State of California

Memorandum

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Ec: CDFW Document Library

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Subject: Native amphibian restoration and monitoring in Mokelumne Wilderness;

Beebe Lakes fish removal and *Rana sierrae* monitoring.

Fish removal activities are complete in the Beebe Lakes drainage (Figure 1); California Department of Fish and Wildlife (CDFW) staff, in partnership with Eldorado National Forest (ENF) personnel, removed 486 brook trout to benefit Sierra Nevada yellow-legged frogs (*Rana sierrae*, SNYLF). Amphibian monitoring data from 2012 through 2017 suggest a stable SNYLF population; CDFW will continue amphibian monitoring the area to document SNYLF response to fish removal.

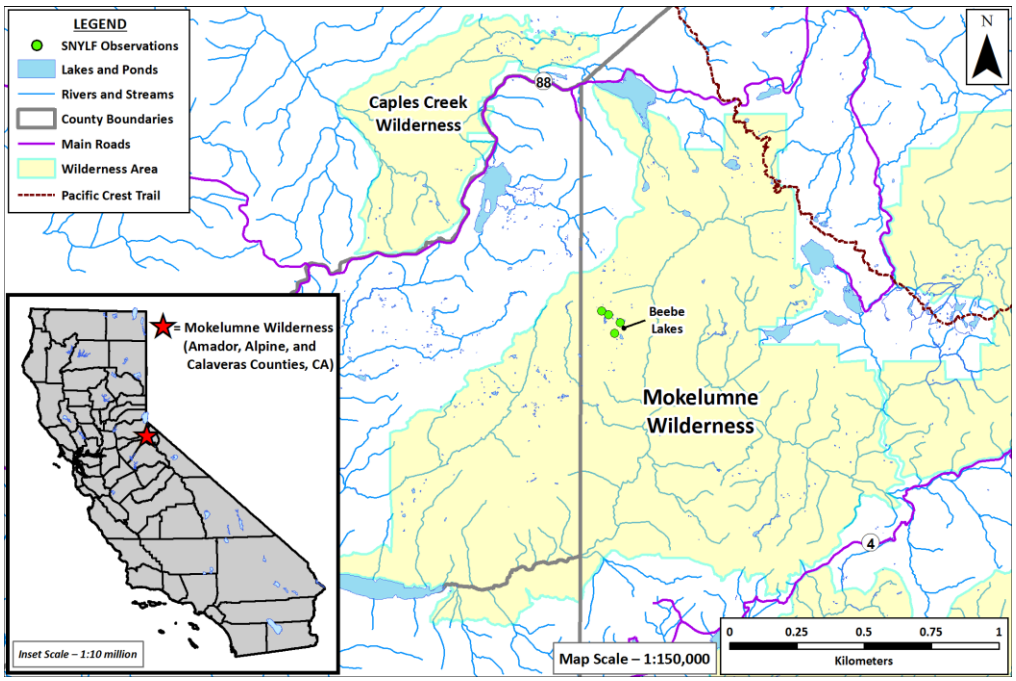


Figure 1: Mokelumne Wilderness, Amador, Alpine, and Calaveras Counties, CA. Green dots showing *Rana sierrae* (SNYLF) sites include positive detections by CDFW staff during recent visual encounter surveys (VES)

ENVIRONMENTAL SETTING

Beebe Lakes drainage is located in the Mokelumne Wilderness, just east of the Alpine County line. The basin is within Lower Summit Creek Planning Watershed (PWS) on the western slope of the Sierra Nevada, between 7,900' and 8,500'. ENF manages the land and issues grazing permits in the area. The site is accessed by driving rough 4x4 roads from the Silver Lake area off Highway 88, then hiking east into the Mokelumne Wilderness, past an old

trading post, and through Ladeux Meadow before reaching Beebe Lakes basin. CDFW crews conducted baseline surveys in 2001 and 2002. Crews observed brook trout (*Salvenlinus fontanilis*) in Beebe Lake. Crews also observed SNYLF (Figure 2) at four sites in the PWS. All of the SNYLF populations are small and isolated. CDFW and ENF determined that eradicating the brook trout population using gill nets and backpack electrofishers would be feasible, and provide SNYLF with more deep-water habitat in the Beebe Lakes drainage. Once fishless, CDFW plans to manage the entire Beebe Lakes drainage as SNYLF breeding habitat (CDFW 2016).

INTRODUCTION

The Aquatic Biodiversity Management Plan for the Upper Mokelumne Management Unit (CDFW 2016) identifies Beebe Lake (Site ID 14797; Figure 3), Lower Beebe Lake (Site ID 2694), Beebe Meadow (Site IDs 14791, 14795, and 14799), approximately one kilometer (km) of stream (Site 52651), three small ponds with consistent SNYLF observations (Site IDs 14774, 14802, and 14829), and several other small ponds in the basin as a Native Species Reserve (NSR; Figure 4) for SNYLF. Thus far, CDFW staff have not observed SNYLF in Beebe Lake. However, although only reaching a maximum depth of about 4 meters (m), Beebe Lake is the deepest wetted habitat in the basin. Additionally, Beebe Lake is located approximately halfway between Pond 14774 and Pond 14802 SNYLF populations. Therefore, removing brook trout from Beebe Lake, Beebe Meadow, and the adjoining stream provides an opportunity to create a series of interconnected aquatic habitats for SNYLF.

Beebe Lake was stocked with brook trout from 1930 until 2000. Gill net sampling conducted by CDFW staff in 2001 and 2010 revealed that the brook trout population in Beebe Lake was self-sustaining. Beginning in 2011, CDFW, with assistance from ENF personnel, began removing brook trout from Beebe Lake and the surrounding area to benefit SNYLF. As of 2017, after two years of monitoring without detecting brook trout, the basin is likely fishless. The most recent brook trout capture was in 2015. However, CDFW staff plan to use a backpack electrofishing unit to sample from Beebe Meadow upstream through the entire stream reach (Site ID 52651) as final confirmation of brook trout eradication. Additionally, CDFW will continue to survey regularly to monitor the Beebe Lakes basin SNYLF population status and trends. Staff will also monitor the area for presence of any latent non-native trout.

Figure 2. Adult Sierra Nevada yellow-legged frog (*Rana sierrae*) basking on a log in the stream channel just below Pond 14785 in September 2017. (CDFW)

Figure 3.Beebe Lake in July 2015, looking north. (CDFW)

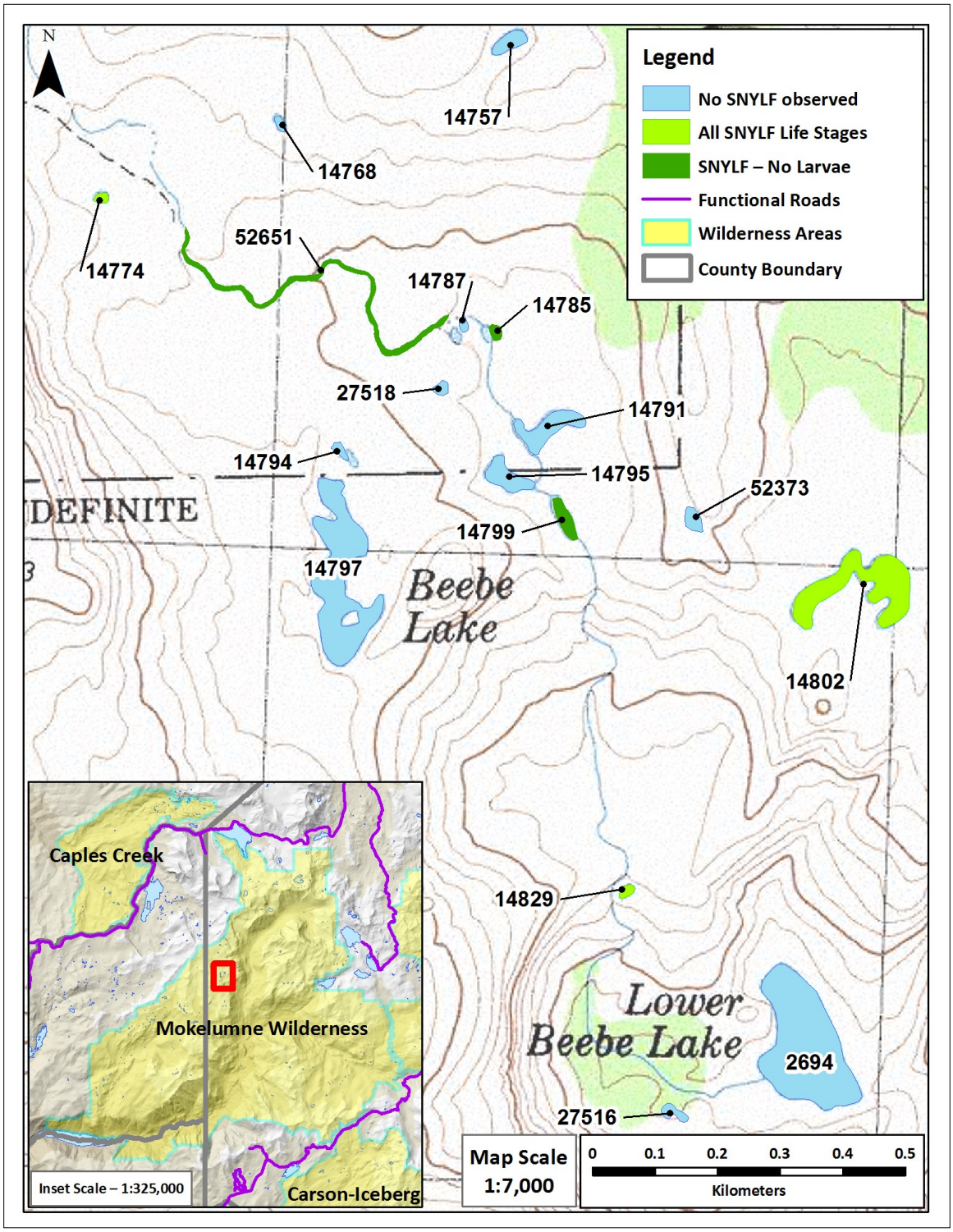


Figure 4: Beebe Lakes Native Species Reserve (NSR). CDFW staff have observed Sierra Nevada yellow-legged frogs of all life stages in four ponds within the drainage (Site IDs 14774, 14802, 14829, and 14706). Pond 14706 is located north of the main Beebe Lakes basin and not shown on the map. No SNLYF have been observed in Pond 14706 since 2010, when CDFW staff observed three egg masses. Pond 14706 has not been surveyed since 2012. Since fish removal began, CDFW staff have observed SNYLF adults and subadults in several other parts of the basin, including Stream 52651, Pond 14785, and Pond 14799. All flowing waters in the basin drain south, through Lower Beebe Lake, east into Summit City Creek, and eventually into the North Fork Mokelumne River.

THREATS

- ***Disease*** – All SNYLF populations in the Mokelumne Wilderness are positive for chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*). Lower Summit Creek PWS SNYLF were genetically sampled using epithelial swabs and screened for the presence of *Bd* DNA using real-time quantitative polymerase chain reaction (qPCR) analysis in 2008 and 2010. Staff collected eleven swabs from sites 14774, 14802, and 14829, and results from both years detected very light to moderate zoospore loads (a general measure of infection intensity).

- ***Marginal Habitats*** – SNYLF populations in Lower Summit Creek PWS are persisting at small, isolated ponds and their seasonally flowing tributaries (Figure 4). Any disturbance, natural or otherwise, that threatens overwintering habitats presents a potential extirpation risk. Potential risks include severe winter conditions, extended drought, or anthropogenic habitat disturbances.

- ***Introduced Fish*** – All sites supporting SNYLF in Lower Summit Creek PWS are fishless. However, brook trout were persisting in much of the available aquatic habitat, including Beebe Lake and the nearby meadow/stream complex. The stream that connects Pond 14787 to Lower Beebe Lake flows seasonally and dries to a series of deep tannin pools by late summer. It is not ideal trout habitat, yet brook trout were persisting in the absence of stocking. The fish-containing habitats may have been acting as population sinks for migrating SNYLF. Additionally, brook trout likely precluded any successful SNYLF breeding and recruitment in Beebe Lake, which supplies the only deep water habitat in the basin.

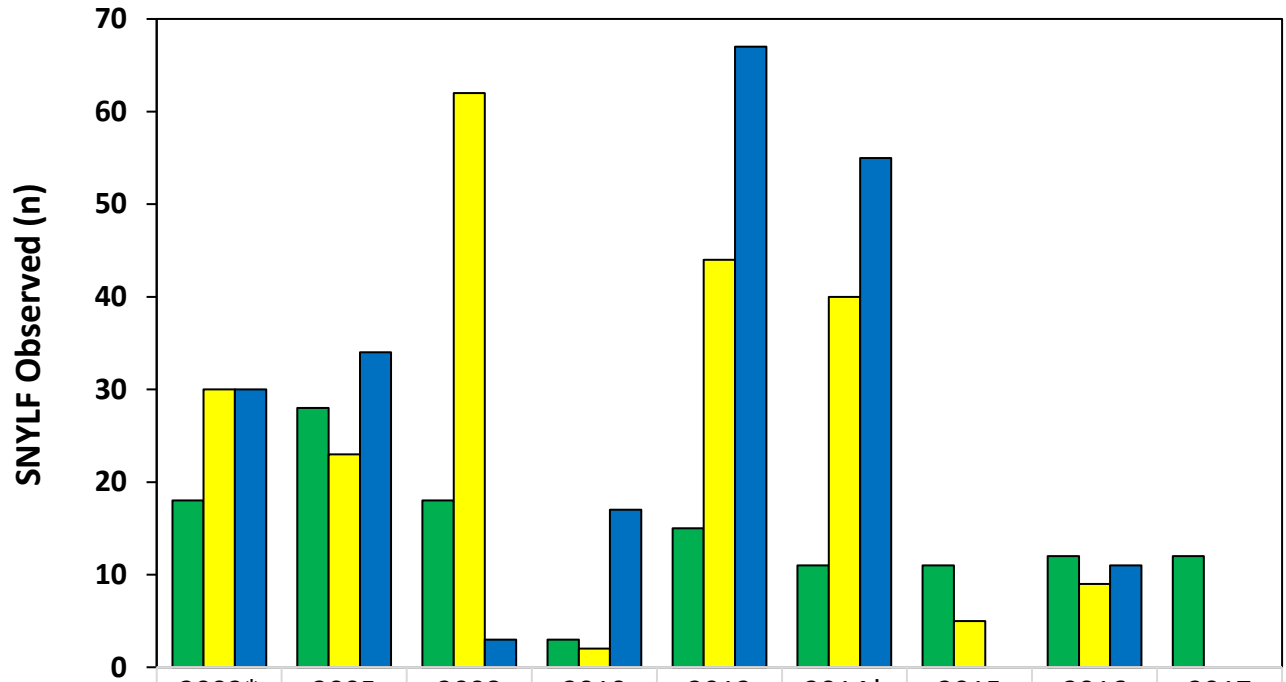
- ***Cattle Grazing*** –Studies investigating direct interactions between cattle and SNYLF populations have not been conducted. However, the U.S. Forest Service (USFS) acknowledges cattle impacts to aquatic resources in the Mokelumne Wilderness Management Guidelines (USFS 1995). Additionally, potential negative effects of livestock grazing on SNYLF habitat are discussed in the U.S. Fish and Wildlife Service (USFWS) final rule for listing SNYLF as a federally endangered species (USFWS 2014, pg. 24628–24630). USFWS concluded: "*Current livestock grazing activities may present an ongoing, localized threat to individual populations in locations where the populations occur in stream riparian zones and in small waters within meadow systems, where active grazing co-occurs with extant frog populations."* The USFWS concluded that livestock grazing that complies with USFS grazing guidelines is not expected to negatively affect most SNYLF populations (USFWS 2014).

- ***Loss of Genetic Diversity*** – Like many SNYLF populations in the northern Sierra Nevada, the population in Beebe Lakes is small and isolated. Although there are small populations in relatively close proximity (e.g., Ladeux Meadow, Devils Hole Lake, Bear River, and Deadwood Canyon), the rugged landscape of the Upper Mokelumne results in Ladeux population being the only realistic source for gene flow from a source outside Beebe Lakes. The nearest location with fairly widespread SNYLF occupancy is the Jeff Davis Creek area, which is about 14 km east of Beebe Lakes. In addition to the threats presented by stochastic environmental events when a population is geographically isolated (e.g., drought or especially harsh winter), genetic isolation can lead to factors such as inbreeding depression, genetic drift, fixation of deleterious alleles, and loss of genetic diversity, all of which are population genetic factors exacerbated in small populations like those in Beebe Lakes (Frankham et al. 2009).

POPULATION STATUS

Although still very small, the SNYLF population in Beebe Lakes drainage is persisting (Figure 5). The sites in which a majority of SNYLF have been observed during VES in the Beebe Lakes drainage are Pond 14774 (Figure 6), Pond 14802 (Figure 7), and Pool 14829 (Figure 8).

Long term monitoring will be required to derive population trends and quantify the SNYLF population in the Beebe Lakes area. As brook trout have been removed, CDFW staff have observed SNYLF occupying microhabitats within the NSR in which SNYLF were not observed when fish were present. Notably, CDFW staff have observed frogs within stream channel 52651 and other small downstream ponds into which the stream flows (e.g., Pond 14799; Figure 4). CDFW monitored the Beebe Lakes SNYLF population annually during fish removal efforts, and staff plan to continue monitoring at least biennially. Now that fish removal is complete, CDFW manages all sites in the NSR as amphibian resources.



Year	2002*	2005	2008	2010	2012	2014†	2015	2016	2017
Adult	18	28	18	3	15	11	11	12	12
Subadult	30	23	62	2	44	40	5	9	0
Larvae	30	34	3	17	67	55	0	11	0

Figure 5: Total number of Sierra Nevada yellow-legged frogs (SNYLF) of each life stage observed in the Beebe Lakes area between 2002 and 2017. Yearly totals primarily include observations from Ponds 14774, 14802, and 14829. The chart also includes one adult observed in stream widening Pool 14785 in 2017 and one adult observed in Pool 14799 in 2015. This chart does not include observations from Pond 14706 (see below).

*CDFW crews did not survey Pond 14829 in 2002.

†CDFW crews began surveying stream segment 52651 in 2014. Crews have only observed post-metamorphic SNYLF in stream segment 52651 (one in 2014, one in 2015, five in 2016, and one in 2017).

Figure 6: Pond 14774 in July 2015, looking south. This pond is located approximately 500 m northwest of Beebe Lake. CDFW survey crews have observed breeding Sierra Nevada yellow-legged frogs (SNYLF) and southern long-toed salamander larvae (*Ambystoma macrodactylum sigillatum*, AMMA) in this pond. Fifteen years of monitoring data suggest that this population is declining. However, deriving trends is difficult due to the extremely small population size. CDFW staff did not observe SNYLF in Pond 14774 during 2015 or 2016 and it was not surveyed in 2017. However, due to several years of drought conditions, the pond dried to a small, shallow pool by late summer. In 2015, staff observed adult and subadult SNYLF in nearby wetted habitat, so frogs may have temporarily emigrated from this area to seek more persistent water sources.. Surveying this site in 2018 will be a priority during the Beebe Lake basin monitoring surveys. (CDFW)

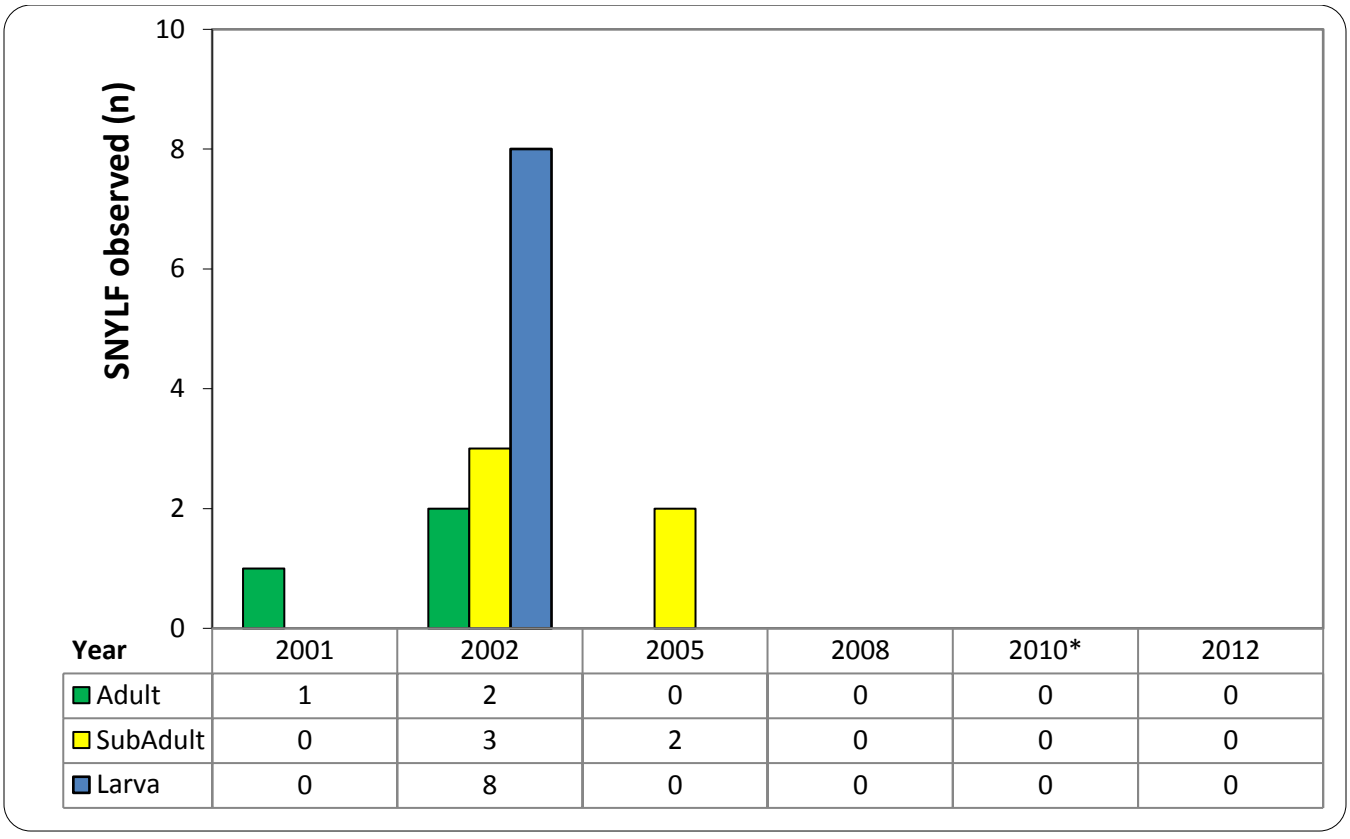
Figure 7: Pond 14802 in July 2015, looking west. This pond was first surveyed by CDFW in 2002. This pond is located about 600 m east of Beebe Lake. CDFW survey crews have consistently observed breeding SNYLF and AMMA) in this pond. SNYLF appear to be declining at this location, although staff observed 27 SNYLF egg masses on July 26, 2010, suggesting that at least 27 females were present in the area. Pond 14802 is connected to Pool 14829 by a seasonal stream not shown in Figure 4, and frogs may move between the sites. (CDFW)

Figure 8: Stream widening Pool 14829 in July 2015, looking northeast. Pool 14829 is not a pond, but a heavily vegetated stream widening that consistently holds water. This pond is located approximately 500 m south of Beebe Lake. In the 2001 baseline survey at this location, CDFW found no SNYLF. However, in 2005, staff observed 13 adults and 1 larva. Since that time, CDFW staff have consistently observed adult SNYLF at the site. SNYLF may be plentiful here, but observing individuals in the thickly vegetated terrain is difficult. Additionally, the extent of wetted habitat likely varies widely based on water conditions and time of year. Pool 14829 is connected to Pond 14802 by a seasonal inlet, so SNYLF may be occasionally moving between the two areas. As with other locations in the Beebe Lakes area, population trends are difficult to estimate because of the very low number of detections and habitat that is difficult to effectively survey. (CDFW)

Pond 14706

Pond 14706 (Figure 9) is located about 2 km north of Beebe Lake, close to the Mokelumne Wilderness boundary, above Telephone Gulch. Pond 14706 is the only other area in the Beebe Lakes drainage in which CDFW crews have observed SNYLF during VES. During the baseline survey in 2001, CDFW crews observed a single adult SNYLF (Figure 10). Staff observed a few SNYLF of various life stages in 2002, and only two subadults in 2005. Staff did not observe SNYLF larvae or post-metamorphic frogs in 2008 and 2010. However, CDFW did detect three egg masses in late July 2010. SNYLF may now be extirpated from this pond. Given that crews observed SNYLF egg masses in 2010, and CDFW has not surveyed the site since 2012, staff should conduct a VES in 2018 to provide further evidence regarding whether or not SNYLF are extirpated from Pond 14706.

Figure 9: Pond 14706 in August 2012, looking southwest.



Year	2001	2002	2005	2008	2010*	2012
Adult	1	2	0	0	0	0
SubAdult	0	3	2	0	0	0
Larva	0	8	0	0	0	0

Figure 10: Maximum SNYLF counts by life stage at Pond 14706. *Three egg masses observed in 2010 are not displayed. CDFW has not surveyed Pond 14706 since 2012.

FISH REMOVAL

The fish removal areas in the Beebe Lakes drainage included Beebe Lake (Site ID 14797), Beebe Meadow (Site IDs 14791, 14795, and 14799), and the fish-bearing stream segment flowing into Beebe Meadow (Site IDs 14785, 14787, and 52651; Figure 11). The discussion below summarizes the details of fish removal efforts in the Beebe Lake drainage between 2011 and 2017.

Beebe Lake

CDFW and ENF staff initiated fish removal in Beebe Lake in 2011. Staff set six nets in the lake for a few days in early November and caught 74 brook trout. CDFW then placed nine nets in the lake to capture brook trout overwinter. Crews returned to the site in July 2012 and removed 52 brook trout from the overwinter gill nets. CDFW and ENF staff placed additional nets in Beebe Lake for summer 2012, during which crews captured another 134 brook trout. Staff set overwinter gill nets in Beebe Lake during the 2013 field season and did not capture any brook trout. Additionally, staff did not capture any fish in multiple nets set during summer 2014. On October 9, 2014, CDFW set six overwinter gill nets in Beebe Lake. Staff pulled these nets in July 2015 and returned zero brook trout. Field crews have not captured or observed any brook trout since October 12, 2012. Therefore, CDFW declared Beebe Lake brook trout removal completed in summer 2015. However, staff will continue occasional monitoring over the next several years to provide additional confirmation.

Beebe Meadow and the associated stream channel

Around the time ENF and CDFW initiated fish removal efforts in Beebe Lake, research undertaken by CDFW, USFS, and university partners began demonstrating that SNYLF utilize meadow and stream habitat in the Northern Sierra Nevada more widely than previous research efforts suggested. Concurrently, during the 2012 field season, CDFW and ENF staff observed brook trout in a small pond within a stream channel below Beebe Lake. Although not directly connected to the lake, the topography in the area is relatively level. Therefore, staff concluded that it might be possible for brook trout to move from the stream back into Beebe Lake during a very large water year. In addition, staff observed a post-metamorphic SNYLF co-existing with fish in wetted sections of the stream.

Drought beginning in 2012 created conditions that allowed brook trout removal from Beebe Meadow and the associated stream using gill nets and electrofishing units. Removing brook trout from the whole meadow/stream complex is highly desirable, not only to prevent brook trout from returning to Beebe Lake during a high water year, but also because brook trout have relegated the remaining SNYLF populations to marginal habitats outside Beebe Lake and Beebe Meadow (Figure 11). CDFW determined that eradicating brook trout from the meadow/stream complex would potentially allow free movement between all remaining SNYLF populations in the watershed, and provide SNYLF access to additional high quality fishless habitat.

As a result, in July 2014, CDFW began removing fish from Beebe Meadow, associated pools, and the connected stream channel to provide additional aquatic habitat for SNYLF. Staff removed 203 brook trout, including young of the year, indicating that brook trout had successfully bred in 2013 despite drought conditions. CDFW determined that enough adult brook trout were removed in 2014 to prevent spawning. Crews set three overwinter nets in Beebe Meadow during winter 2014–2015 and captured no brook trout. During summer 2015, staff removed 23 brook trout (11 with gill nets and 12 with backpack electrofishing units) from the stream and associated meadow ponds. Staff did not capture any brook trout during the last two visits of the season. Staff also did not observe any trout fry at any time in 2015, suggesting that adult fish did not spawn in 2014. Exceptionally dry conditions in late summer 2015 provided an additional stressor for any remaining fish.

CDFW staff set a few gill nets in the stream and Beebe Meadow ponds during summer 2016. Staff captured no brook trout. Additionally, ENF crews performed multiple electrofishing passes of the stream segment (Site ID 52651) in September and detected no brook trout. Staff left six nets in the Beebe Meadow ponds (Site IDs 14791, 14795, and 14799) overwinter to provide confirmation of brook trout removal in the meadow (Figure 12).

On August 9, 2017, CDFW staff removed the six overwinter gill nets from Beebe Meadow area. Staff did not capture any brook trout or otherwise observe any fish while removing gill nets. Staff returned to the area on September 6, 2017 to conduct VES for SNYLF, and remained vigilant for brook trout. Staff did not detect any fish during visual searches of the basin, including complete surveys of Beebe Lake, the drainage from stream segment 52651 downstream to Lower Beebe Lake (Site ID 2694), and various small ponds in the vicinity (Figure 4).

In total, CDFW and ENF crews removed 486 brook trout from the site during brook trout eradication efforts between 2011 and 2017. An additional 57 brook trout had been removed from the basin during lake monitoring surveys (in which crews set a single overnight gill net to assess fish populations) in Beebe Lake (17 brook trout collected in 2001, 37 brook trout collected in 2010), stream pond 14785 (one brook trout in 2012), and stream pond 14787 (two brook trout in 2012). CDFW has determined that the basin is now likely fishless. However, staff plan to use a backpack electrofishing unit to survey the stream segment (52651) one more time during summer 2018 to provide additional evidence of brook trout eradication. Additionally, staff will continue occasional monitoring at the site to survey for brook trout.

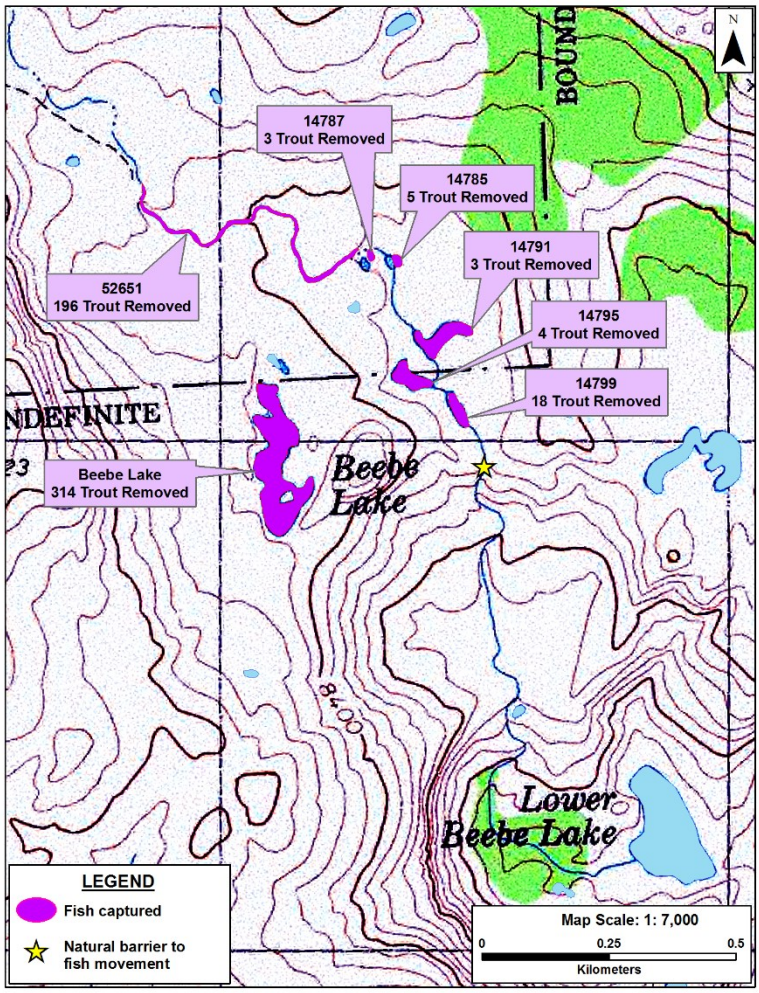


Figure 11: Locations with fish captures during Beebe Lakes drainage fish removal. Labels show lake site IDs and the number of brook trout captured at that site between 2011 and 2015. (Total also includes brook trout removed from Beebe Lake in 2001 and 2010 during baseline gill net surveys.) Apart from 170 brook trout removed from stream 52651 using backpack electrofishing units, all brook trout were removed using gill nets. No brook trout were captured during fish removal efforts from fall 2015–summer 2017. Location of natural barrier to upstream fish movement is shown at the yellow star.

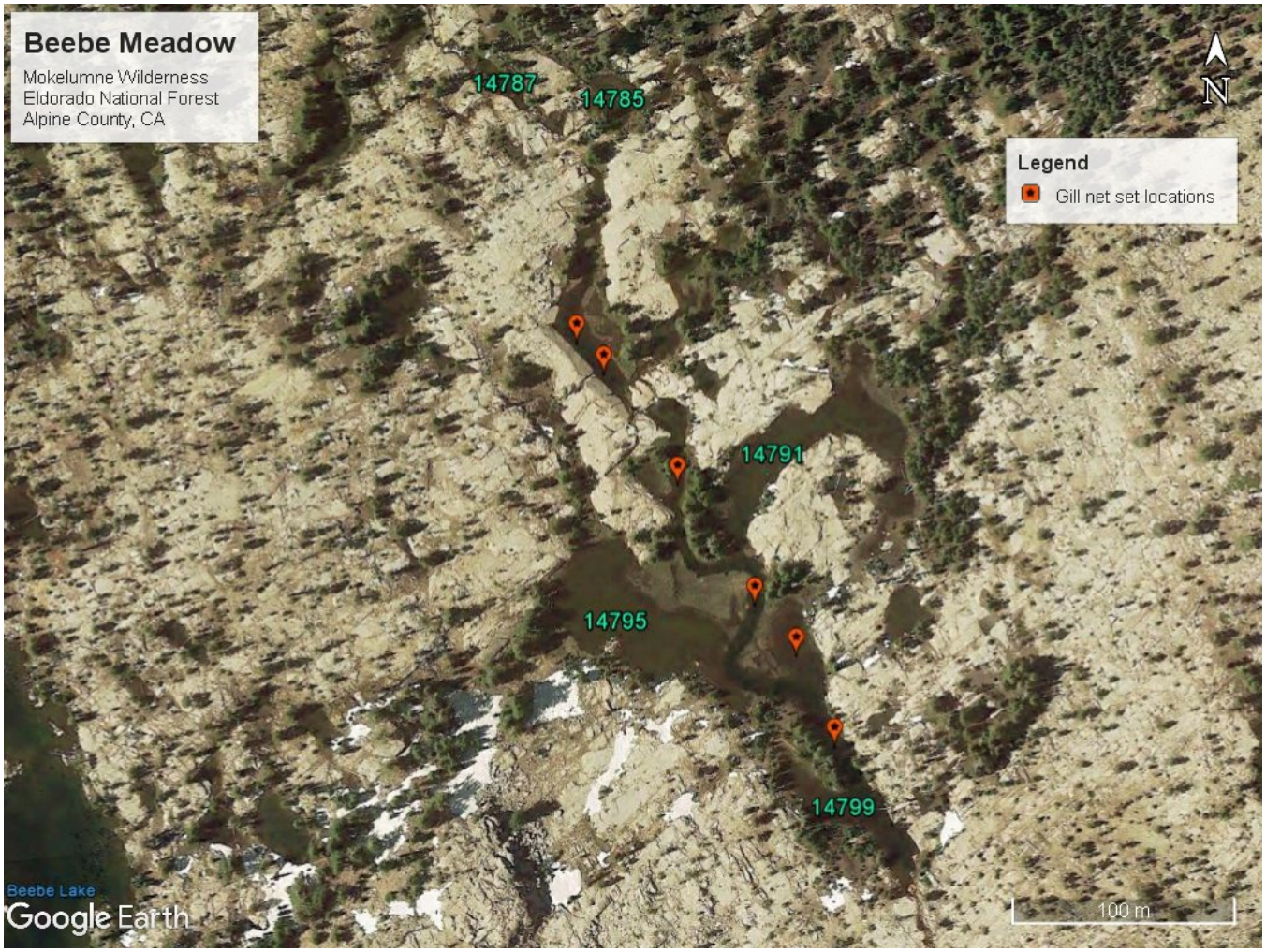


Figure 12: Locations of final gill nets placed in Beebe Meadow during winter 2016–2017. This map also shows the 2m deep channel between 14799 and 14795 that will potentially provide larval SNYLF habitat. (Google Maps)

DISCUSSION

Beebe Lake presented a rare opportunity to remove fish from a site in Alpine County with a persistent SNYLF population in the vicinity. Opportunities to increase the availability of fishless habitat for SNYLF in a wilderness setting with low public use and locally extant frog populations are increasingly rare, particularly in Alpine County. CDFW selected Beebe Meadow for further fish removal for three primary reasons: 1) preventing the possibility of non-native trout reinvading Beebe Lake, 2) providing connectivity between several small SNYLF populations restricted to small ponds by trout, and 3) providing SNYLF with fishless habitats (a stream segment and several small ponds) recently found to be beneficial for the species. A combination of physical fish removal methods and environmental conditions allowed for successful fish removal in the basin.

As of fall 2015, Beebe Lakes drainage is likely fishless. CDFW is confident that increasing available habitat and reconnecting isolated populations will improve the likelihood that SNYLF will persist in Lower Summit Creek PWS. Although the local SNYLF population may have been slowly declining, surveyors have generally observed that most places that continue to hold water also contain SNYLF. Therefore, there is reason for optimism: now that brook trout are absent from the upper watershed, SNYLF may begin to rebound over the next several years.

<u>Recent Environmental Conditions</u>

The cumulative period between summer 2012 and summer 2015 may be the worst drought in modern times (Robeson 2015). Additionally, severity of the drought was greatly exacerbated by record high temperatures

(AghaKouchak et al. 2014), which add support to the 2012–2015 drought being one of the worst California has experienced in over a thousand years (Griffin and Anchukaitis 2014, Hatchett et al. 2015). The increased temperatures worsened drought impacts, in part by resulting in earlier snowmelt, speeding snowmelt rates, and causing precipitation in the form of rain for many elevations that normally receive snow (Garfin et al. 2014). Climate models predict that severe events like the 2012–2015 drought may become more common (Mastrandrea et al. 2011), which could prove deleterious for cold-water aquatic ecosystems in the Sierra Nevada (Null et al. 2013).

The low snowpack and early season drying may have negatively affected SNYLF populations throughout the Sierra Nevada (CDFW, unpubl. VES data). Smaller, shallower habitats may be at increased risk for drying earlier (or, in some years, drying altogether) during these exceptionally warm and extended dry periods. This drying may be detrimental to SNYLF because, in many locations, nonnative fish have restricted frog populations to smaller, shallower, more ephemeral habitats. For example, in 2015, many small streams that normally flow well into early fall were dry by early in the summer. Numerous ephemeral ponds, including areas occupied by SNYLF, dried early in the season during the drought period. The early season drying of more ephemeral wetland habitats (e.g., meadows, small streams, and small/shallow ponds) may have led to more limited dispersal ability and reproductive success for some SNYLF populations. However, lower numbers of frogs and tadpoles could also be the result of many other factors, including survey conditions, observer bias, and mortality caused by *Bd*.

Alternatively, other SNYLF populations in the northern Sierra Nevada appeared to increase during the drought period (CDFW, unpubl. VES data), possibly because the reduced snowpack, warmer temperatures, and overall mild conditions helped increase overwinter survival. However, although SNYLF populations may have benefitted from the atypical overwinter conditions in the short-term, it is equally possible that prolonged drought could prove detrimental to SNYLF populations in the long-term.

Drought and warming are a serious concern for California (in terms of reduced snow pack, less snow pack persistence, increased temperatures, and higher evaporation rates; Garfin et al. 2014). However, from a restoration perspective, there was a great benefit to the drought conditions in 2012–2015: less available aquatic habitat for brook trout. The drought resulted in parts of Beebe Meadow drying completely, lower water levels in all fish-containing ponds, and reduced spawning habitat. From a logistical perspective, lower water levels and drying helped improve the efficiency of eradication efforts by concentrating brook trout into more manageable areas. Additionally, reduced flow between sections of the Beebe Lakes drainage helped limit fish from being able to access new areas, or recolonize locations from which crews had already removed fish.

In direct opposition to the drought, precipitation quantity during winter 2016–2017 was record-setting in the northern Sierra Nevada (CDWR 2017a). The northern Sierra Nevada received a well above average snowpack (about 150% of average on April 1, 2017; CDWR 2017b). These conditions resulted in Beebe Lakes basin being covered in snow well into July 2017 (Figure 13). These conditions may have increased SNYLF mortality, which can occasionally happen during years with long winters and deep snow pack (Bradford 1983). However, such events are natural: SNYLF have evolved in an environment with variable winter conditions.

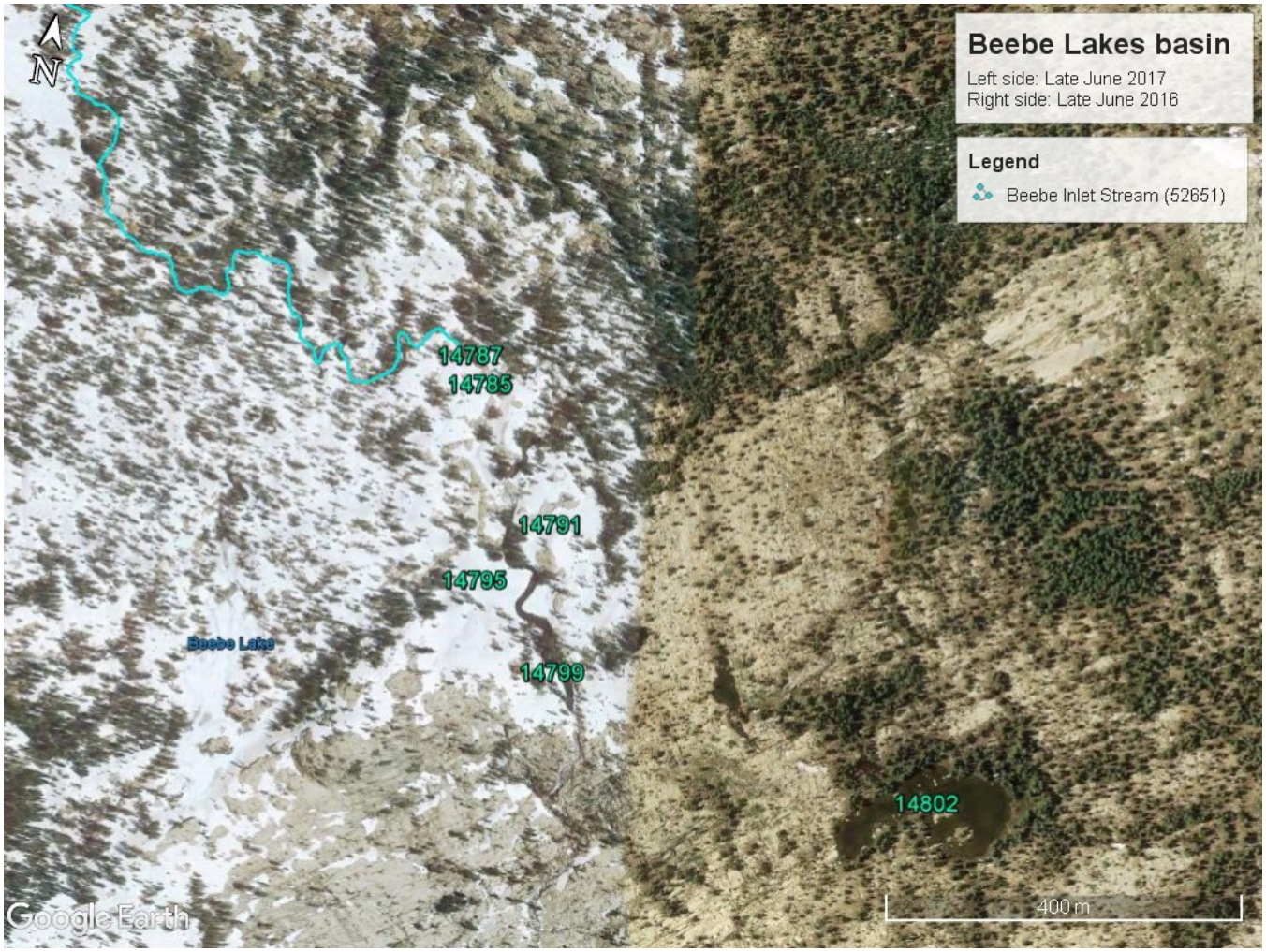


Figure 13: Comparison of snow cover in the Beebe Lakes basin between late June 2017 (left side of the image) and late June 2016 (right side of the image). Beebe Lake and much of the surrounding basin was still completely covered in snow and ice well into July 2017 (Google Maps)

Monitoring Considerations

Seventeen years of monitoring data suggest the Beebe Lakes SNYLF populations are slowly declining, although data collected since 2012 suggest a stable population. However, observer bias, variation in survey conditions, and relatively low number of detections all make deriving trends difficult. Additionally, 2015 was the first season that SNYLF did not have to share high quality stream and meadow habitat with introduced brook trout. Another consideration is that the pendulous swing from one extreme in conditions (drought) to another (record precipitation) makes interpreting population trends even harder.

It is possible that the SNYLF populations in the Beebe drainage will begin increasing during the next several years. Additionally, it is worth noting the habitat around Beebe Lake consists of the lake, several small tannin ponds (into which visibility can be highly limited), multiple springs, a long stream channel, and a large meadow complex with dozens of isolated depressions that occasionally hold water. Habitat around many of the deeper wetted areas also consists of dense vegetation. All of these conditions result in a variety of habitat for SNYLF to select from throughout the year, including recently fishless deep water habitat in Beebe Lake and very difficult conditions for staff conducting visual encounter surveys. The difficulty of detecting SNYLF makes meaningful population size estimation problematic. CDFW will continue to monitor the Beebe Lake SNYLF population to assess the population status over time.

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