

State of California
Department of Fish and Wildlife

Memorandum

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Sierra District Supervisor;
North Central Region Fisheries

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

Cc: Region 2 Fish Files

Ec: CDFW Document Library

Subject: Native amphibian restoration and monitoring in Mokelumne Wilderness;

- Beebe Lakes *Rana sierrae* monitoring
- Updates on non-native fish removal



Beebe Lake (June 2020; CDFW)

SUMMARY

Beebe Lakes drainage is an area from which California Department of Fish and Wildlife (CDFW) and Eldorado National Forest (ENF) staff had worked to remove introduced Brook Trout (*Salvelinus fontinalis*; BK) to restore habitat for the state threatened Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF). Those interested in learning more about the previous Beebe Lakes drainage BK removal may consult the [2017 Beebe Lakes area survey memorandum](#) (CDFW 2018).

In late June 2020, CDFW staff visited the Beebe Lakes drainage (**Figure 1**) to conduct visual encounter surveys (VES) for native amphibians. During the visit, CDFW staff observed small fish in the littoral zone of Beebe Lake. These observations triggered a follow-up visit in September, during which CDFW captured 63 BK from two monofilament gill nets set for two weeks. Following these observations, CDFW deployed more gill nets into Beebe Lake and the meadow area east of Beebe Lake. CDFW also reinstated backpack electrofishing in the stream channel north of Beebe Lake, which flows into Beebe Meadow.

Amphibian monitoring data from 2012 through 2020 suggest a small SNYLF population that may be stable or declining. CDFW will continue annual amphibian monitoring to document SNYLF response to fish removal. Additionally, CDFW will continue intensive BK removal efforts in 2021, with the goal of removing all fish from Beebe Lake, Beebe Meadow, and stream inlet to Beebe Meadow.

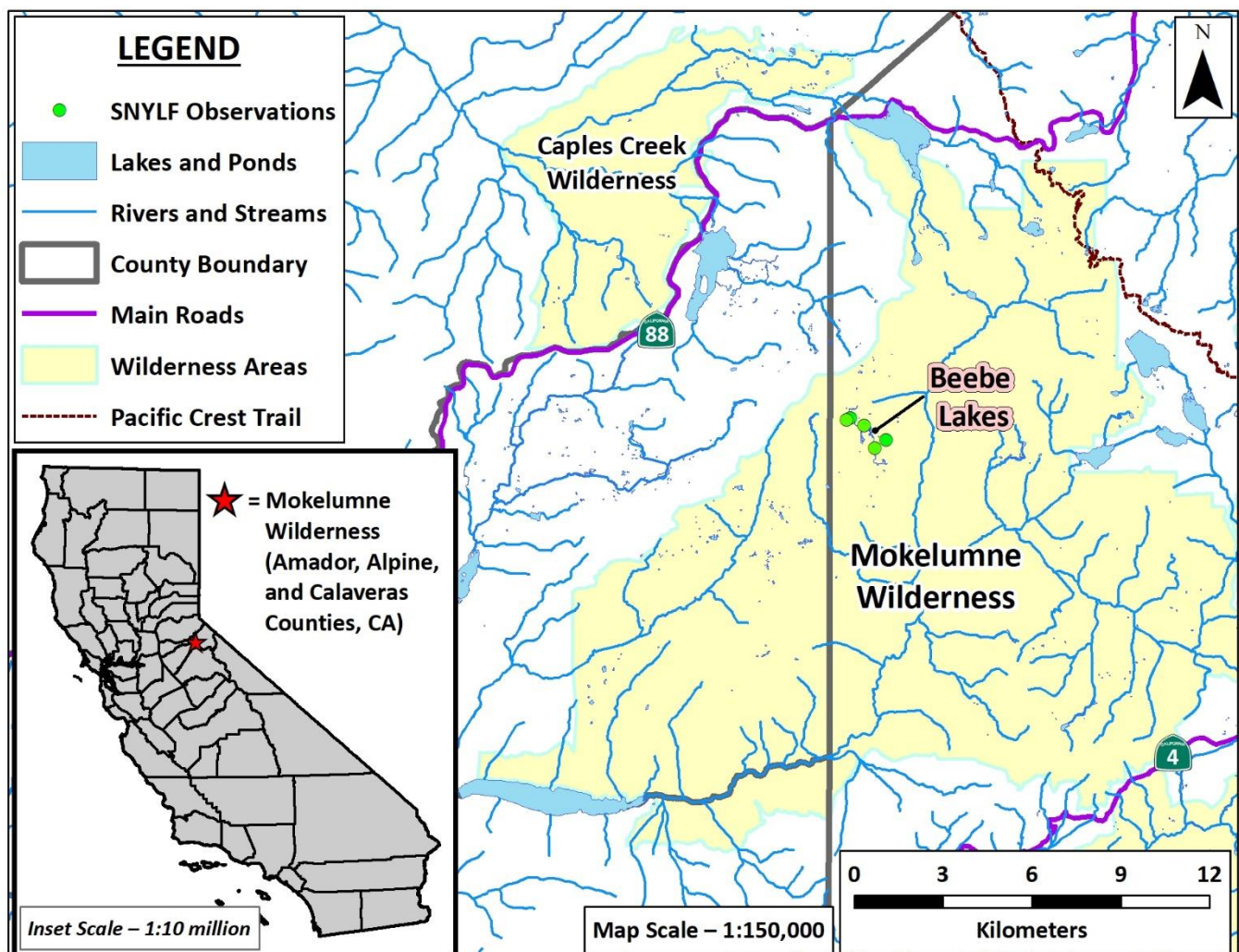


Figure 1. Mokelumne Wilderness, Amador, Alpine, and Calaveras Counties, CA. Green dots show Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) detections by California Department of Fish and Wildlife (CDFW) staff during 2020 visual encounter surveys (VES).

ENVIRONMENTAL SETTING

Beebe Lakes drainage is located in the Mokelumne Wilderness, just east of the Alpine County line. The basin is on the western slope of the Sierra Nevada, between 2,408 and 2,591 meters (m; or 7,900 and 8,500 feet [ft]) in elevation. Eldorado National Forest manages the land and issues grazing permits in the area. The site is accessed by driving rough four-wheel drive roads from the Silver Lake area off State Route 88, then hiking east into the Mokelumne Wilderness, past an old trading post, and through Ladeux Meadow before reaching Beebe Lakes basin. CDFW staff conducted baseline surveys in 2001 and 2002, during which staff captured BK in Beebe Lake during an overnight gill net survey. Staff also observed SNYLF (**Figure 2**) at four sites in the area. All SNYLF populations in the area are small and isolated. CDFW and ENF determined that eradicating BK from the Beebe Lakes area using gill nets and backpack electrofishers would be feasible and provide SNYLF with more deep-water habitat.

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; which is filling in and no longer a lake, but rather an occasionally flooded meadow with a stream channel), Beebe Meadow (Site IDs 14791, 14795, and 14799), approximately 1.5 kilometers (km) of stream (Site IDs 52651, 52707, and 52783), three small ponds with consistent SNYLF observations (Site IDs 14774 [**Figure 4**], 14802, and 14829), and several other small ponds in the basin as a Native Species Reserve (NSR; **Figure 5**) for SNYLF. Thus far, CDFW staff have not observed SNYLF in Beebe Lake. However, although only reaching a maximum depth of about 4 m, Beebe Lake is the deepest wetted habitat in the basin. Additionally, Beebe Lake is located approximately halfway between Site IDs 14774 and 14802. Therefore, removing BK from Beebe Lake, Beebe Meadow, and the adjoining stream is required to create a series of interconnected fishless aquatic habitats for SNYLF.

Beebe Lake was stocked with BK from 1930 until 2000. Gill net sampling conducted by CDFW staff in 2001 and 2010 revealed that the BK population in Beebe Lake was self-sustaining. Beginning in 2011, CDFW, with assistance from ENF personnel, began removing BK from Beebe Lake and the surrounding area to benefit SNYLF. As of 2018, after three years of monitoring without detecting BK, CDFW had determined the basin was fishless. Prior to 2020, the most recent BK capture was in 2015. However, in 2020, CDFW discovered that BK had reemerged in the basin. Therefore, CDFW has reinstated fish removal efforts. Additionally, staff will continue to regularly survey the Beebe Lakes basin SNYLF population and increase monitoring for presence of any latent BK.



Figure 2. Adult Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) at Site ID 52707 in June 2020. (CDFW)



Figure 3. Beebe Lake (Site ID 14797) in June 2020, looking north. (CDFW)



Figure 4. Site ID 14774 in June 2020, looking southeast. This meadow pool is one of the few locations in Beebe Lakes basin where California Department of Fish and Wildlife staff (CDFW) have observed Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) breeding. (CDFW)

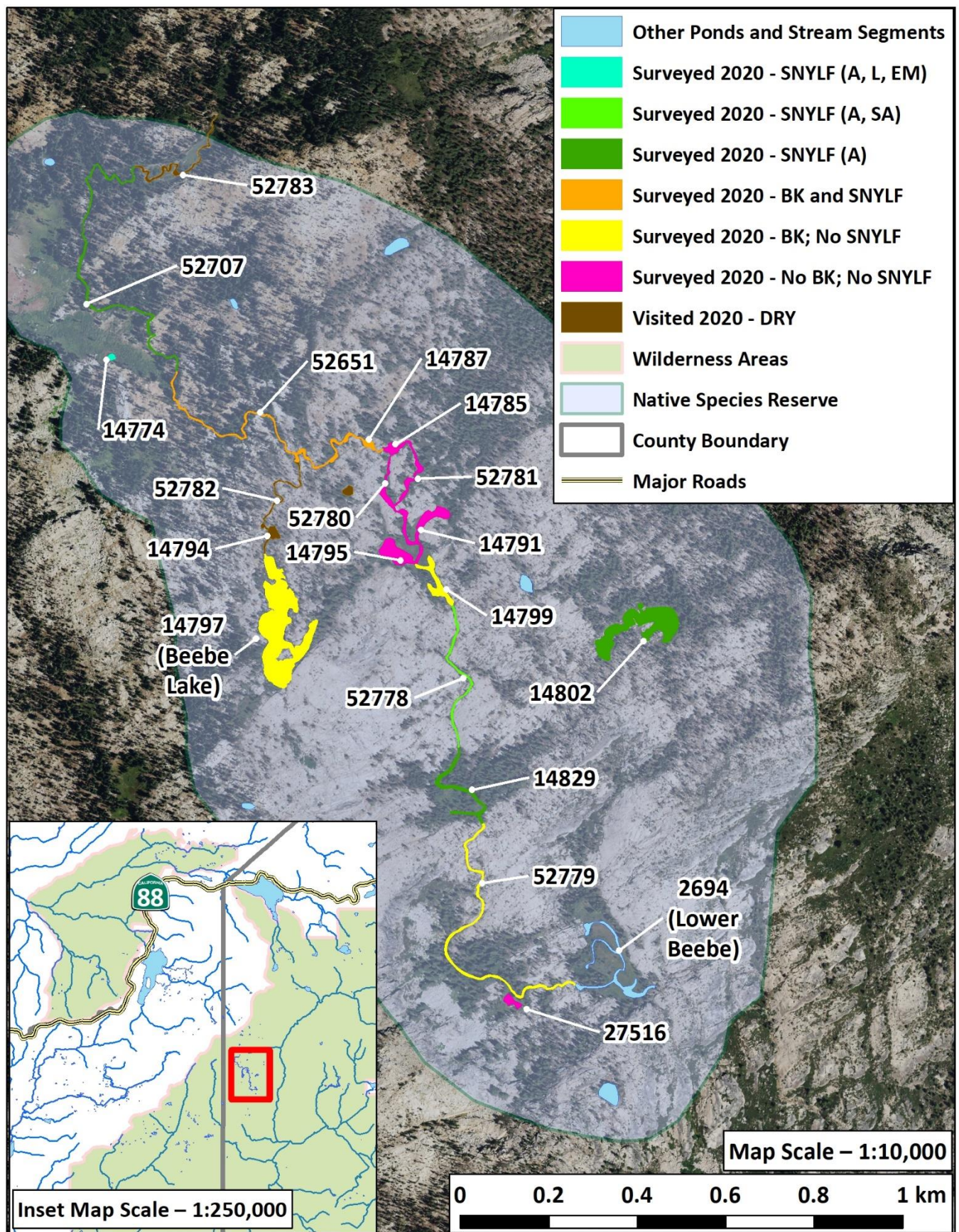


Figure 5. [See figure caption at the beginning of the next page.]

Figure 5 (continued). Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) and Brook Trout (*Salvelinus fontinalis*; BK) detections in Beebe Lakes Native Species Reserve (NSR) by California Department of Fish and Wildlife (CDFW) field staff in 2020. In prior surveys, CDFW staff have observed all SNYLF life stages in three ponds within the NSR (Site IDs 14774, 14802, and 14829). In the time since fish removal efforts began in 2011, CDFW staff have observed SNYLF adults and/or subadults in several other parts of the basin, including Site IDs 14785, 14799, 52651, 52707, 52778, and 52781. SNYLF letter codes in the legend, which indicate the life stage(s) observed during recent surveys, are as follows: “A” = adults, “SA” = subadults, “L” = larva (tadpoles), and “EM” = egg masses. In 2020, CDFW field staff discovered that BK had reinvaded several areas of the NSR (discussed in the [“THREATS”](#) and [“BROOK TROUT REMOVAL: DISCUSSION”](#) sections below). Number labels are unique site identification codes that CDFW uses for data collection. All flowing waters in the basin drain south, then east into Summit City Creek, and eventually into the North Fork Mokelumne River. In 2020, CDFW added several new Site IDs to the Beebe Lakes NSR, including 52778 (the stream segment between Beebe Meadow and 14829), 52779 (the stream segment between 14829 and 2694 [Lower Beebe]), 52780 (the western stream channel between 14785 and 14791 that contains a long, deep pool), 52781 (the eastern stream channel between 14785 and 14791), 52782 (the ephemeral stream flowing from Beebe Lake to 52651), and 52783 (an ephemeral meadow stream segment just upstream of 52707). CDFW also updated several existing GIS polygons to reflect the composition of the depicted waterbodies more accurately.

THREATS

Disease

All known SNYLF populations in the Mokelumne Wilderness are positive for chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*). In 2008 and 2010, CDFW collected epithelial swabs from SNYLF in the Beebe Lakes NSR and had the samples screened for the presence of *Bd* DNA using real-time quantitative polymerase chain reaction (qPCR) analysis. Staff collected 11 swabs from sites 14774, 14802, and 14829, and results from both years detected very light to moderate zoospore loads.

Marginal Habitats

SNYLF populations in the surrounding area are persisting at small, isolated ponds and their seasonally flowing tributaries (**Figure 5**). 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

Those interested in a detailed accounting of previous Beebe Lakes drainage BK removal may consult the [2017 Beebe Lakes area survey memorandum](#) (CDFW 2018). What follows is a summary of those earlier efforts and a discussion of findings in 2020. CDFW and ENF staff originally began removing introduced BK from Beebe Lake in 2011. Before 2020, the last BK to be captured in Beebe Lake were during summer 2012. Subsequent gill net sets from fall 2012 until early summer 2015 yielded no BK captures. Therefore, CDFW removed gill nets from Beebe

Lake in July 2015, after more than two years of constant gill net sets with no BK captured. One notable event during the latter period of fish removal occurred in summer 2014, during which one or more people removed most of the nets from the lake. The looters damaged several nets, including somehow stringing several into the canopies of dead trees adjacent to Beebe Lake (**Figure 6**). Between July 2015 and August 2020, CDFW set no gill nets in Beebe Lake.



Figure 6. Gill net sabotage at Beebe Lake in September 2014. (CDFW)

CDFW also used gill nets and electrofishing to remove BK from Beebe Meadow and the inlet stream (i.e., Site IDs 52707 and 52651; **Figure 5**). Staff had gill nets set in the meadow pools from July 2014 to August 2017. Late September 2015 was the last time CDFW captured any BK in Beebe Meadow or the inlet stream. In September 2016, ENF crews performed multiple electrofishing passes of the meadow inlet stream and detected no BK. In 2016, CDFW staff left six gill nets in the Beebe Meadow ponds (Site IDs 14791, 14795, 14799, and 52780; **Figure 5**) overwinter to provide confirmation of BK removal in the meadow. In August 2017, CDFW staff removed the six overwinter gill nets, none of which contained fish. The final confirmation rounds of electrofishing for the BK removal project occurred in late September 2018, during which CDFW staff completed three full passes of the Beebe Meadow inlet stream with no BK detected. In all, between 2016 and 2018, CDFW and ENF staff completed 14 electrofishing passes of the Beebe Meadow inlet stream (areas holding water in Site IDs 52707 and 52651; **Figure 5**) with no BK detected.

During VES in late June 2020, CDFW field staff observed small fish in the littoral zone of Beebe Lake. These observations triggered a follow-up visit in mid-September, during which CDFW set two gill nets in Beebe Lake to attempt capturing and identifying the fish present. The gill nets captured 63 BK during a two-week set (**Figure 7**). All fish captured were either large adults (≥ 300 mm total length [TL]; $n = 16$) or approximately age 1 (“juveniles”; ~ 100 – 130 mm TL; $n = 47$; Hall 1991). Following these observations, CDFW returned to the site from 30 September to 1 October and deployed twelve 30-m (100-ft) monofilament gill nets into Beebe Lake. Staff also set three

gill nets into the deeper ponds in Beebe Meadow. Staff could not deploy additional gill nets in the meadow due to extremely low water levels following one of the driest water years on record (CDEC 2020a). Additionally, staff used a backpack electrofisher to capture fish in areas with shallow water in Beebe Meadow, nearby connected ponds (e.g., Site IDs 14785 and 14787), and the wetted stream segments (i.e., Site IDs 52651 and 52707; **Figure 5**).

During these efforts, staff removed 74 BK from Beebe Lake (nine adults and 65 juveniles) and two BK from the stream channel that flows into Beebe Meadow (an adult from Site ID 14787 and a juvenile from Site ID 52651). CDFW left the 12 gill nets in Beebe Lake and the three gill nets in the meadow from 1–19 October, after which staff returned to check the nets. On 19 October, staff removed 32 BK from Beebe Lake (three adults and 29 juveniles) and one adult from Site ID 14799. In total, CDFW removed 172 BK from the Beebe Lake NSR in 2020 (**Table 1**). Before leaving the site on 20 October, CDFW staff removed all gill nets from the meadow (in which nets tend to get damaged and/or buried by early season high flows) and half of the gill nets from Beebe Lake. Six gill nets remain in Beebe Lake, which CDFW will check once the site becomes accessible in early summer 2021.

Table 1. Date(s), location(s) (Site ID[s]), effort (number of gill nets [# nets] per date range; or backpack electrofishing [e-fishing]), and total number of Brook Trout (*Salvelinus fontinalis*; BK) removed from the Beebe Lakes area by California Department of Fish and Wildlife (CDFW) field staff in September and October 2020. All adult BK were ≥ 300 mm total length (TL) and “juveniles” were all approximately age 1 fish (~ 100 –130 mm TL). See **Figure 5** for specific locations of all Site IDs listed below.

Date(s) of effort	Site ID(s)	# nets (or e-fishing)	# of BK adults	# of BK juveniles	Sum BK (row)
9–23 Sep	14797 (Beebe Lake)	2	16	47	63
30 Sep–1 Oct	14797 (Beebe Lake)	12	9	65	74
1–19 Oct	14797 (Beebe Lake)	12	3	29	32
19 Oct– [~Jun 2021]	14797 (Beebe Lake)	6	Will check in 2021.	Will check in 2021.	N/A
30 Sep–1 Oct	14791	1	0	0	0
30 Sep–1 Oct	14799	1	0	0	0
30 Sep–1 Oct	52780	1	0	0	0
1–19 Oct	14791	1	0	0	0
1–19 Oct	14799	1	1	0	1
1–19 Oct	52780	1	0	0	0
30 Sep	14785, 14787, 14791, 14795, 14799, 52651, 52707, 52780, 52781	e-fishing	1 (in Site ID 52651)	1 (in Site ID 14787)	2
1 Oct	14791, 14795, 14799	e-fishing	0	0	0
TOTAL BK			30	142	172



Figure 7. Brook Trout (*Salvelinus fontinalis*; BK) captures from two gill nets set in Beebe Lake between 9 and 23 September 2020. All fish were either large adults (~300 mm total length [TL]) or age 1 juveniles (~100–130 mm TL). Subsequent fish removal work during fall 2020 resulted in captures exclusively within these two size classes.

CDFW does not know whether BK were still present somewhere in the NSR following initial fish removal efforts, or if fish were illegally planted back into Beebe Lake. Although sabotage is possible, CDFW cannot rule out failure of the original eradication efforts. More detailed considerations are included below in the [“BROOK TROUT REMOVAL: DISCUSSION”](#) section.

Cattle Grazing

Studies investigating direct interactions between cattle and SNYLF populations have not been conducted. However, the U.S. Forest Service (USFS) acknowledges cattle effects 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). Cattle are often present in the NSR. CDFW field staff observed a cattle herd in the upper meadow of the NSR in fall 2020, and there was abundant evidence of cattle use throughout the area, including tracks and manure.

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; CDFW 2016), the rugged landscape of the Upper Mokelumne results in the 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 (CDFW 2014). In addition to the threats presented by stochastic environmental events (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).

***Rana sierrae* POPULATION STATUS: RESULTS**

In the past, the sites in which a majority of SNYLF have been observed during VES in the Beebe Lakes drainage are Site IDs 14774, 14802, and 14829 (**Figure 5**). During backpack electrofishing on 26 September 2018, CDFW staff observed two adult and three subadult SNYLF in the Beebe Lake meadow inlet stream (Site ID 52651; **Figure 5**). CDFW field staff did not conduct any additional VES during summer 2018. CDFW returned to Beebe Lake in late September 2019, during which staff detected very few SNYLF (**Figure 8**). However, CDFW conducted the surveys late in the summer and conditions were atypically cold during VES.

In late June 2020, CDFW field staff returned to VES the Beebe Lake area. Conditions during these survey efforts were more ideal than those staff experienced in late summer 2019. In 2020, staff surveyed 16 Site IDs in the NSR (**Figure 5**), during which staff observed 12 adults, two subadults, and 132 tadpoles (**Figure 8**). Staff detected nearly all larvae in the perennial meadow pool (Site ID 14774; **Figures 4 and 5**). This is the highest larval SNYLF count observed so far by CDFW in the Beebe Lakes area. The number of post-metamorphic SNYLF that staff observed in 2020 is very similar to counts during the past decade, although subadult SNYLF counts have occasionally been notably higher (e.g., 2008, 2012, and 2014; **Figure 8**). However, the high subadult counts in some years is likely an artifact of survey timing, since observed subadults are often frogs that metamorphosed later in the summer and early fall.

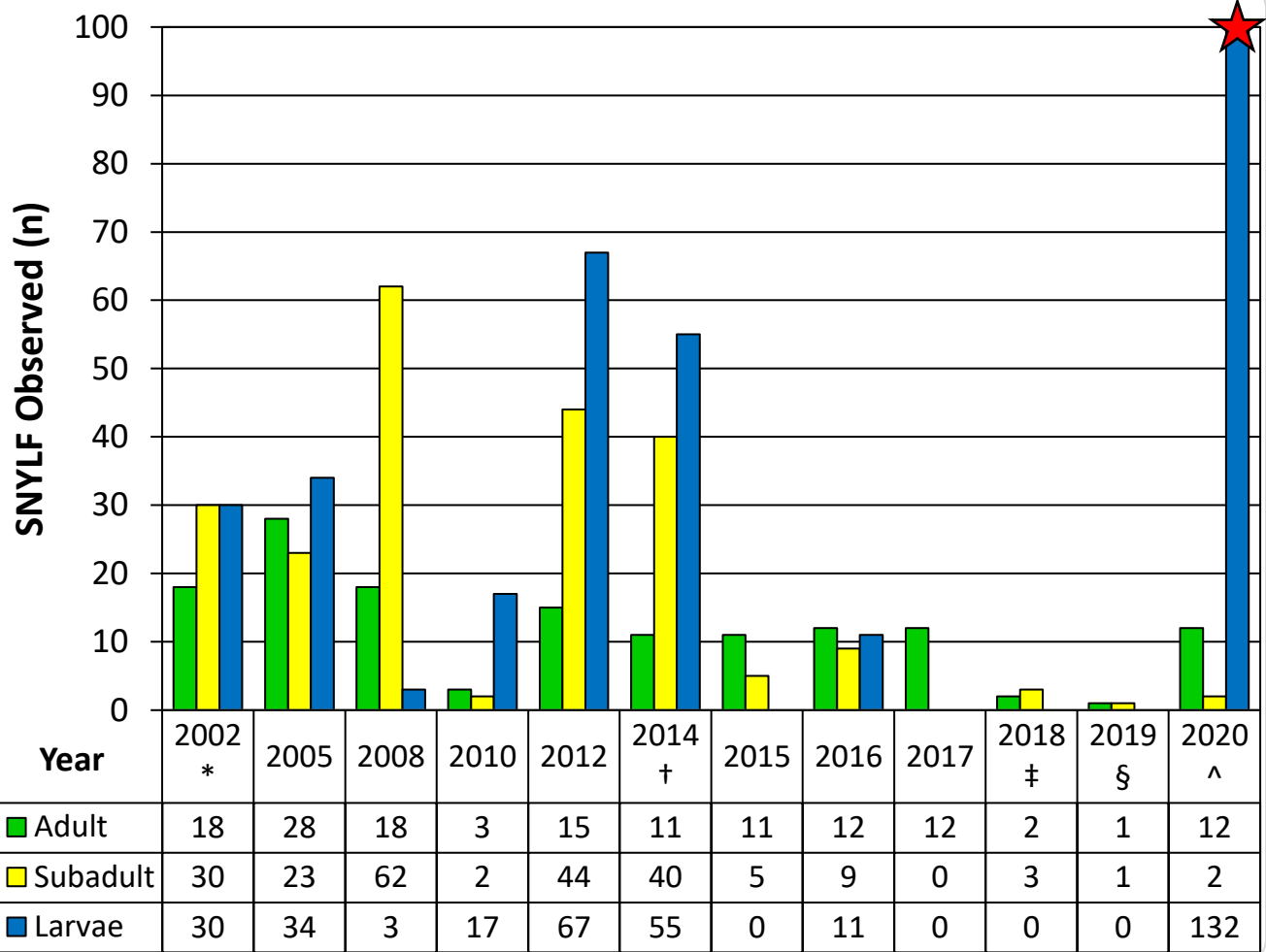


Figure 8. Total number of Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) of each life stage observed in the Beebe Lakes area by California Department of Fish and Wildlife (CDFW) staff between 2002 and 2020. Yearly totals primarily include observations from Site IDs 14774, 14802, and 14829. The chart also includes occasional SNYLF adult individuals seen Site IDs 14785, 14787, 14799, and 52707.

*CDFW did not survey Site ID 14829 in 2002.

†CDFW began surveying Site ID 52651 in 2014. Until 2020, staff had only observed post-metamorphic SNYLF in Site ID 52651 (one in 2014, one in 2015, five in 2016, one in 2017, and five in 2018). However, CDFW observed one subadult and one tadpole in late June 2020.

‡In 2018, CDFW staff did not conduct visual encounter surveys (VES) for SNYLF in the Beebe Lakes basin. Staff only incidentally surveyed Site ID 52651 during three passes of backpack electrofishing on 26 September 2018.

§CDFW staff began surveying Site ID 52707 in 2019.

^In 2020, CDFW staff surveyed farther up the Beebe Meadow inlet stream (Site ID 52707) than during previous surveys. Staff also surveyed the entire stream reach between Lower Beebe and Beebe Meadow (Site IDs 52779, 14829, and 52778).

★ [Red star] Indicates a larval SNYLF count above the scale range of the histogram (n = 132).

***Rana sierrae* POPULATION STATUS: DISCUSSION**

Nineteen years of monitoring data suggest the Beebe Lakes SNYLF population is either remaining relatively stable (albeit at a small population size) or declining (**Figure 8**). However, observer bias, variation in survey conditions, and relatively low number of detections all make deriving trends difficult. Additionally, SNYLF have been forced to contend with introduced predators (BK) for many decades. Although BK were nearly absent from the NSR by 2016, observations in 2020 prove that there was only a brief window—of at most three years—during which SNYLF were not functionally overlapping with BK in at least some locations in the Beebe Lakes area.

Another confounding factor is recent drastic changes in water years. These dramatic seasonal fluctuations increase the difficulty of interpreting population trends. For example, since 2012, winter precipitation in the northern Sierra Nevada has alternated from far below average during an extended drought (2012–early 2016), to record-setting (2016–2017), to well below average (2017–2018), to well above average (2018–2019), and back to far below average (2019–2020, which was even drier than any water year during the 2012–2016 drought; CDEC 2020a). SNYLF mortality can increase during long winters with deep snowpack (Bradford 1983). Contrarily, drought conditions can dry up many areas normally occupied by SNYLF, especially in places like the Beebe Lakes NSR, where much of the available aquatic habitat is small, shallow ponds and ephemeral streams. One of the mitigating factors to exceptionally dry water years is that sections of the meadow west of Site ID 52707 appear to be perennial, and this spring-fed water source prevents the largest pool in the meadow (Site ID 14774; **Figure 4**) and the Beebe Meadow inlet stream from drying entirely during poor water years. Clearly, this water source provides a refuge for SNYLF, in part indicated by the consistent reproduction observed in Site ID 14774.

Two other important environmental considerations are survey timing and weather during the survey. CDFW amphibian VES at Beebe Lakes in 2017 and 2019 occurred during the first and second weeks of September, respectively. Although these dates are within the window of time that survey conditions are generally favorable for SNYLF detectability, weather becomes less predictable during September, and cooler evening temperatures become more common. The Beebe Lake area is one of the higher elevation SNYLF sites in the northern Sierra Nevada (2,560 m [\sim 8,400 ft]), so temperatures at Beebe Lakes during any given time tend to be cooler when compared with many other SNYLF sites in the northern Sierra Nevada.

During both survey occasions in 2017 and 2019, weather conditions were less than ideal. For example, in 2017, VES followed an afternoon of heavy thunderstorms and cool temperatures. Weather conditions were overcast and relatively cool (\sim 17° C [62° F] for a mid-day high) during the survey. In 2019, it was even cooler on the day of surveying, with a mid-day high air temperature of 14° C [57° F] in the NSR. During both years, CDFW surveyed several sites in the morning, during which air temperatures were even cooler (\leq 10° C [\leq 50° F]). SNYLF activity in both years may have been reduced during these relatively cold late summer temperatures.

The habitat composition of Beebe Lakes drainage is another reason that estimating SNYLF abundance is difficult. Available habitat consists of Beebe Lake, numerous 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. Dense vegetation surrounds many of these aquatic areas. This habitat variety is likely beneficial for SNYLF. However, the habitat complexity and thick vegetation also reduces visibility and maneuverability for surveyors. Therefore, SNYLF detectability during VES in the Beebe Lakes drainage is likely very limited.

Despite these challenges, CDFW will continue to monitor the Beebe Lake SNYLF population regularly to assess the population status over time. Long-term monitoring will be required to derive population trends and quantify the SNYLF population in the Beebe Lakes area, particularly following the reemergence of BK in the NSR. In 2021, CDFW will be visiting the area regularly to check gill nets and electrofish the stream channels. Therefore, there will be many opportunities to conduct VES for SNYLF during quality weather conditions.

Finally, given the low detectability and limited number of SNYLF detections, CDFW may begin marking adult SNYLF in the Beebe Lakes area with passive integrated transponder (PIT) tags. Over time, marking adult SNYLF in this manner would allow capture-mark-recapture analysis, which can provide a more accurate estimation of population size, especially for a relatively small population occupying habitat that is challenging to survey (Mazerolle et al. 2007). Next summer (2021) may be a good time to begin these efforts, since CDFW staff will be on site regularly for fish removal work, which will also include time to search for SNYLF and begin marking adults. Over time, these marking efforts may provide CDFW with a better idea of the true SNYLF population size in the Beebe Lakes NSR.

BROOK TROUT REMOVAL: DISCUSSION

The reemergence of BK is an unfortunate setback to SNYLF conservation in Beebe Lakes basin. CDFW may not be able to conclusively determine whether BK remained in the basin following eradicated work from 2011–2018, or if someone illegally planted BK. Given the results of fish removal work discussed in the [Introduced Fish](#) section above, and additional thoughts provided below, the scenario in which some BK remained in Beebe Meadow may be the most likely explanation. Whether failed initial eradication or illegal fish planting, CDFW's response—reinstating fish removal—is the same. However, the explanation for BK reemergence is important for long-term management and potential for project success. Therefore, the topic is considered in more detail here.

The presence of two discrete BK size classes captured in Beebe Lake in fall 2020, with no fish captured in the ~150–300 mm (6–12 inch) TL range, is an indication that BK recently reinvaded Beebe Lake. Five years passed between CDFW removing gill nets from Beebe Lake and redetecting BK in 2020. If BK had remained in Beebe Lake after CDFW removed gill nets in 2015, or if fish had somehow reinvaded the lake several years ago, it is reasonable to assume that a wider range of size classes—and a much larger BK population—would now be present. There were three above average precipitation years in the northern Sierra Nevada between 2015 and 2020 (2015–2016, 2018–2019, and 2019–2020; CDEC 2020a), during which more ideal fall spawning conditions may have been available for BK in the Beebe Lake drainage. Water years

2016–2017 (two years post-fish removal) and 2019–2020 (four years post-fish removal) were well above the 1966–2015 precipitation average (136% and 183%, respectively; CDEC 2020a). However, the snowpack during both the 2016–2017 and 2019–2020 water years was similar, particularly in the late spring and early summer (CDEC 2020b). These conditions may have provided conditions sufficient to allow BK spawning in fall 2017 and fall 2019. However, based on presence of only a single juvenile size class during gill netting in 2020, it appears that BK only successfully spawn once, which most likely occurred in 2019. Therefore, the BK reinvasion likely occurred in early 2019 and the single spawning event would have occurred in fall 2019.

One potential explanation for the BK reemergence is that fish were fully eradicated from Beebe Lake, but some BK remained in Beebe Meadow and/or the inlet stream to Beebe Meadow. Even during exceptionally dry years (e.g., 2020), portions of the main channel flowing through Beebe Meadow remain over 1 m deep (e.g., Site IDs 52780, 14791, and 14795), and Site ID 14799 can hold enough water to retain fish (**Figure 5**). Additionally, the stream that flows into Beebe Meadow is spring fed via the meadow west of Site ID 52707, which prevents portions of the stream from going completely dry. In late winter and spring, there is an ephemeral outlet (Site ID 52782) flowing from the north end of Beebe Lake into the stream segment flowing into Beebe Meadow (Site ID 52651; **Figure 5**). During the right flow conditions (e.g., high flows during snowmelt, particularly during bigger water years like 2017 and 2019), BK may be able to ascend this stream channel to enter Beebe Lake from the stream below. The stream channel is steep and contains several drops over bedrock. However, it is still possible that Site ID 52782 does not contain a barrier to upstream fish movement under all flow conditions. If so, this stream provides a seasonal connection between Site ID 52651 and Beebe Lake that can occasionally be exploited by BK.

Given the greater difficulty of removing BK from the more complex meadow and stream habitat, this scenario is more plausible than BK having remained in Beebe Lake. However, a few assumptions are required: 1) there is no definitive barrier to upstream fish movement between Site ID 52651 and Beebe Lake, 2) despite the results of electrofishing and gill netting efforts in the stream and meadow, BK were still present, and 3) many ~6–9-inch TL stream form adult BK (i.e., at least the number of large adults captured in gill nets during fall 2020) were able to ascend the stream and enter Beebe Lake. Given the similar size of the adults captured in 2020, and the presence of only one juvenile cohort in Beebe Lake, the reinvading BK would have most likely entered Beebe Lake from Site ID 52651 via Site ID 52782 (**Figure 5**) in early 2019.

Before 2020, the last BK detections in the meadow inlet stream (Site IDs 52707 and 52651) were during electrofishing in September 2015. The 2012–early 2016 drought likely helped CDFW greatly reduce or eradicate BK from the stream channel via electrofishing. However, the deep channel running through Beebe Meadow (which constitutes portions of Site IDs 52780, 14791, 14795, and 14799) is perennial, and holds enough water, even during dry years, to retain fish. This channel is relatively wide and deep, darkly stained with tannins, and contains submerged large woody debris in some locations: all conditions that lead to ineffective backpack electrofishing, particularly with only a single electrofisher. However, the water is also shallow

enough during dry years, and contains enough emergent vegetation during low water, that gill netting can be inhibited in some areas. CDFW suspects that these conditions in the main meadow channel resulted in a portion of the BK population evading capture during the meadow eradication efforts from 2014–2017.

In addition to the more likely scenarios discussed above, CDFW also considered other possible, albeit less likely, explanations for the reemergence of BK in the Beebe Lake area. One of these scenarios is that BK remained in Beebe Lake after eradication efforts were completed. However, if BK had still been present when nets were pulled in 2015, it seems highly likely that a much wider range of size classes would now be present. Additionally, mechanical trout removal has been achieved successfully at many sites over more than two decades of work across the Sierra Nevada. Having two years of gill netting in a small lake without a single BK capture is extremely implausible if fish are still present, especially in a relatively small waterbody without complex habitat composition, such as Beebe Lake.

Another possibility for the reemergence of BK in the basin is that someone illegally planted fish. This assumption is given some credence based on the extraordinary effort put into net vandalism in 2014 (**Figure 6**) and a later incident where a district fisheries biologist received public comments threatening to plant fish back into Beebe Lake. If illegal planting was the cause of BK reinvasion, the event(s) likely occurred between summer 2017 and summer 2019. These BK were either of reproductive age when planted, or they became reproductively mature by 2018. In 2020, CDFW only caught 30 total adult BK in the basin (**Table 1**), and capture rates of these large adults were rapidly declining after only a few weeks of gill net sets (e.g., only four adults were caught from 15 gill nets set between 1 and 19 October). These capture results suggest that as few as 30 small adult BK could have been planted into Beebe Lake (which would have then grown rapidly in a fishless environment with an abundant food source of aquatic macroinvertebrates, which rebounded in the years after eradication in 2015). Such an effort could be achievable, particularly on horseback. These fish were then able to spawn in fall 2019. In this scenario, a few of these fish flushed down the outlet stream of Beebe Lake into Beebe Meadow in 2019 and/or early 2020. The fact that CDFW staff were able to catch a couple BK during one electrofishing pass of Site ID 52651 in fall 2020, after zero BK captured during multiple passes during the same time of year in 2018 (another low water year; CDEC 2020a), is another line of evidence suggesting that BK did not reenter the stream until 2019 at the earliest.

However, among all of these potential scenarios, the most likely explanation is that BK endured in Beebe Meadow through the attempted eradication efforts in 2014–2017, due to complex habitat and insufficient gill netting effort. These few remaining fish may have spawned in the meadow at least once during better water years (e.g., in fall 2017 and/or fall 2019), and some of these fish subsequently moved upstream from the meadow into Site ID 52651. A subset these fish were then able to use Site ID 52782 (the ephemeral Beebe Lake outlet stream) to move upstream into Beebe Lake in early 2019. These fish, now having accessed a new environment with abundant prey and no competition, grew substantially during summer 2019. Given excellent body condition following several months of bountiful feeding and growth, BK in Beebe

Lake then successfully spawned in fall 2019, and some of those offspring provided even more of food for the small, thriving adult population.

These results provide an opportunity to adapt eradication techniques to focus more effort on fish removal in the meadow, including setting more nets in the main meadow channel and checking those nets more frequently, which will improve capture success. CDFW's increased focus on gill netting in the meadow will be in tandem with continued electrofishing in the meadow inlet stream and gill netting in Beebe Lake. Additionally, although it is likely that BK were not completely removed during initial efforts, electrofishing and gill netting in fall 2020 suggest that the BK population in the meadow is still small, which will help expedite eradication efforts. The inception of gill netting in September 2020, and extremely low water year, likely helped prevent another spawning event, which will improve the chances of restoring the basin to its natural fishless condition. Another below average water year in 2020–2021, which is currently predicted (NOAA 2020), would also facilitate fish removal work in summer 2021. Years with dry conditions limit the available aquatic habitat for BK, reduce fall spawning potential, and consolidate fish into smaller areas for more targeted eradication.

The reemergence of BK in Beebe Lake basin emphasizes the importance for regular follow-up monitoring at fish removal sites. Periodic gill net sets will help detect any incipient non-native trout reinvasion. Catching these events early will likely make removing fish easier to achieve. Once BK are removed, SNYLF will finally have the chance to reclaim the larger, more perennial waterbodies in the basin. During summer 2021, CDFW will continue BK removal in the Beebe Lake NSR.

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