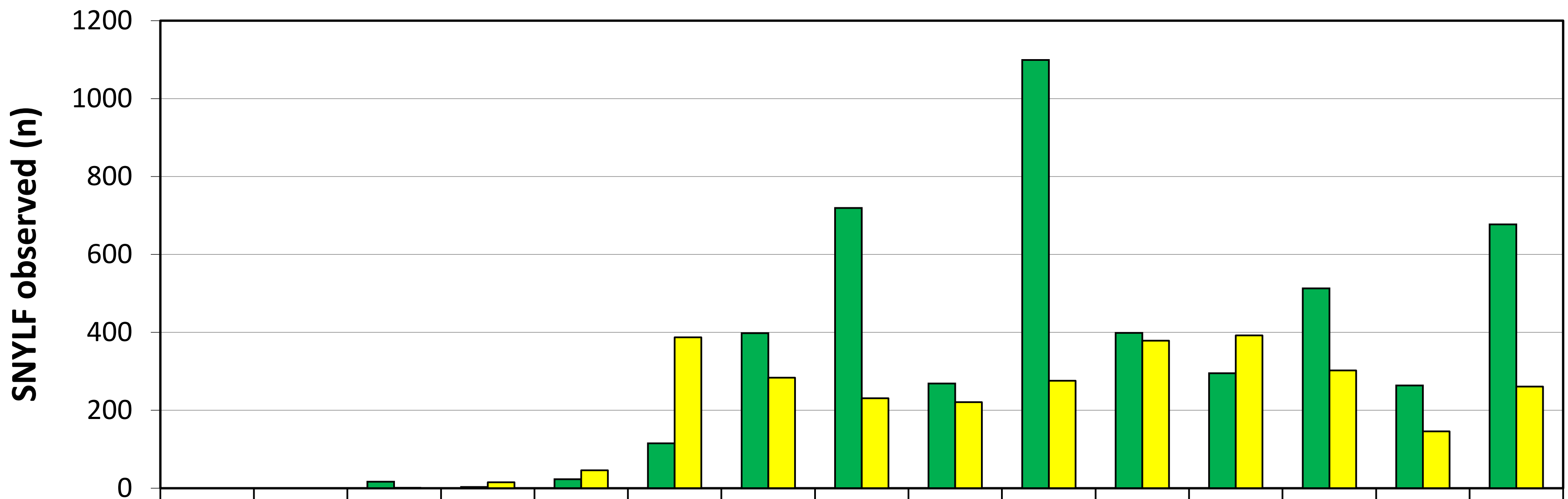
HIGHLAND LAKE DRAINAGE SNYLF POPULATION STATUS: RESULTS

Although CDFW did not detect SNYLF in the Highland Lake drainage prior to 2008, ENF staff have been monitoring this population since 1993 (USFS 1993). VES data between 2013 and 2023 confirm that the population has increased dramatically when compared with survey results prior to 2014 (**Figures 5 and 6**). As the RT population declined, CDFW staff observed SNYLF moving into previously unoccupied microhabitats. Notably, as the RT population diminished, staff observed a large increase in tadpoles, particularly at Highland Lake, suggesting SNYLF had begun to successfully utilize additional breeding habitats.

For a detailed summary of VES results from 2014 to 2022, see the Highland Lake drainage results section from **the previous memorandum**, which provides an update on Highland Lake survey results through 2022 (CDFW 2023). What follows is a brief recap of results from 2014–2023, followed by more detailed discussion of survey results in 2023.

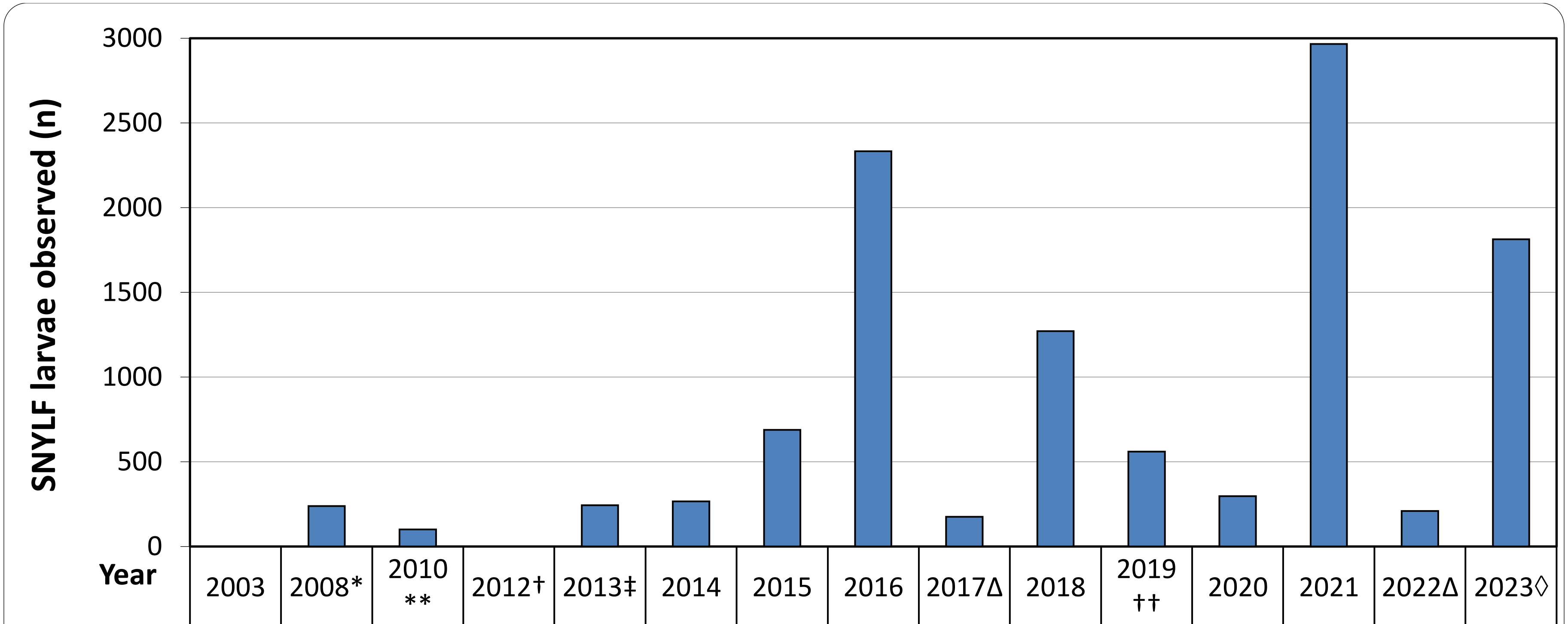
Each summer from 2014 to 2023, CDFW staff have surveyed the entire Highland Lake drainage at least once per season, including Highland Lake, inlets to the main lake, the Highland Lake outlet stream (which includes two stream-widening ponds), and adjacent wetted habitat (**Figure 3**). The only minor exceptions to survey coverage occurred in 2017, when staff did not survey Site ID 13892; 2019, when staff did not survey the furthest downstream section of the Highland Lake outlet within the NSR (Site IDs 52670 and 52671; **Figure 3**); and 2023, when staff did not survey the stream segments below Site ID 13896; **Figure 3**). During the period 2014–2023, post-metamorphic SNYLF detections have varied, but staff have detected at least several hundred post-metamorphic SNYLF each season (**Figure 5**). During the same period, larval SNYLF observations have been more variable, with staff detecting anywhere from approximately 200 to nearly 3,000 tadpoles (**Figure 6**).

CDFW will continue monitoring to assess the long-term status of the Highland Lake drainage SNYLF population. During the next several years, CDFW will monitor the Highland Lake drainage at least once each summer. CDFW staff will also survey 4-Q Lakes, the translocation recipient site, to monitor the status of the translocated SNYLF population.



Year	2003	2008*	2010 **	2012†	2013‡	2014	2015	2016	2017Δ	2018	2019 ††	2020	2021	2022Δ	2023◊
Adult	0	0	17	3	23	115	398	719	269	1099	399	295	513	264	677
Subadult	0	0	1	15	46	387	284	231	221	276	379	392	302	146	261

Figure 5. Number of adult and subadult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) detected during visual encounter surveys (VES) in the Highland Lake drainage between 2003 and 2023. From 2014–2018, and 2020–2022, surveys occurred throughout the entire drainage, including Highland Lake, the outlet stream, and the two downstream ponds.
*2008 surveys only included Highland Lake and the larger downstream pond (Site ID 13896).
**Surveys in 2010 only included the two stream ponds (Site IDs 13896 and 13903).
†CDFW did not conduct formal surveys in 2012 (staff only noted anecdotal observations during gill net setting).
‡Surveys in 2013 only include Highland Lake and the two downstream ponds.
†† CDFW did not survey Site IDs 52670 and 52671 in 2019.
ΔIn 2017 and 2022, weather conditions were cold and windy in the Highland Lake drainage. See CDFW (2023) for details.
◊In 2023, due to time constraints and weather conditions, CDFW did not survey the Site IDs downstream of 13896 (Site IDs 52650, 52670, and 52671).



Year	2003	2008*	2010 **	2012†	2013‡	2014	2015	2016	2017Δ	2018	2019 ††	2020	2021	2022Δ	2023◊
Larva	0	239	101	0	244	267	689	2333	176	1272	560	297	2967	209	1814

Figure 6. Number of larval Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) detected during visual encounter surveys (VES) in the Highland Lake drainage between 2003 and 2023. (See **Figure 5** for caveats about surveys.) Steady winds and occasional strong gusts during the Highland Lake survey on 10 September 2017, 7 August 2019, 11 August 2020, and 6 July 2022 made visibility into the lake difficult, which may account for the low larval SNYLF observations when compared with other recent survey years.

HIGHLAND LAKE DRAINAGE SNYLF POPULATION STATUS: DISCUSSION

As part of a larger project to inventory fish and native amphibians throughout the Sierra Nevada (CDFG 2012), fish stocking at Highland Lake ceased in 2000. The decision to manage the watershed for native species, rather than fish, occurred years before active fish removal began. Based on the small number of RT captured during active removal, the fish population had declined soon after CDFW stopped aerial plants at Highland Lake. Therefore, the SNYLF population increase may be partly attributable to the decrease in fish numbers in the absence of stocking. A decline in the RT population allowed SNYLF to begin breeding and feeding with less interference from an efficient aquatic predator. The observation of larval SNYLF in Highland Lake in 2008—four years before active fish removal began—supports this idea.

SNYLF benefitted from reduced fish densities in the watershed, but the subsequent population increase in a *Bd*-positive environment was initially uncertain, given the high variability in *Bd*-positive SNYLF population dynamics (Briggs et al. 2010). However, recent SNYLF population monitoring in other areas of the Sierra Nevada suggests that *Bd*-positive SNYLF populations can rebound in the absence of other stressors, such as trout (Knapp et al. 2016). In addition to fish removal, other environmental factors may have helped the SNYLF population rebound, including short winters, increased temperatures, and increased food availability during the 2012–2015 and 2020–2022 drought periods. Regardless, monitoring efforts over a 20-year period demonstrate that the SNYLF population in the Highland Lake watershed has made a dramatic comeback since management in the area switched from a focus on non-native trout stocking to a focus on restoring habitat for native amphibians.

In 2023, CDFW observed the third highest count of post-metamorphic and larval SNYLF during the 2003–2023 survey record (**Figures 5 and 6**). These totals occurred despite limited available survey time due to weather conditions, which resulted in staff being unable to survey the lower section of stream below Site ID 13896, which CDFW typically surveys annually. When staff hiked into the basin on 14 August 2023, strong thunderstorms had developed, resulting in heavy rain and hail during early afternoon. The stormy conditions persisted through the afternoon, but cleared later that evening. Staff conducted VES the following morning under favorable survey conditions, with clear skies, light wind, and warm air temperatures. However, storms built again, and weather conditions became less favorable by early afternoon. This second round of thunderstorms resulted in the need to postpone surveys for several hours on the afternoon of 15 August. Following the storm, staff conducted some additional surveying in late afternoon; however, conditions were less favorable, with cooler air temperatures and skies still overcast. Staff departed the basin the following morning.

Survey conditions may be one of the most important factors explaining differences in SNYLF detections in the Highland Lake drainage. Similar to some other high alpine sites in Desolation Wilderness, numerous visits by CDFW over the past approximately 20 years suggest that Highland Lake basin is prone to periods of strong winds. These windy conditions greatly limit visibility through the water for observing tadpoles or detecting post-metamorphic frogs resting on lake and stream bottoms. Additionally, high winds and frequent gusts appear to reduce basking behavior of post-metamorphic SNYLF, when compared with calmer conditions (I. Chellman, pers. obs.; M. Lockhart, pers. comm.). Frogs may be more likely to seek refuge underwater and beneath lakeside cover objects during cooler and windier periods. Winds were stronger during VES in 2017, 2019, 2020, and 2022, all years during which CDFW staff detected fewer SNYLF tadpoles. By comparison, less wind occurred during CDFW surveys at Highland Lake in 2016, 2018, 2021, and 2023, all years during which staff detected more tadpoles and basking SNYLF (**Figure 7**).

Figure 7. Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) basking on granite at the edge of Highland Lake on the morning of 15 August 2023. (CDFW)

In discussing past results, CDFW brought up the topic of harsh winter conditions and the effect those conditions may occasionally have on SNYLF populations (CDFW 2023), since poor SNYLF survivorship can occur during long, harsh winters (Bradford 1983). Thankfully, the above average northern Sierra Nevada snowpack in winter 2022–2023 (when the April 1st northern Sierra Nevada snow water content reached approximately 200% of the 30-year average; CDEC 2024b) did not appear to significantly impact the SNYLF population in the Highland Lake drainage, at least in terms of detection rates during surveys in August 2023.

Overall, VES results can be difficult to compare, due to numerous factors, including weather conditions, time of year, and observer bias (Mazerolle et al. 2007). A particularly instructive example occurred in summer 2016, during which CDFW conducted three separate surveys of the Highland Lake drainage, in June, August, and September. When compared with other recent years, the June and September 2016 surveys at Highland Lake resulted in relatively few SNYLF detections (82 frogs and 13 larvae, then 130 frogs and 1 larva, respectively). These detection rates were comparable to observations at Highland Lake in September 2017 (102 frogs and 32 larvae). However, the August 2016 survey of Highland Lake resulted in dramatically higher SNYLF detections (693 frogs, 2,008 larvae). The higher SNYLF detections in August may have resulted from excellent survey conditions, coincidental timing with the height of summer SNYLF activity in the basin, more attentive surveying, or a combination of factors. These results help emphasize that VES are a helpful measure for quickly and cost-effectively determining general population status of SNYLF, but proper interpretation of the results requires consideration of the assumptions inherent with VES (Heyer et al. 1994).

In 2024, CDFW plans to survey the entire Highland Lake drainage (i.e., all areas within the NSR shown in **Figure 3**). Additionally, if time and weather conditions allow, CDFW will survey further downstream of previously monitored portions of the Highland Lake outlet stream, to determine if there may be resident SNYLF occurring farther down the drainage. CDFW plans to attempt surveying the basin during calm and warm conditions, given the better odds of such conditions allowing staff to obtain a more accurate estimate of relative SNYLF abundance in the basin.

SNYLF TRANSLOCATION

For complete details about the translocations of SNYLF from Highland Lake to 4-Q Lakes in 2018 and 2019, including background on the translocation recipient site, consult the **survey memo for the 2019 Highland-4-Q Lakes VES and translocation** (CDFW 2020). Additionally, details on the 2021 and 2022 translocations, including methods and photographs, were included in **the 2022 update for Highland and 4-Q Lakes** (CDFW 2022) and **last year's update** (CDFW 2023). Below is a brief summary of the previous translocation efforts, followed by detailed discussion of follow-up surveys at 4-Q Lakes in 2023.

Translocation Summary

CDFW has thus far conducted four translocations of adult SNYLF from Highland Lake to 4-Q Lakes (**Figure 8**). The first, in July 2018, involved moving 60 adults (26 males and 34 females); the second, in August 2019, involved moving 40 adults (18 males and 22 females); the third, in July 2021, involved moving 51 adults (28 females and 23 males); and the fourth, in July 2022, involved moving 26 adults (14 females and 12 males). In total, CDFW and ENF staff have translocated 177 adult SNYLF (98 females and 79 males) from the Highland Lake drainage to 4-Q Lakes. During each translocation, staff intentionally collected a female-biased sample to attempt increasing the odds of successful reproduction at the recipient site.

Before each translocation, CDFW and ENF field staff conducted VES of the entire upper Highland Lake drainage to determine the current relative abundance of the SNYLF population (described in detail in the HIGHLAND LAKE DRAINAGE SNYLF POPULATION STATUS: RESULTS and DISCUSSION sections above). In general, the interagency technical team recommends removing no more than 10% of observed adults at the source population per year (MYLF ITT 2018, Attachment 3). Given high reproductive potential and the inability to detect all individuals during VES, the 10% threshold is highly conservative (MYLF ITT 2018, Attachment 3). Therefore, if field staff observed fewer than 200 adult SNYLF in the Highland Lake drainage, less than 20 adults could be collected for the translocation. Given the time, effort, and coordination needed to accomplish these actions, CDFW managers have decided that it may not be worthwhile to undertake a translocation with fewer than 20 adult SNYLF. Conversely, to allow for adequate time for capture, processing, and moving in the same day, CDFW decided to collect a maximum of 60 adult SNYLF per translocation action.

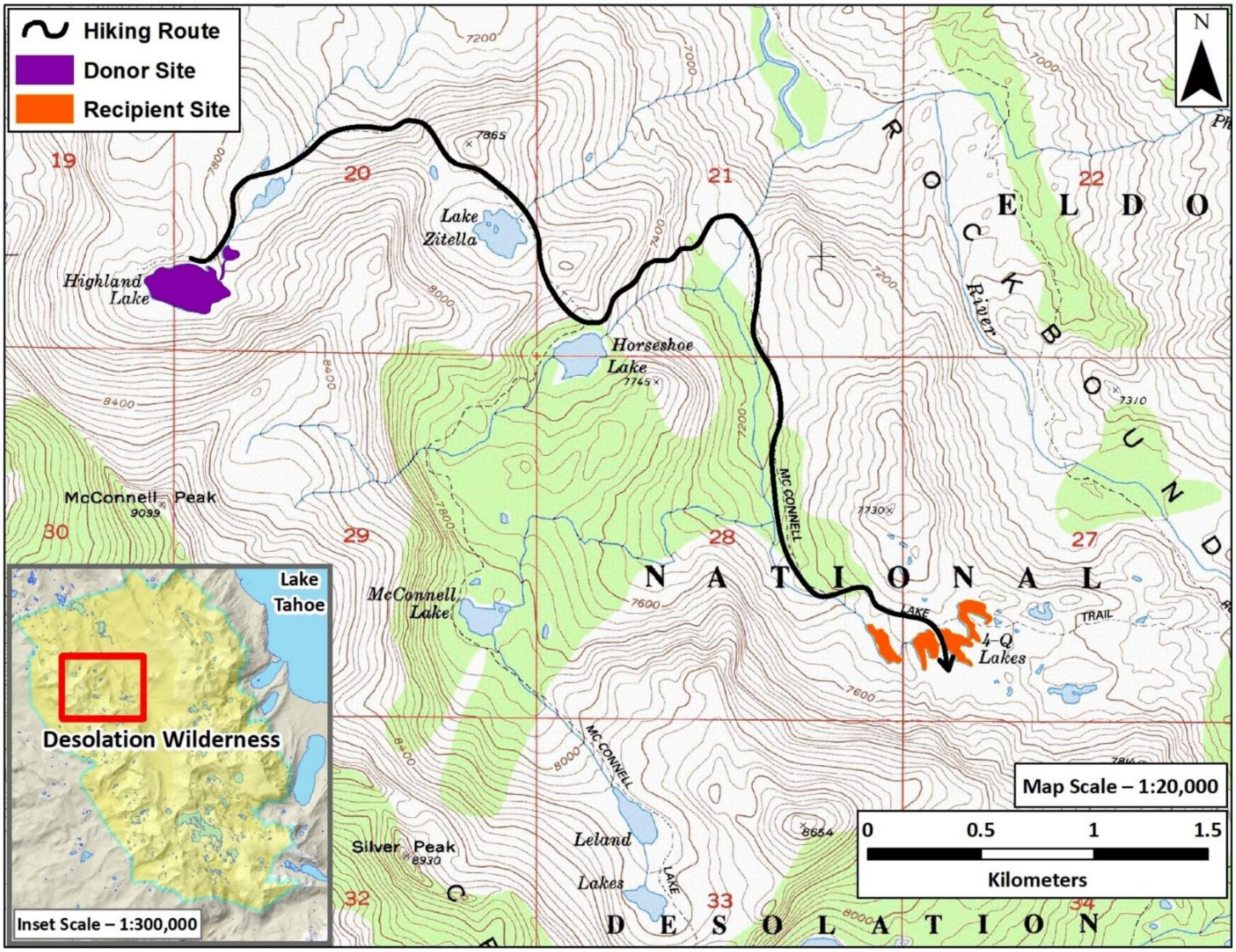


Figure 8. Path of travel for the Sierra Nevada Yellow-legged Frog (*Rana sierrae*) translocations from Highland Lake (donor site) to 4-Q Lakes (recipient site). Travel distance between the two sites via the route shown is approximately 6 kilometers (3.7 miles). The hike takes about two hours to complete.

Follow-up Surveys

During each summer from 2018–2023, CDFW staff conducted post-translocation surveys to assess if the frogs: 1) had moved from the original release sites, 2) appeared in good health, 3) were behaving normally, and 4) had successfully reproduced. In addition to the translocations, CDFW revisited 4-Q Lakes two or three times during each year, 2018–2023 (**Table 1**).

In 2023, CDFW surveyed 4-Q Lakes basin on 26 July, and 19–20 September. During each visit, staff surveyed the main 4-Q Lakes, an assortment of nearby ponds that retained water, and the outlet stream (see **Figure 9** for specific survey locations by date).

In July 2023, available survey time was limited, so only one CDFW staff member was present in the basin for one day. However, despite the brief survey duration, staff surveyed the primary (largest) lakes, plus several additional ponds (**Figure 9**). Additionally, staff surveyed the 4-Q Lakes outlet stream down to the confluence with the outlet of Site ID 52692 (**Figure 9**).

CDFW staff observed 22 adult SNYLF individuals in late July (six males and six females, plus 10 additional young adult frogs on which sex could not yet be definitively determined), and 15 adult SNYLF individuals in September (two males and thirteen females; **Table 1**). Of the 22 SNYLF adults observed in July, seven were recaptured in September. Among all adult SNYLF captures in 2023, 20 individuals were young adults originally born at 4-Q Lakes that staff newly captured and PIT-tagged (15 tagged in July, and five tagged in September). Combining both surveys in 2023, CDFW observed 30 SNYLF individuals (8 males, 15 females, and seven on which sex could not yet be definitively determined; for clarification, three of the original 10 frogs on which sex could not be determined in July were recaptured in September, and those three individuals had grown enough that staff could make a more definitive determination of the frog's sex).

Subtracting the 20 newly marked adults—plus one additional adult observed on 26 July 2023 that was originally marked at 4Q Lakes in July 2022—all of which were born at 4-Q Lakes, CDFW observed 9 of the 177 translocated SNYLF in 2023 (5%; **Table 1**). Of the nine translocated adult recaptures, three were translocated to 4-Q in 2018, two were translocated to 4-Q in 2019, three were translocated to 4-Q in 2021, and one was translocated to 4-Q in 2022. When combining data for all follow-up surveys at 4-Q Lakes from 2018–2023, CDFW has observed 86 of the 177 released adult SNYLF individuals at least once (49%; **Table 1**).

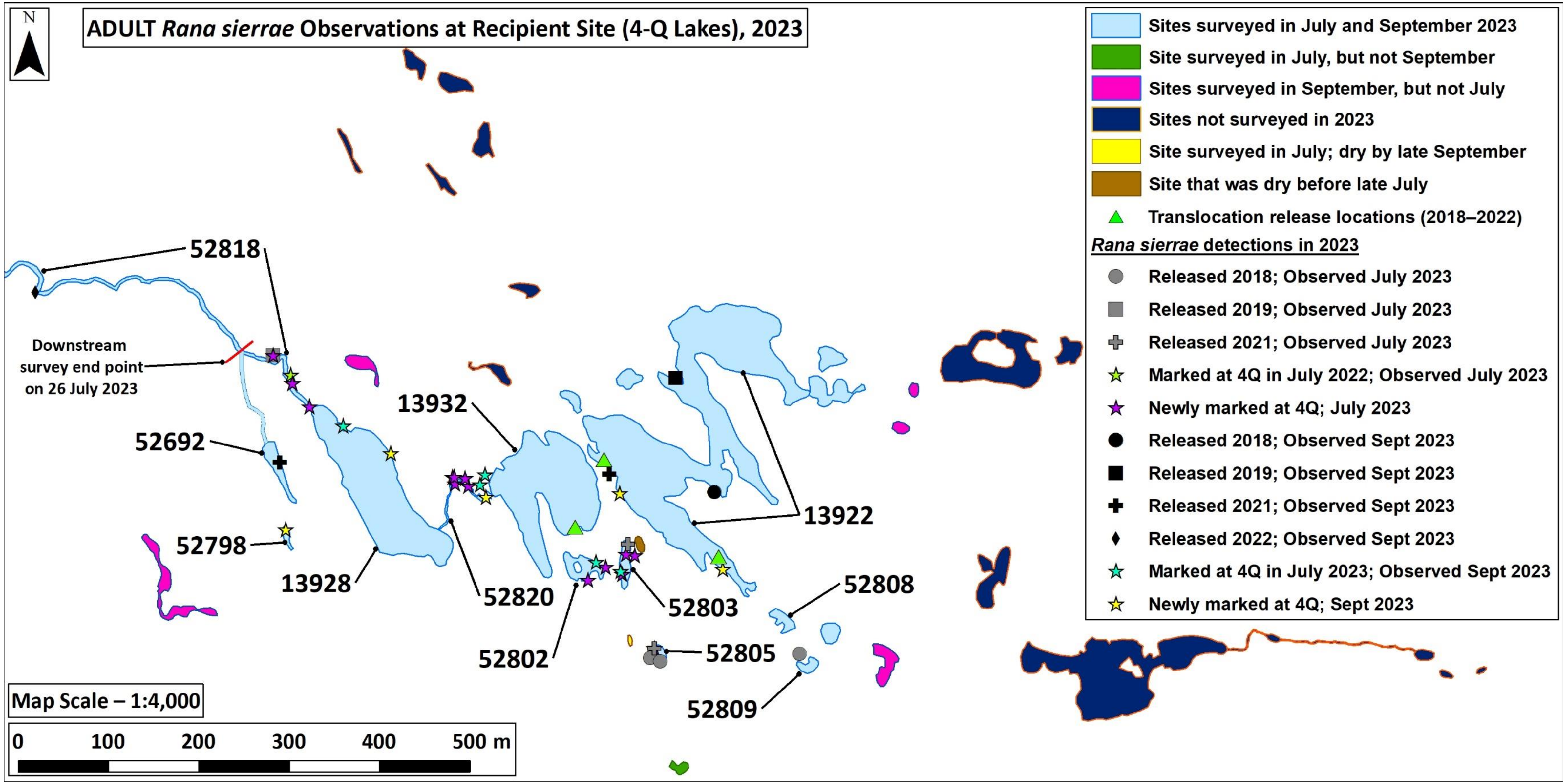


Figure 9. [See figure caption on the next page.]

Figure 9 (continued). Map showing locations of all adult Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) individuals detected by California Department of Fish and Wildlife (CDFW) field staff during capture-mark-recapture (CMR) surveys at 4-Q Lakes in 2023. Number labels shown are unique site identification codes for locations where CDFW staff detected adult SNYLF in 2023. The map also shows locations where adult SNYLF translocated from Highland Lake were released in 2018 (n = 60; 26 males, 34 females), 2019 (n = 40; 18 males, 22 females), 2021 (n = 51; 23 males, 28 females), and 2022 (n = 26; 12 males, 14 females; green triangles).

In 2023, CDFW conducted surveys at 4-Q Lakes on 26 July, and 19–20 September. During both surveys, staff visited all ponds shown in light blue. The site displayed in dark green was visited in July, but not September; and sites displayed in pink were visited in September, but not July. Additionally, staff surveyed down the basin outlet stream (exiting the figure to the west). In July, staff only surveyed downstream to the confluence of the Site ID 52692 outlet; in September, staff surveyed the entire stream reach, from Site ID 13928 to the confluence with the outlet of McConnell Lake. In 2023, staff did not survey any of the sites shown in dark blue. However, in all surveys at 4-Q Lakes from 2018–2023, staff have only observed a single subadult SNYLF at one of the ponds shown in dark blue. Therefore, SNYLF occupancy currently appears to be much less likely at the ponds that did not receive surveys in 2023.

During average water years, most of the small ponds shown in this map dry by late summer. However, summer 2023 followed a winter with above average precipitation (CDEC 2024a,b), so many of the small ponds shown retained water into the summer.

CDFW staff observed 22 SNYLF individuals in June (grey circles indicate frogs released in 2018, grey squares indicate frogs released in 2019, grey crosses indicate frogs released in 2021, purple stars indicate young adults born at 4-Q Lakes and newly tagged in July, and the green star indicates one adult born at 4-Q Lakes that was originally tagged in July 2022).

In September 2023, staff observed 15 SNYLF individuals (black circles indicate frogs released in 2018, black squares indicate frogs released in 2019, black crosses indicate frogs released in 2021, and black diamonds indicate frogs released in 2022). Additionally, the bright blue stars indicate the recapture locations of SNYLF newly tagged in July, and the yellow stars indicate frogs born at 4-Q Lakes and newly tagged in September.

[***End of figure caption***.]

Table 1 (see next page). Dates of adult Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) translocations and follow-up surveys at 4-Q Lakes, Desolation Wilderness, between 2018 and 2023; and number of SNYLF translocated, recaptured, or newly captured during each event. SNYLF numbers shown in each row (females, males, and total) are the number of unique individuals recaptured or newly marked during that site visit (i.e., not capture events, since some SNYLF individuals were caught more than once during each visit). The grand total rows display the following: **1)** the sum of SNYLF individuals originally translocated from the Highland Lake drainage that have been recaptured at least once since the first follow-up survey in July 2018 (in yellow). In total, CDFW has moved 177 adult SNYLF from the Highland Lake drainage to 4-Q Lakes between 2018 and 2023. Of those 177 translocated frogs, CDFW has recaptured at least* 86 individuals (49% of all translocated adults) at least once during post-translocation follow-up surveys at 4-Q Lakes. **2)** The sum of all unique adult SNYLF individuals that have been observed at 4-Q Lakes at least once since 2018, including frogs translocated from the Highland Lake drainage and new adults that were born at 4-Q Lakes (in pink).

(**See below for why the total number of recaptured individuals is not known precisely, given a few recaptured frogs with PIT tag issues.*)

†For tallies showing the original year of translocation (in grey), CDFW does not know the release year of three SNYLF individuals. There is a chance that two of these unknown individuals are in fact the same frog. Staff captured the first SNYLF with an unknown release year in August 2020. This frog had a passive integrated transponder (PIT) tag, but the tag was unreadable (i.e., the Biomark 601 PIT tag reader displayed "AVID tag detected," although no AVID tags have been inserted into frogs during this project). The frog was a male with snout-to-urostyle (SUL) length of 57 mm and a weight of 22 g. Staff captured the second SNYLF with an unknown release year in June 2022. This frog contained a PIT tag, but the tag would not read (staff could clearly see a PIT tag underneath the skin above the frog's urostyle, but the Biomark HPR Lite PIT tag reader did not detect the tag and nothing was displayed on the reader). Therefore, staff retagged the frog with a new PIT tag that was readable. The frog was a male with 59 mm SUL and a weight of 26 g. Given the PIT tag malfunctions and sizes of these two male frogs, there is a chance that the frog with an unreadable tag caught in August 2020 is the same individual as the frog caught in June 2022. However, since that possibility cannot be known definitively, the tallies below record these two frogs as separate individuals. Staff captured the third SNYLF with an unknown release year in August 2022. Staff found this frog dead and highly decomposed, so they could not determine the frog's sex. Additionally, staff did not detect a PIT tag in this dead SNYLF. Given this dead individual's large size, the frog had likely been translocated from Highland Lake. However, since staff did not detect a PIT tag in this individual, CDFW was unable to determine the potential translocation year.

[***End of caption for Table 1***.]

Table 1. (see caption on previous page).

Year	Dates	Females	Males	Unk Sex	Total	Notes
2018	**3 July**	**34**	**26**	**0**	**60**	**Translocation #1**
2018	17–18 July	5	7	0	12	
2018	21 Aug	13	2	0	15	
2018		***14***	***8***	***0***	***22***	***Total individuals observed in 2018***
2019	6 Aug	5	4	0	9	
2019	**8 Aug**	**22**	**18**	**0**	**40**	**Translocation #2**
2019	4 Sept	10	9	0	19	
2019	*4 Sept*	*2*	*2*	*0*	*4*	*Frogs released in 2018; all 4 also seen on 6 Aug 2019*
		8	*7*	*0*	*15*	*Frogs released in 2019*
2019		***13***	***11***	***0***	***24***	***Total individuals observed in 2019***
2020	16–17 June	14	6	0	20	
2020	11–12 Aug	10	6	0	16	
2020	*Trips*	*4*	*2*	*0*	*6*	*Frogs released in 2018*
	Combined–	*16*	*7*	*0*	*23*	*Frogs released in 2019*
	Unique Individuals	*0*	*1*	*0*	*1*	*Frog with unknown release year; (see table heading on previous page)*
2020		***20***	***10***	***0***	***30***	***Total individuals observed in 2020***
2021	30 June	10	5	0	15	
2021	**6 July**	**28**	**23**	**0**	**51**	**Translocation #3**
2021	11 Aug	18	3	0	21	
2021	*Trips*	5	3	0	8	*Frogs released in 2018*
	Combined–	7	3	0	10	*Frogs released in 2019*
	Unique	6	1	0	7	*Frogs released in 2021*
	Individuals	4	1	0	5	*Newly tagged at 4Q Lakes in 2021*
2021		***22***	***8***	***0***	***30***	***Total individuals observed in 2021***
2022	22–23 June	*4	†10	1	‡15	*One female SNYLF found dead. †One male SNYLF detected inside a Sierra Gartersnake (*Thamnophis couchii*). ‡One additional adult, which was not one of the other 14 individuals tallied, escaped capture.
2022	**7 July**	**14**	**12**	**0**	**26**	**Translocation #4**
2022	26–27 July	9	8	0	17	One dead adult anuran also found; not included in tally. (Species unknown due to decomposition—SNYLF or *Anaxyrus* [*Bufo*] *boreas*; no PIT tag detected.)
2022	30–31 Aug	12	12	1	*25	*One additional SNYLF found dead and included in total; (no PIT tag, sex unknown due to decomposition).
2022	*Trips*	*2	3	0	5	*Frogs released in 2018; *one of the females was found dead.*
	Combined–	2	7	0	9	*Frogs released in 2019*
	Unique	3	*4	0	7	*Frogs released in 2021; *one of the males was eaten by a gartersnake*
	Individuals	10	5	0	15	*Frogs released in 2022*
		0	1	1	*2	*Frogs w/ unknown release year (*Includes one adult SNYLF of unknown sex found dead with no PIT tag detected).*
		1	**1**	**1**	***3**	***Adult SNYLF mortalities seen in 2022 (*sex of one individual unknown).***
		4	3	0	7	*Newly tagged at 4Q Lakes in 2022*
2022		***21***	***23***	***1***	****45***	***Total individuals observed in 2022*** *(*Includes one adult SNYLF of unknown sex found dead with no PIT tag detected).*
2023	26 July	6	6	10	22	10 newly marked adults small enough that sex ID was not definitive.
2023	19–20 Sept	13	2	0	15	
2023	*Trips*	1	2	0	3	*Frogs released in 2018*
	Combined–	1	1	0	2	*Frogs released in 2019*
	Unique	2	1	0	3	*Frogs released in 2021*
	Individuals	1	0	0	1	*Frogs released in 2022*
		0	1	0	1	*Newly tagged at 4Q Lakes in 2022*
		10	3	7	20	*Newly tagged at 4Q Lakes in 2023*
2023		***15***	***8***	***7***	***30***	***Total individuals observed in 2023***
	2018–2023	***17***	***11***	***0***	***28***	***Frogs released in 2018***
	Unique	***16***	***13***	***0***	***29***	***Frogs released in 2019***
	Individuals	***9***	***5***	***0***	***14***	***Frogs released in 2021***
	Only	***10***	***5***	***0***	***15***	***Frogs released in 2022***
		18	***7***	***7***	***32***	***Newly tagged at 4Q Lakes***
		0	***2***	***1***	***†3***	***Frogs with unknown release year;*** *(†see table heading on previous page).*
		52	***34***	***0***	***86***	***Grand total of translocated individuals recaptured at 4-Q Lakes at least once during the period 2018–2023.***
		70	***43***	***8***	***†121***	***Grand total of all unique adult SNYLF observed at 4-Q Lakes at least once during the period 2018–2023.*** *(†see table heading on previous page for details regarding SNYLF with unknown release year).*

In keeping with the female-skewed sex ratios for the releases, sex ratios among recaptures during follow-up surveys have been dominated by females. During post-translocation surveys from 2018–2023, CDFW has recaptured 52 of the females and 34 of the males that were translocated. These ratios among overall recaptures (1.53 females:1 male) correspond roughly with the sex ratios of total released frogs (1.27 females:1 male).

Most frogs detected during follow-up surveys at 4-Q Lakes have appeared to be in good condition. All live recaptured SNYLF had grown substantially since their initial translocation, suggesting that the SNYLF are healthy and feeding well in their new habitat. Growth, in terms of increased SUL and mass, was particularly pronounced in females, which grew approximately twice as much as males (**Table 2**). These trends in growth patterns between the sexes were consistent in individuals with data available for timespans between one month and three years between release and most recent capture (**Table 2**).

Looking at longer periods of growth, female growth rates were strikingly higher than males. CDFW collected data from six females for which the most recent recapture event was three years following translocation to 4-Q Lakes. Average growth for these six females was 41 g and 26 mm SUL (**Table 2**). Meanwhile, average growth for seven males most recently recaptured three years post-translocation was 11 g and 8 mm SUL. Although the seven males averaged somewhat larger than the six females when translocated (the eight males averaged 19 g and 54 mm SUL when translocated, whereas the six females averaged 17 g and 49 mm when translocated), the females exhibited much faster growth rates (**Table 2**). Like many explosive breeding anuran species (Wells 2007, pg. 389), SNYLF females are on average much larger than males, and the data presented in **Table 2** demonstrates that females can achieve these larger sizes in relatively short timeframes.

For additional visualization of the growth over time among all recaptured male and female SNYLF, see **Figures A1–A4** provided in the Appendix.

SNYLF released at 4-Q Lakes have continued to disperse from their original release points and now occupy many areas in 4-Q Lakes basin (**Figure 9**). In 2023, CDFW staff observed SNYLF occupying numerous areas in the basin, in all of which staff have previously detected SNYLF. Additionally, staff noted an interesting spatial distribution of frogs in 2023. During the survey on 26 July 2023, all SNYLF observed were occupying stream segments and small ponds adjacent to the main 4-Q Lakes. Staff detected no SNYLF in the largest lakes (Site IDs 13922, 13928, and 13932). However, by late September, staff detected SNYLF among a wider selection of sites, including the main lakes and connected streams. These observations may suggest that SNYLF at 4-Q Lakes prefer smaller ponds and ephemeral stream segments when they are available.

For further details on early life stage SNYLF detections and locations, see the *Reproduction* section below.

Table 2. Average growth summary statistics—partitioned by timeframe† and sex (F = female, M = male)—for adult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) translocated from Highland Lake to 4-Q Lakes. Measurements displayed are original (“1st” = measurement on translocation day, or day of initial capture for frogs born at 4-Q Lakes) and most recent (“latest” = measurement from most recent recapture event) average snout-to-urostyle length (SUL, in millimeters [mm]) and average weight (mass, in grams [g]) of unique individuals recaptured from 2020–2023 for which California Department of Fish and Wildlife (CDFW) had original measurements*. Both SUL and mass have a column showing the average difference between the original and most recent measurements of each row (“diff.”). The first column displays the number of individual SNYLF measurements incorporated in each average value within a row. On average, for any given period of growth, females grew approximately twice as much as males in mass. The final rows display the average difference in measurements for 11 females and three males during a two-month period between capture events, and 10 females and four males during a one-month period between capture events, respectively. In those brief intervals, on average, females gained 6 g per month.†

sex (years of growth†); sample size	**SUL (1st)**	**SUL (latest)**	**SUL (diff.)**	**Mass (1st)**	**Mass (latest)**	**Mass (diff.)**
F (3); n = 6	49 mm	75 mm	+26 mm	17 g	58 g	+41 g
M (3); n = 7	54 mm	62 mm	+8 mm	19 g	30 g	+11 g
F (2); n = 10 [‡See below re: 2-yr males]	53 mm	72 mm	+19 mm	20 g	46 g	+26 g
F (1); n = 10	54 mm	65 mm	+11 mm	20 g	31 g	+11 g
M (1); n = 7	49 mm	56 mm	+7 mm	16 g	20 g	+4 g
F (2 *months*); n = 11	51 mm	59 mm	+8 mm	15 g	27 g	+12 g
M (2 *months*); n = 3	48 mm	54 mm	+6 mm	13 g	20 g	+7 g
F (1 *month*); n = 10	51 mm	56 mm	+5 mm	17 g	23 g	+6 g
M (1 *month*); n = 4	50 mm	52 mm	+2 mm	14 g	16 g	+2 g

†CDFW has recaptured six additional frogs that have longer timeframes between translocation and most recent capture, including one 5-year interval female, one 4-year interval female, two 5-year interval males, and two 4-year interval males. However, given low samples sizes, these individuals were omitted from this table.

‡No growth statistics were available for the two-year growth interval in males (only one male was two years removed from the original capture event), so the table omits that category.

*CDFW staff did not record morphological data during recapture trips at 4-Q Lakes in 2018 and 2019.

Reproduction

Establishing a self-sustaining SNYLF population at 4-Q Lakes is the principal objective of this translocation project. Fortunately, in June 2020, field staff observed a recently hatched SNYLF egg mass at Site ID 13922 and one large tadpole, which evaded follow-up detection. During the second visit in August, CDFW staff observed more early life stage SNYLF, including at least five tadpoles and 14 subadults. The total number of tadpoles and subadults is not known because these life stages are unmarked. However, when totaling counts of early life stage SNYLF detections from one pass of each waterbody during the same survey day, the total was 5 larvae and 14 subadults. In 2021, staff detected at least 12 subadults in June, and at least 27 subadults in August. Staff did not detect SNYLF tadpoles in 2021. Staff detected even higher numbers of early life stage SNYLF in 2022 (see CDFW 2023 for full details). In particular, the survey trip in August 2022 resulted in the largest number of early life stage SNYLF observed at 4-Q Lakes since the inception of translocations, during which staff detected at least 82 subadults and 8 tadpoles in the basin.

Staff observed fewer subadult SNYLF in 4-Q Lakes in 2023. Staff did not detect young subadults on 26 July and staff only detected seven subadults in September. However, these more limited detections may have been due to multiple factors that likely affected detection outcomes, including the short survey duration in July, the timing of visits (given the above-average preceding winter, the July survey was early enough that recent metamorphs had likely not yet emerged, and the second survey was late enough that many recently metamorphosed SNYLF may have dispersed or been otherwise unavailable for detection), observer bias, and weather. Although survey conditions were excellent during the brief visit on 26 July, staff encountered storms and hail during the visit in September. The weather resulted in overall poorer survey conditions, and the need to pause surveys on several occasions. These conditions very likely affected detection probability of SNYLF in the basin. Weather likely also played a role in the lower detections of translocated adults in 2023 (see *Follow-up Surveys* section above).

Despite the poorer survey conditions in September, staff detected 104 SNYLF tadpoles at 4-Q Lakes, nearly all of which were at Site ID 13932. These observations, in combination with detecting 20 new young adults recently recruited into the population, are great signs that the newly established SNYLF population at 4-Q Lakes is doing well.

Looking ahead: 2024

In 2024, CDFW staff plan to visit Highland and 4-Q Lakes to maintain current demographic data on both SNYLF populations. As of January 2024, the recent Section 6 grant that covered translocations and monitoring at Highland and 4-Q Lakes (Federal Grant Award #F21AP00483) has ended; however, CDFW has one remaining year on a State Wildlife Grant (SWG; Federal Grant Award #F22AF01541), which will allow monitoring to continue at Highland and 4-Q Lakes in 2024 and spring 2025. CDFW is applying for additional monitoring funds under the current Section 6 funding cycle for the 2024–25 fiscal year. If selected for funding and awarded, that grant will allow continued monitoring at Highland and 4-Q Lakes from summer 2025–fall 2027, and allow for another supplemental translocation from the Highland Lake drainage to 4-Q Lakes, assuming the SNYLF source population continues to remain large enough to accommodate adult collections.

For each adult captured during subsequent monitoring visits to 4-Q Lakes, staff will record PIT tag, sex, location coordinates, weight, and length measurements (staff will only record weight and length measurements once per site visit for each individual). Now that new SNYLF recruitment is occurring, CDFW will continue PIT-tagging any new adults observed at 4-Q Lakes. These data will be used for capture-mark-recapture (CMR) analysis to determine abundance and survivorship in the SNYLF population more accurately (Mazerolle et al. 2007). Given the conservation importance of this population, CDFW needs current information obtained through annual monitoring.

Other notable observations

On 26 July 2023, CDFW observed evidence of an avalanche that occurred sometime during winter 2022–2023 (**Figure 10**). When arriving at 4-Q Lakes, staff observed numerous broken and downed trees and large quantities of smaller woody debris along the south side of the basin, particularly near the southeast cove of Site IDs 13922 (**Figures 11 and 12**). The dense accumulation of downed vegetation had created an insulating layer that retained several large, deep piles of snow (**Figure 13**). Staff also observed avalanche damage at various locations along the slope of south of the main 4-Q Lakes (**Figures 14 and 15**), and off the southeast side of Site ID 13928 (**Figure 16**).

CDFW does not know with certainty what, if any, effects this avalanche event may have on the SNYLF population. In localized areas, the deeply piled snow may have delayed emergence or caused the mortality of some frogs hibernating in waterbodies below the main avalanche paths. However, there is now an abundance of cover within which frogs can forage, breed, and seek shelter from predators. Although detecting frogs will be more challenging in areas now inundated with substantial debris piles, the additional woody habitat features may prove beneficial for the SNYLF at 4-Q Lakes.

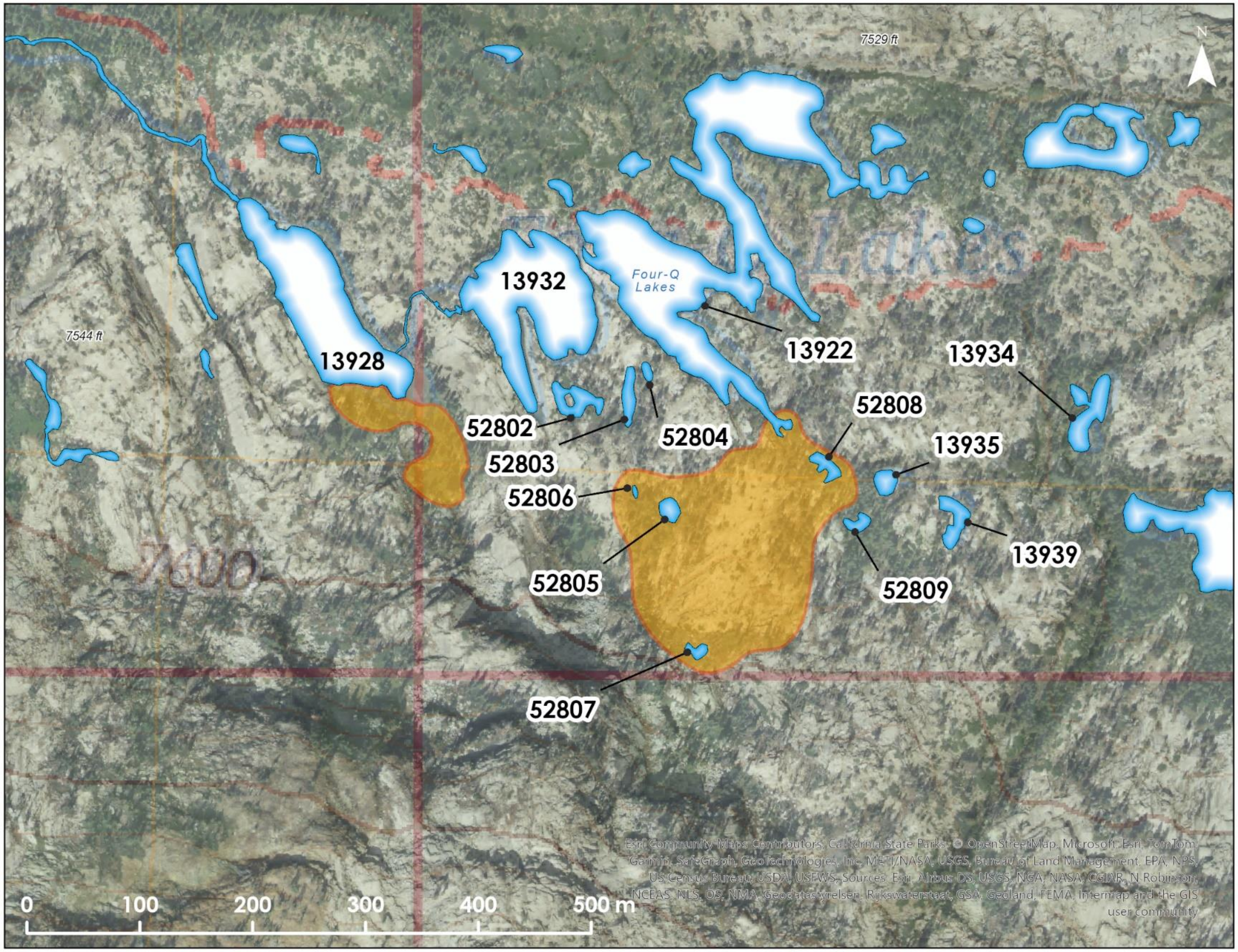


Figure 10. Hillshade relief map showing the approximate areas (in light orange) of 4-Q Lakes basin where CDFW staff observed avalanche evidence on 26 July 2023.

Figure 11. View looking southeast at downed trees and woody debris among lingering snow piles at Site ID 52808 on 26 July 2023. An avalanche appeared to have occurred in 4-Q Lakes Basin sometime during winter 2022–2023, resulting in substantial tree damage and deep snow piles along portions of the largest 4-Q Lakes southern margins.

Figure 12. View looking northwest at downed trees and woody debris among lingering snow piles at Site ID 52808 on 26 July 2023. An avalanche appeared to have occurred in 4-Q Lakes Basin sometime during winter 2022–2023, resulting in substantial tree damage and deep snow piles along portions of the largest 4-Q Lakes southern margins.

Figure 13. One of several dense snow mounds still remaining near Site ID 52808 on 26 July 2023. An avalanche appeared to have occurred in 4-Q Lakes Basin sometime during winter 2022–2023, resulting in substantial tree damage and deep snow piles along the southern margins of 4-Q Lakes (Site IDs 13928 and 13922). (CDFW)

Figure 14. While visiting 4-Q Lakes on 26 July 2023, CDFW staff observed littered with snapped off mature conifers littering the slope south of Site ID 13922. Many of the trees had been broken off between approximately half a meter and three meters above the ground, presumably during an avalanche event that occurred sometime during winter 2022–2023. (CDFW)

Figure 15. More downed trees and other avalanche evidence near Site ID 52805 on 26 July 2023. (CDFW)

Figure 16. Broken branches littering the surface of a small pond connected during high water to the southeast side of Site ID 13928. (CDFW)

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APPENDIX: Growth over time among Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) recaptured at 4-Q Lakes from 2018–2023.

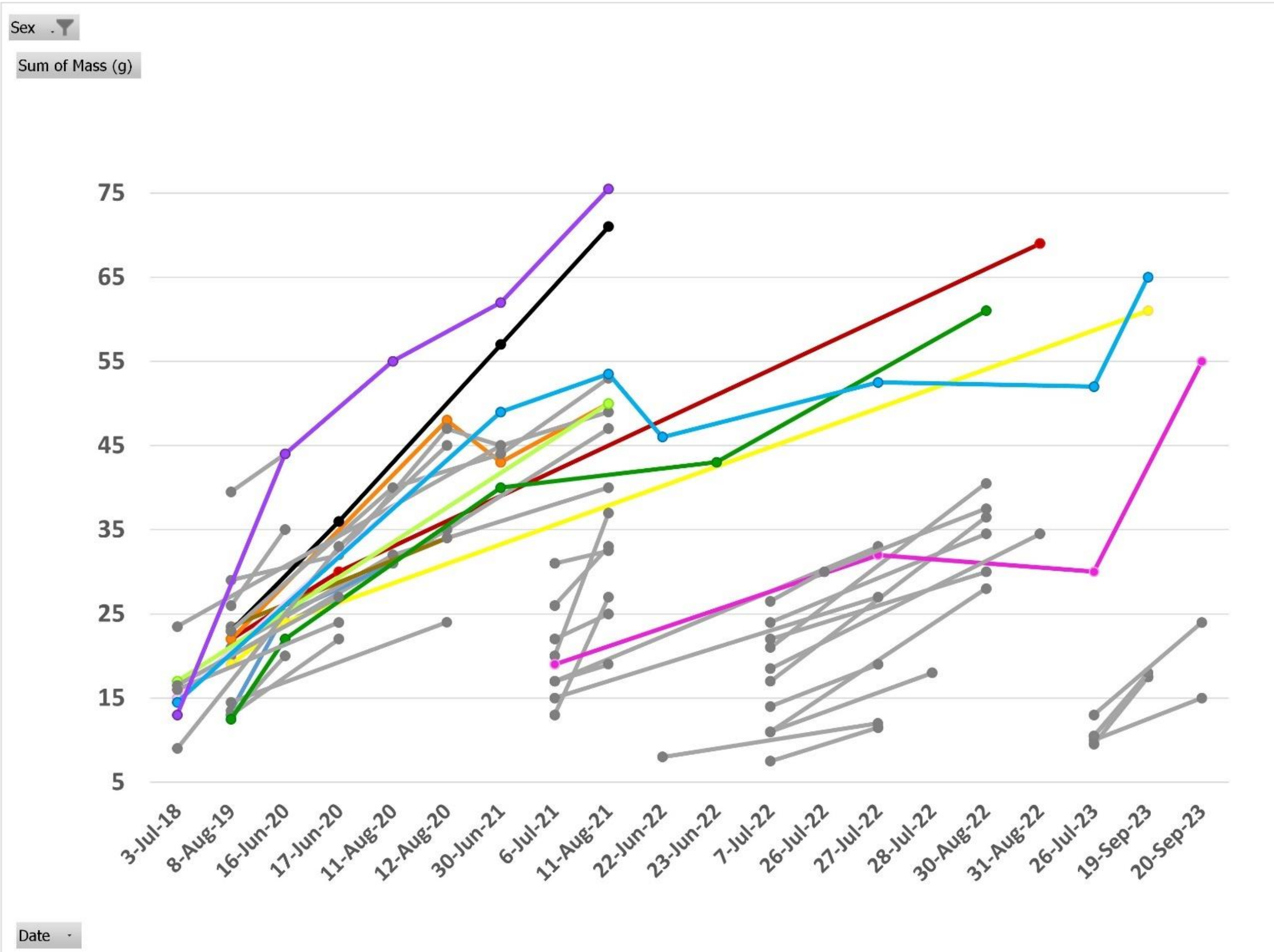

Figure A1. Changes in mass (in grams) over time among recaptured female SNYLF at 4-Q Lakes. Each dot represents a capture event and each line is an individual adult frog. Most individuals are shown in grey. Other colors highlight a selection of female individuals that have 1) been recaptured multiple times, and/or 2) had the highest growth rates of the various females recaptured. Each separate color corresponds with the same individual in Figure A3, which shows change in snout-to-urostyle (SUL) length over time among recaptured females (e.g., the female shown in purple in this figure is the same individual shown in purple in Figure A3).

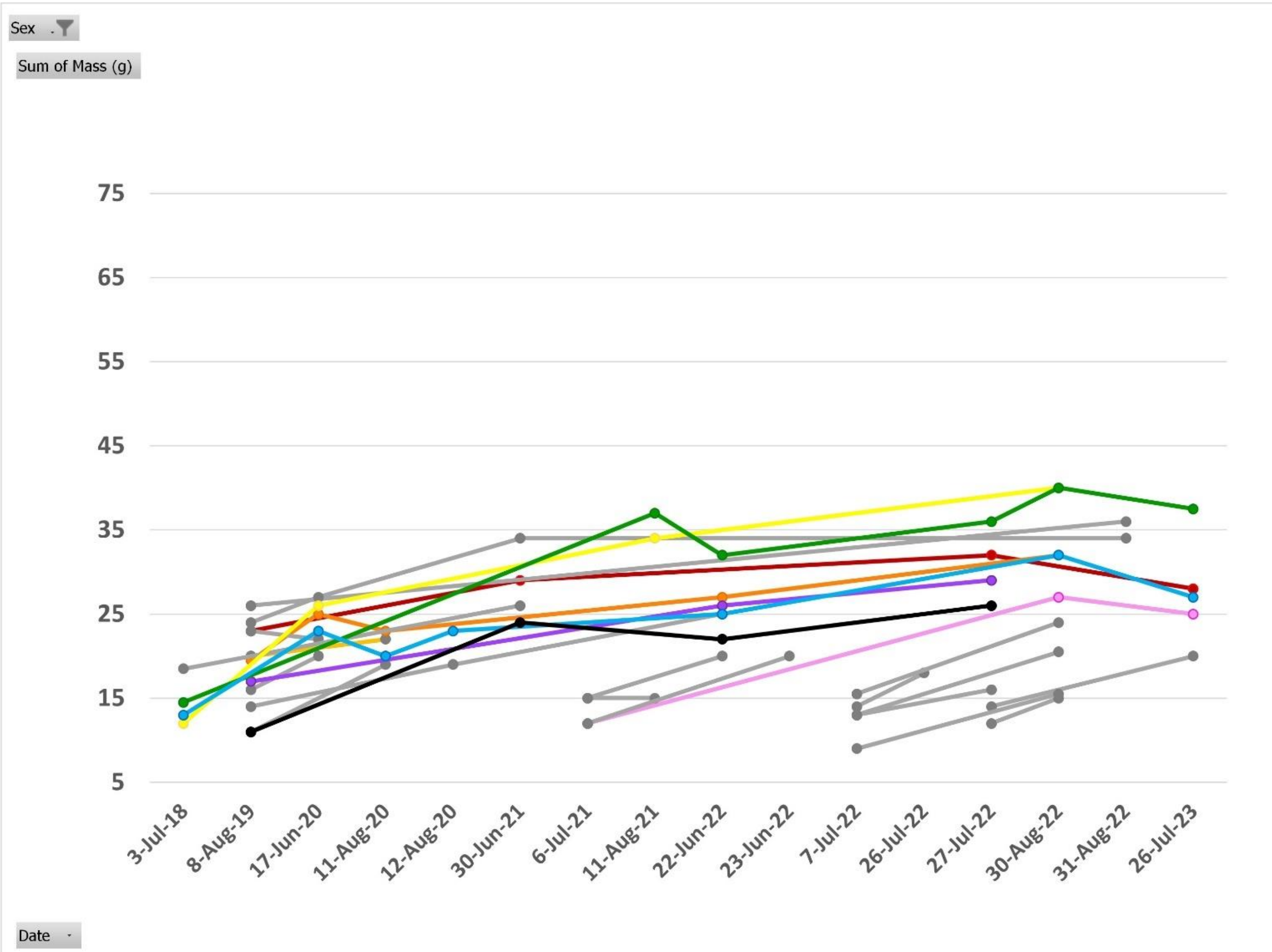

Figure A2. Changes in mass (in grams) over time among recaptured male SNYLF at 4-Q Lakes. Each dot represents a capture event and each line is an individual adult frog. Most individuals are shown in grey. Other colors highlight a selection of male individuals that have 1) been recaptured multiple times, and/or 2) had the highest growth rates of the various males recaptured. Each separate color corresponds with the same individual in Figure A4, which shows change in snout-to-urostyle (SUL) length over time among recaptured males (e.g., the male shown in dark green in this figure is the same individual shown in dark green in Figure A4).

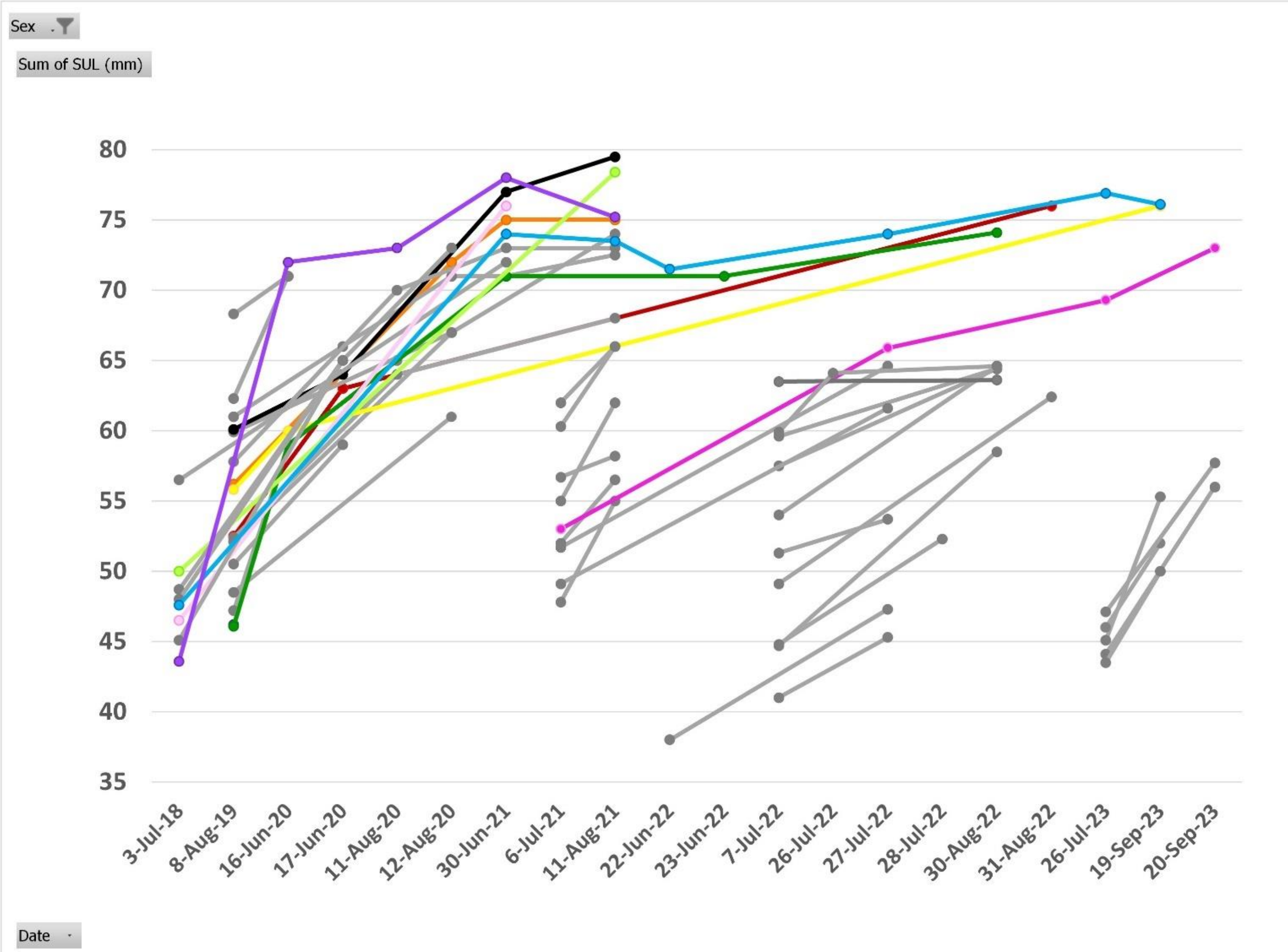

Figure A3. Changes in snout-to-urostyle (SUL) length (in millimeters) over time among recaptured female SNYLF at 4-Q Lakes. Each dot represents a capture event and each line is an individual adult frog. Most individuals are shown in grey. Other colors highlight a selection of female individuals that have 1) been recaptured multiple times, and/or 2) had the highest growth rates of the various females recaptured. Each separate color corresponds with the same individual in Figure A1, which shows change in mass over time among recaptured females (e.g., the female shown in purple in this figure is the same individual shown in purple in Figure A1). *Note: small reductions in SUL over time among some individuals are due to measuring bias between different surveyors, not a true reduction in frog length. SUL measurements are more prone to errors than weight measurements, since SUL measurement can more easily change based on the body position of the frog and the placement of calipers when measuring. Although staff do their best to standardize the way frogs are handled and positioned when measuring, SUL measurements can still vary by several millimeters, depending on small differences in the aforementioned factors.*

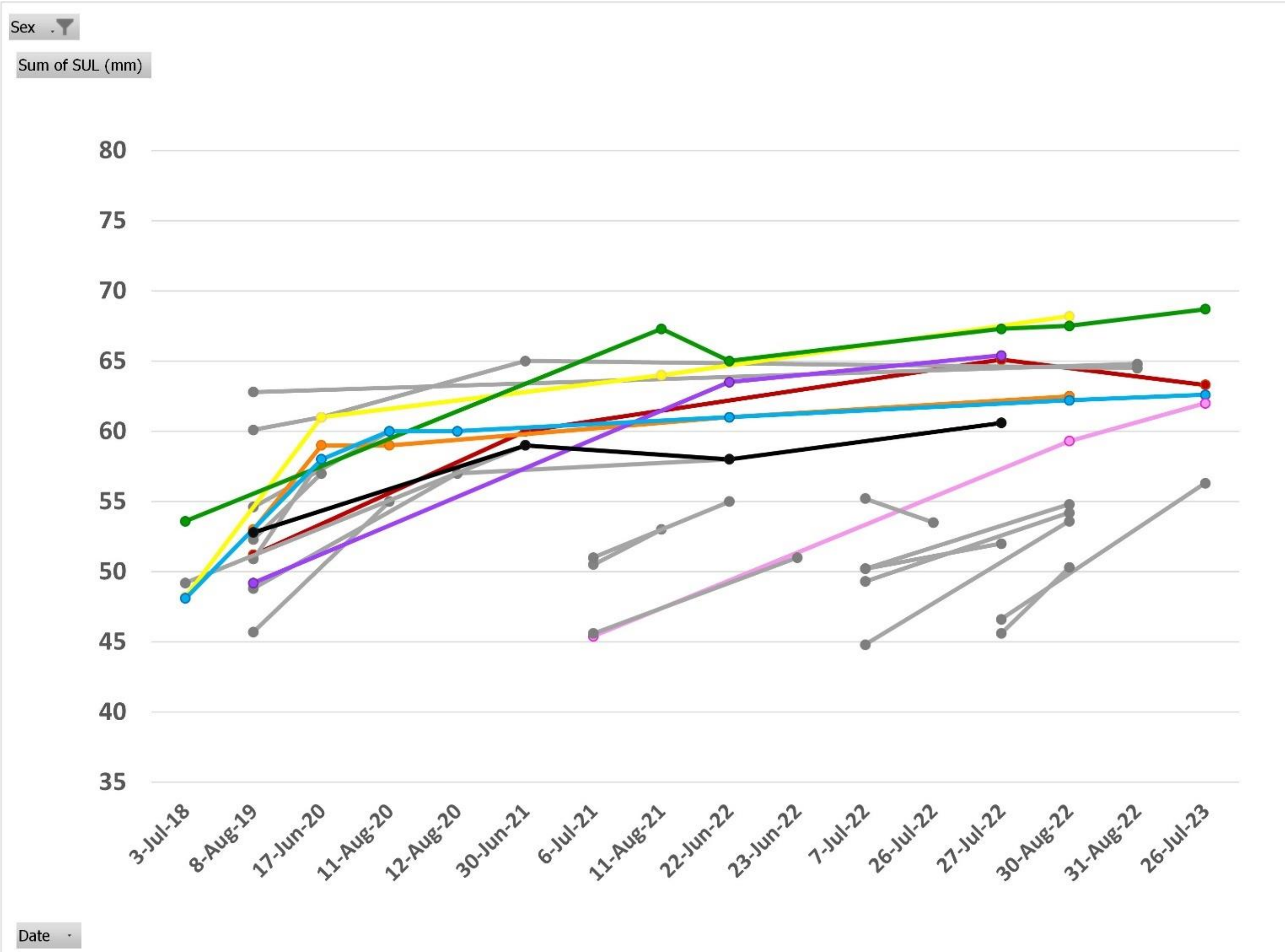

Figure A4. Changes in snout-to-urostyle (SUL) length (in millimeters) over time among recaptured male SNYLF at 4-Q Lakes. Each dot represents a capture event and each line is an individual adult frog. Most individuals are shown in grey. Other colors highlight a selection of male individuals that have 1) been recaptured multiple times, and/or 2) had the highest growth rates of the various males recaptured. Each separate color corresponds with the same individual in Figure A2, which shows change in mass over time among recaptured males (e.g., the male shown in dark green in this figure is the same individual shown in dark green in Figure A2). *Note: small reductions in SUL over time among some individuals are due to measuring bias between different surveyors, not a true reduction in frog length. SUL measurements are more prone to errors than weight measurements, since SUL measurement can more easily change based on the body position of the frog and the placement of calipers when measuring. Although staff do their best to standardize the way frogs are handled and positioned when measuring, SUL measurements can still vary by several millimeters, depending on small differences in the aforementioned factors.*