State of California

Memorandum

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Subject: Native amphibian restoration and monitoring in Desolation Wilderness.

Highland Lake fish removal and *Rana sierrae* monitoring.

Fish removal activities are complete in the Highland Lake drainage (Figure 1); California Department of Fish and Wildlife (CDFW) staff removed 26 golden trout to benefit Sierra Nevada yellow-legged frogs (*Rana sierrae*, SNYLF). Amphibian monitoring data from 2003 through 2017 suggest an increasing SNYLF population; CDFW will continue amphibian monitoring the area to document SNYLF response to fish removal.

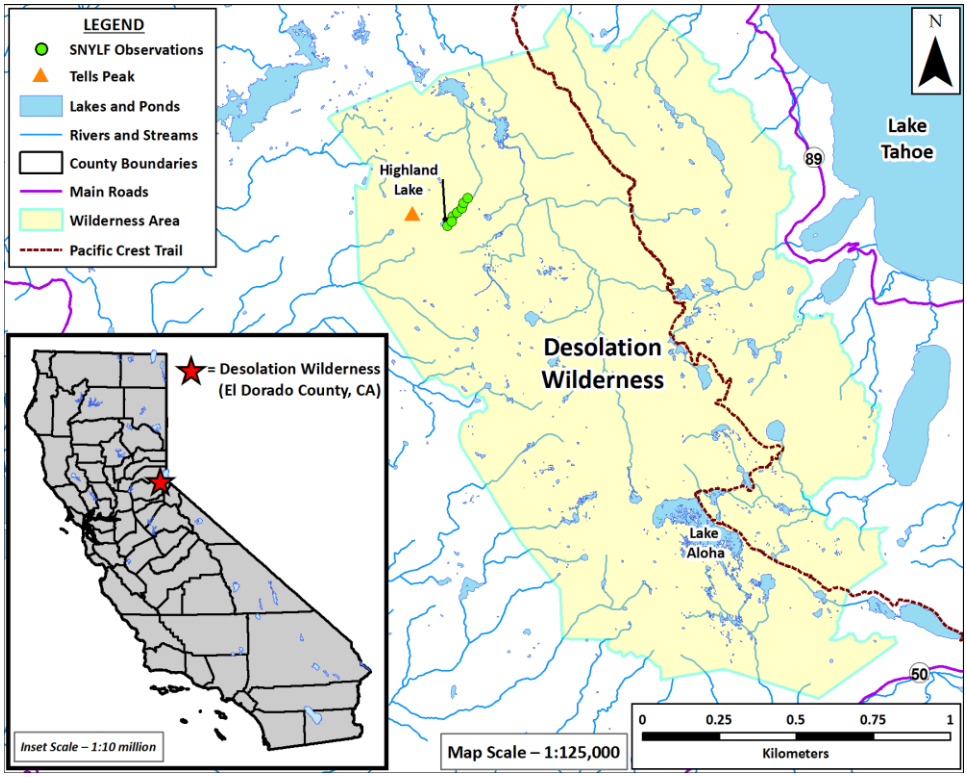


Figure 1: Desolation Wilderness, El Dorado County, CA. Green dots showing *Rana sierrae* (SNYLF) sites include positive detections by CDFW staff during recent visual encounter surveys (VES).

ENVIRONMENTAL SETTING

Highland Lake is located in the Desolation Wilderness, northeast El Dorado County. The lake sits in a granite cirque at approximately 7,800' and drains northeast into Rockbound Lake. Eldorado National Forest (ENF) manages this section of Desolation Wilderness and the surrounding land. No official trails access Highland Lake, but a clearly marked use trail from nearby Forni Lake, which proceeds over a saddle just south of Tells Peak, indicates regular visitation by hikers (Figure 1). In 2008, CDFW crews observed a small SNYLF population in the area. Staff also detected rainbow trout (*Oncorhynchus mykiss*) in Highland Lake and the outlet stream. CDFW managers, in partnership with ENF, determined that eradicating the low-density rainbow trout population using gill nets and

backpack electrofishers would be feasible, and provide an opportunity to recover the SNYLF population in the Highland Lake drainage. Once fishless, CDFW planned to manage Highland Lake, the outlet stream, and associated ponds as SNYLF breeding habitat.

INTRODUCTION

The Aquatic Biodiversity Management Plan for the Desolation Wilderness Management Unit (CDFW 2012) identifies Highland Lake (Site ID 13904; Figure 2), approximately one kilometer (km) of outlet stream (Site IDs 52648, 52649, 52650, 52670, and 52671), and two associated ponds (Site IDs 13903 and 13896) as a Native Species Reserve (NSR) for the Sierra Nevada yellow-legged frog (Figure 3).

Highland Lake was stocked with rainbow trout from 1935 until 2000. The lake contains limited spawning habitat and the rainbow trout exhibited little natural reproduction. In 1955, CDFW constructed a stonemasonry streamflow maintenance dam at the outlet (CDFG 1980). The dam forms an effective barrier to fish moving from the outlet stream into the lake, thereby further reducing spawning potential. Gill net surveys in 2003 and 2010 indicated that rainbow trout were persisting at low density in the absence of stocking. As a result, CDFW decided to eradicate the remaining fish in the lake and manage the site for SNYLF.

Beginning in 2012, CDFW and ENF personnel began removing rainbow trout from Highland Lake to benefit SNYLF. As of 2017, after two years of monitoring without detecting rainbow trout, the lake is fishless. No fish have been seen or captured since 2015. The SNYLF population has expanded into a large population, which CDFW will continue to survey regularly to monitor population status and trends. CDFW staff will also monitor the site for presence of any latent non-native trout.

Figure 2: Highland Lake in September 2017, looking east. (CDFW)

Figure 3. Sierra Nevada yellow-legged frog (*Rana sierrae*) at Highland Lake on September 10, 2017. (CDFW)

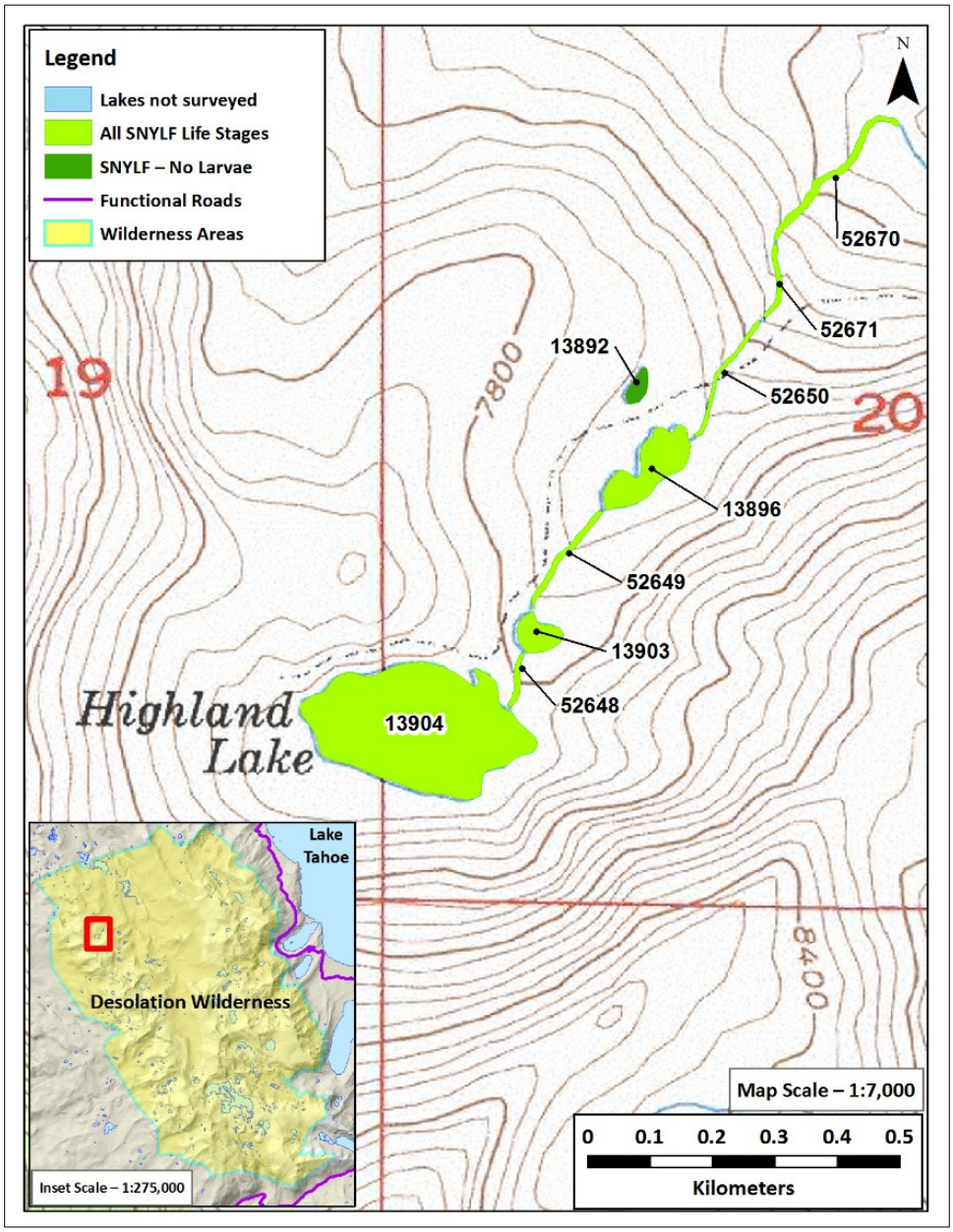


Figure 4: Highland Lake Native Species Reserve (NSR). CDFW staff have observed Sierra Nevada yellow-legged frogs of all life stages throughout the drainage, except for Pond 13892 (in which no SNYLF larvae have been detected), which is a shallow pond disconnected from the outlet stream. All flowing waters drain northeast into Rockbound Lake (not shown).

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* zoospore loads (a general measure of infection intensity).

- ***Marginal Habitats*** – SNYLF are persisting in low numbers at a single large lake, two shallow ponds, and a small seasonal stream (Figure 4). Any disturbance, natural or otherwise, that results in changes to the hydrology or limnology of the deep water habitat poses a potential extirpation risk to the population. Potential risks include the natural deterioration of the Highland Lake dam, severe winter conditions, extended drought, or anthropogenic habitat disturbances.

- ***Introduced Fish*** – Highland Lake, its outlet, and two small ponds along the outlet stream formerly supported a small population of rainbow trout. Rainbow trout predate SNYLF and are a potential source of competition for food (e.g., macroinvertebrates). Rainbow trout 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, rainbow trout 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 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, the immediate threat from trout predation has been mitigated through fish removal efforts.

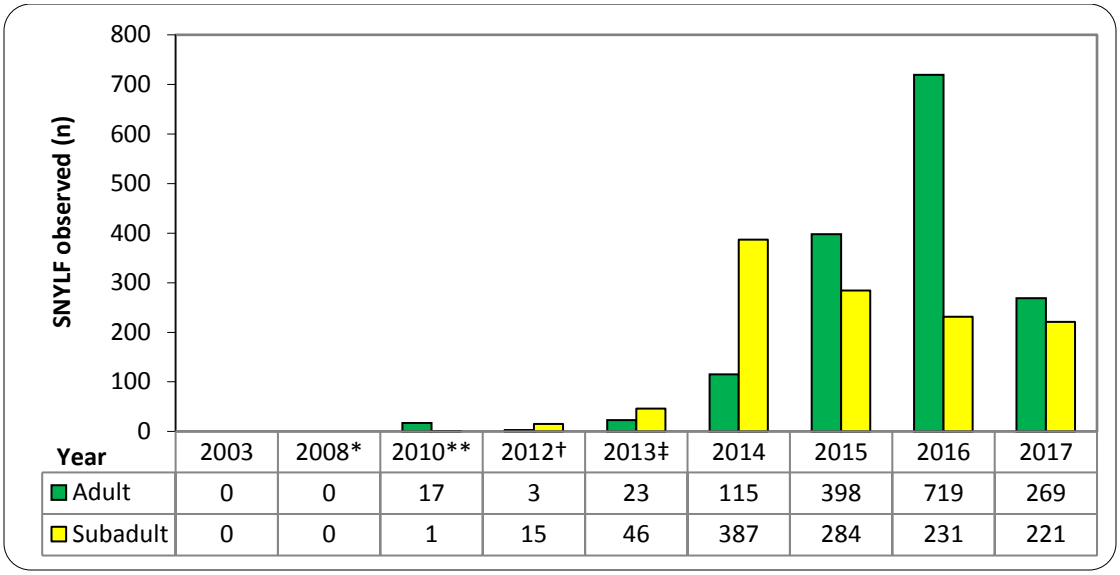
POPULATION STATUS

Long term monitoring is required to derive population trends and quantify the SNYLF population at Highland Lake. However, visual encounter survey (VES) data between 2013 and 2017 suggest the population has increased (Figures 5 and 6). As the rainbow trout population has declined, CDFW staff have observed SNYLF occupying microhabitats within the NSR in which SNYLF were not observed when fish were present. Notably, staff have observed tadpoles within additional habitats, particularly at Highland Lake, suggesting SNYLF are utilizing additional breeding habitats when compared with 2008 and earlier. Although CDFW did not detect SNYLF in the watershed prior to 2008, ENF staff have been monitoring this population since 1993 (CNDDB 2014).

In October 2014 and July 2015, CDFW staff observed SNYLF at two shallow ponds, in which crews had not observed frogs previously. Nearby Lake Zitella (2 km southeast of the Highland Lake drainage) appeared to have experienced a similar large increase in SNYLF observations. On July 30, 2015, CDFW and ENF staff surveyed all sites in the NSR. Results suggested a large increase in SNYLF abundance in the area (Figures 5 and 6). In 2016, CDFW crews surveyed all sites in the NSR three times. In addition to observing another large increase in frogs, crews observed three egg masses in Highland Lake on June 26, 2016. Prior to fish removal, crews only observed egg masses in the outlet ponds, where the likelihood of desiccation or overwinter freezing reduced the likelihood that the larvae would recruit into the adult population.

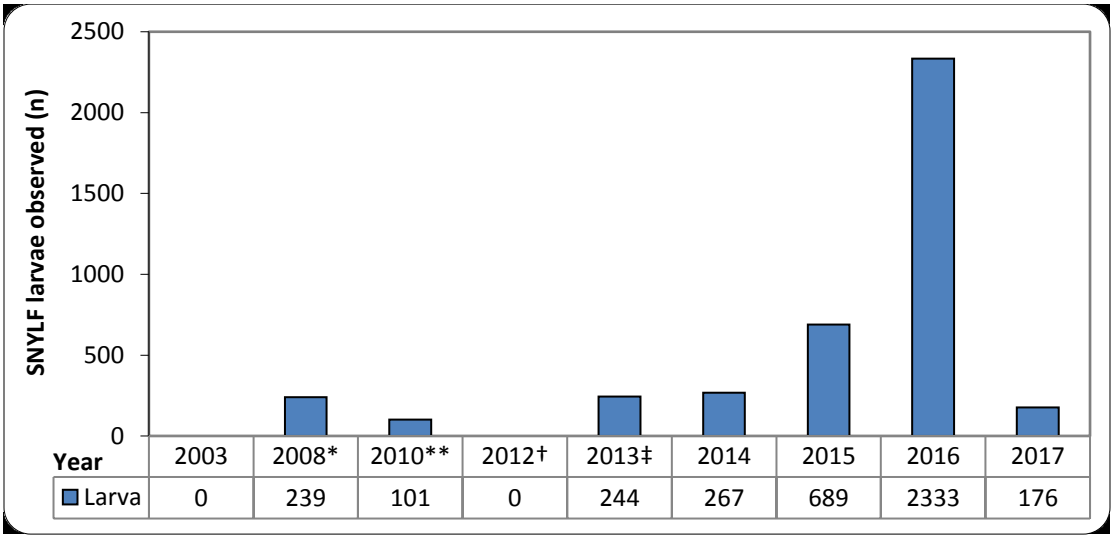
On August 29, 2017, CDFW crews surveyed all sites along the outlet stream, with the exception of Pond 13892, an off channel pond not directly connected to the Highland Lake outlet. Less than two weeks later (September 10, 2017), CDFW staff surveyed Highland Lake. Survey conditions were adequate during all 2017 surveys. However, there was consistent wind, including occasional strong gusts, on the day staff surveyed Highland Lake. The wind resulted in poor visibility, which likely accounts for the much lower number of SNYLF observed when compared with previous years (i.e., availability for detection). There are additional thoughts on the 2017 VES results in the

Discussion section. CDFW plans to continue monitoring at least biennially. Now that fish removal is complete, CDFW manages all sites in the NSR as amphibian resources.



Year	2003	2008*	2010**	2012†	2013‡	2014	2015	2016	2017
Adult	0	0	17	3	23	115	398	719	269
Subadult	0	0	1	15	46	387	284	231	221

Figure 5: Number of adult and subadult SNYLF detected during visual encounter surveys (VES) in the Highland Lake drainage between 2003 and 2017. *2008 surveys only included Highland Lake and the larger downstream pond (13896). **Surveys in 2010 only included the two stream ponds (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. From 2014 onward, surveys include the entire drainage, including Highland Lake, the outlet stream, and the two downstream ponds.



Year	2003	2008*	2010**	2012†	2013‡	2014	2015	2016	2017
Larva	0	239	101	0	244	267	689	2333	176

Figure 6: Number of larval SNYLF detected during visual encounter surveys (VES) in the Highland Lake drainage between 2003 and 2017. (See Figure 5 for caveats about surveys between 2008 and 2013.) Steady winds and occasional strong gusts during the Highland Lake survey on September 10, 2017 made visibility into the lake difficult, which may largely account for the low larval SNYLF observations when compared with the previous two years.

FISH REMOVAL

The fish removal areas in the Highland Lake drainage included Highland Lake, the fish-bearing outlet stream segments (site IDs 52648, 52649, 52650), and associated ponds (Site IDs 13896 and 13903; Figure 7).

CDFW initiated fish removal in the Highland Lake drainage in 2012. Staff set seven overwinter nets on September 19, 2012 and captured six large rainbow trout. Crews re-set seven overwinter nets on September 10, 2013 and pulled the nets in 2014. Crews set two overwinter gill nets in Highland Lake on September 2, 2014. Due to limited spawning habitat and low numbers of fish prior to fish removal, CDFW suspected the lake was fishless by 2014. However, CDFW continued setting gill nets in Highland Lake through winter of 2015–16 to add further evidence of fish absence.

CDFW implemented additional fish removal in the remainder of the NSR below Highland Lake in August 2014. The 2014 drought conditions resulted in poor stream conditions for trout in the Highland Lake outlet. For instance, by August 2014, the stream consisted of disconnected puddles, the ponds were less than one meter deep, and water temperatures exceeded 18° C. Crew set multiple gill nets in each pond and smaller gill net pieces in every wetted pool along the stream. In total, CDFW staff captured 19 rainbow trout in 2014, including four fry (< 60mm total length) between August 12 and September 2. CDFW continued fish removal activities from September 2 until October 17, but staff did not observe or capture any additional fish. Staff removed all nets from the stream sections on October 17, 2014. However, CDFW left three overwinter nets in the deepest pond habitat at sites 13896 and 13903.

On July 28, 2015, CDFW set 22 gill nets in Highland Lake. No fish were captured when the nets were removed on August 21, 2015. At that point, CDFW concluded Highland Lake to be fishless. Staff set no overwinter nets in Highland Lake because only six trout were captured in the lake since restoration activities began in 2012, and no fish were observed or captured since the initial overwinter nets were pulled in 2013. Additionally, CDFW captured no fish in four gill nets set overwinter in Highland Lake and Pond 13903, which staff pulled from the water on June 4–5, 2015. However, CDFW captured a single fish in an overwinter net at Pond 13896. Therefore, staff set three overwinter nets to remain in Pond 13896 until 2016. Conditions in September 2015 were considerably drier than during September 2014. The pool where staff captured fry in 2014 was completely dry during surveys on July 28, 2015. The lack of habitat suggested that any fry resulting from the spring 2015 spawning season did not survive the summer. Staff did not capture or observe fish from additional net sets in Pond 13896 during summer 2015.

CDFW staff captured no fish in two gill nets set in the stream outlet ponds during winter 2015–16 or summer 2016. Additionally, staff observed no fish during three separate rounds of VES in the entire NSR. These observations provided CDFW with further evidence that the Highland Lake drainage is fishless. CDFW staff did not observe any fish during VES of the entire Highland Lake outlet and associated ponds in late August 2017, or at Highland Lake during VES on September 10, 2017. Finally, on October 12, 2017, CDFW staff used a backpack electrofishing unit to sample the outlet stream from a low flow fish migration barrier (the first yellow star encountered when looking north from Highland Lake in Figure 7) up to the stonemasonry dam at Highland Lake. Staff electrofished for two hours and did not observe or capture fish. However, staff observed a mangled and highly decomposed carcass near the stream channel that was the size of an adult trout. Staff could not tell if the carcass actually came from the stream channel. The carcass may have been dropped by a mammal or bird of prey (e.g., osprey). Given the complete lack of trout captures since 2015, it seems highly unlikely that the carcass was a trout resident to the stream segment.

CDFW has determined that Highland Lake NSR is now fishless. Crews will continue occasional monitoring in the area to assess SNYLF population status and monitor for trout. In summer 2018, crews plan to survey the entire NSR at least once. During those monitoring efforts, crews will remain vigilant for trout, and document SNYLF during VES.

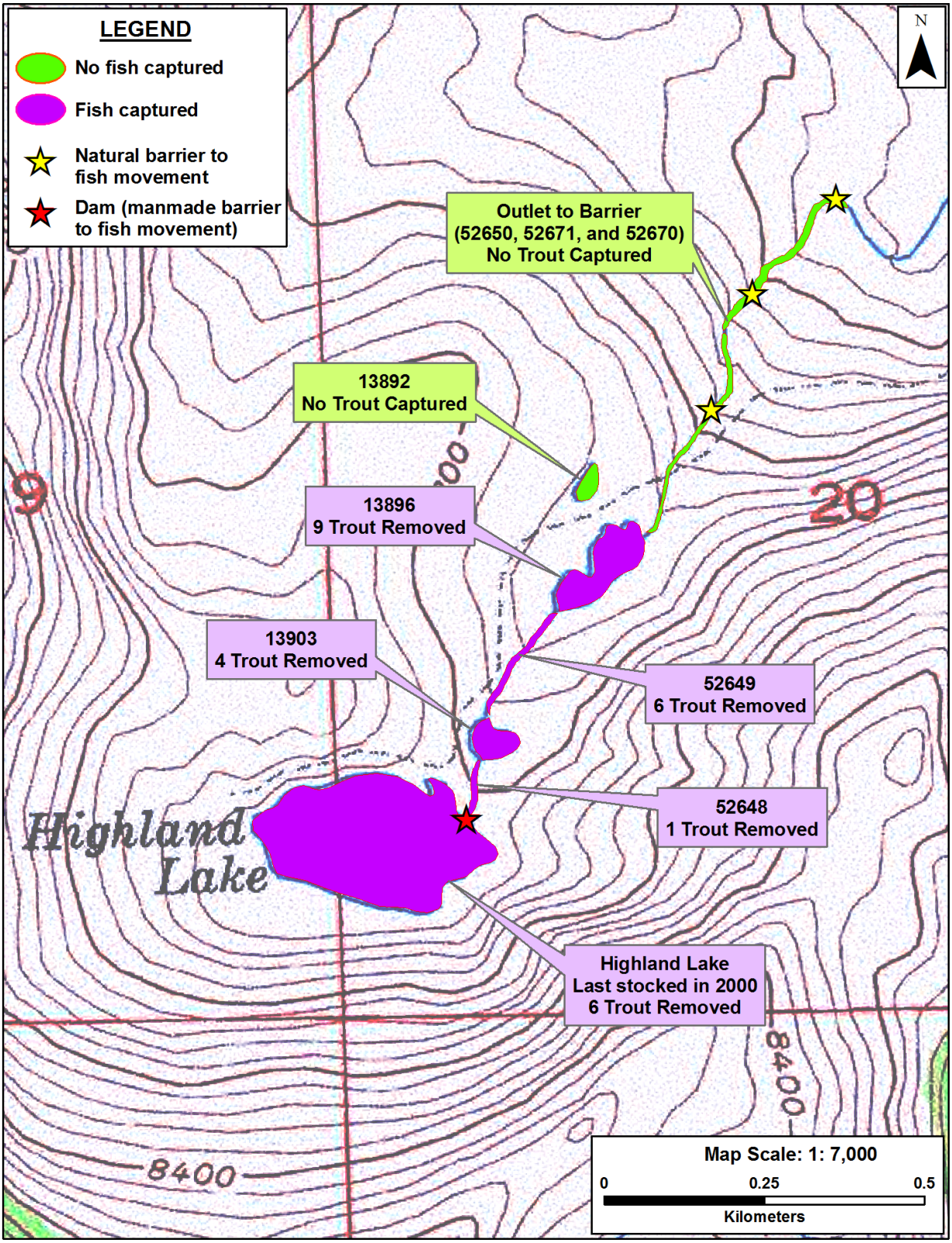


Figure 7: Locations with and without fish captures during Highland Lake drainage fish removal. Labels show lake site IDs and the number of fish captured at that site between 2012 and 2015. No fish were captured during fish removal efforts from summer 2015–summer 2017. Locations of natural barriers to upstream fish movement are shown at the yellow stars. Location of the CDFW streamflow maintenance dam, which preclude fish from moving into Highland Lake, is shown at the red star.

DISCUSSION

Fish stocking at Highland Lake ceased in 2000 as part of a larger project to inventory fish and native amphibians throughout the Sierra Nevada (CDFW 2012). 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 rainbow trout captured during active removal, the fish population began declining soon after CDFW stopped aerially stocking Highland Lake. Therefore, the large SNYLF population increase observed in recent years occurred in tandem with the rainbow trout decline in the watershed. Part of the SNYLF population increase may be attributable to the decrease in fish numbers in the absence of stocking. A decline in the rainbow trout population allowed SNYLF to begin breeding and feeding without as much interference from an efficient predator. (The observation of larval SNYLF in Highland Lake in 2008—four years before active fish removal began—supports this idea.)

Although SNYLF likely benefitted from reduced fish densities in the watershed, the population increase in a *Bd*-positive SNYLF population was initially uncertain, given the high variability in *Bd*-positive SNYLF population dynamics. However, more 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 drought. Regardless, fifteen years of data suggest that 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.

Visual encounter surveys during the 2017 season resulted in lowest number of SNYLF observations of all life stages since 2014. However, survey conditions may largely account for the observations. The day Highland Lake was surveyed (September 10, 2017), there were sustained winds and occasional strong gusts in the basin that consistently disturbed the water surface and resulted in very poor (and in many cases, zero) visibility into the lake. Additionally, these winds likely reduced subadult and adult SNYLF basking, which limits detectability of post-metamorphic frogs during VES.

Visual encounter survey results can be difficult to compare due to numerous factors, including weather conditions, time of year, and observer bias (Mazerolle et al. 2007). For example, in 2016, CDFW conducted three separate surveys of the Highland Lake drainage (in June, August, and September). The June and September 2016 surveys of Highland Lake resulted in similar detections (82 frogs, 13 larvae; and 130 frogs, 1 larvae; respectively) when compared with results from the September 2017 VES of Highland Lake (102 frogs, 32 larvae). However, the August 2016 survey resulted in dramatically higher SNYLF detections (693 frogs, 2008 larvae). The higher SNYLF detections in August 2016 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).

Another factor that may have resulted in lower SNYLF detections in 2017 were environmental conditions during the previous winter. Winter 2016–2017 was record-setting in the northern Sierra Nevada, in terms of precipitation quantity (CDWR 2017a), and northern Sierra Nevada snowpack levels reached about 150% of the April 1st average (CDWR 2017b). These conditions resulted in Highland Lake basin retaining snow well into July 2017 (Figure 8). 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. Thus far (as of March 2018), there has been substantially less precipitation during winter 2017–2018. CDFW will conduct further monitoring at the site in summer 2018 to determine the relative abundance, general reproductive success, and demographic composition of the Highland Lake drainage SNYLF population.

Figure 8: Highland Lake on July 5, 2017. Summer 2017 followed a winter with about 150% snow water content in the Sierra Nevada when compared with the average since the late 1800's (CDWR 2017b). Additionally, winter 2016–2017 was record-setting in the northern Sierra Nevada for total precipitation (CDWR 2017a). Therefore, the snow and ice lingered at high elevation sites, such as Highland Lake, well into the summer. These conditions can be harsh on SNYLF: many individuals may die during especially long and difficult winters (Bradford 1983).

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