State of California

Memorandum

Date: 3/12/2019

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Subject: Native amphibian restoration and monitoring in Bucks Lake Wilderness.

GOLD LAKE AND MOUNT PLEASANT AREAS – *RANA SIERRAE* MONITORING.

GOLD LAKE FISH REMOVAL UPDATE

INTRODUCTION

Bucks Lake Wilderness is located in western Plumas County, south of Interstate 70 and north of Bucks Lake, and consists of 9,695 hectares. The Pacific Crest Trail bisects the wilderness, and local elevations range from about 2,400 feet (730 meters [m]) near the northern border along the Feather River, to 7,067 feet (2,154 m) at the summit of Mount Pleasant. California Department of Fish and Wildlife (CDFW) staff observed two Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) populations in Bucks Lake Wilderness while conducting baseline surveys in 2003 and 2004. Subsequent surveys have revealed one SNYLF population south of Silver Lake in the Gold Lake area, and a second population persisting in a small drainage southeast of Mount Pleasant (Figure 1).

Amphibian monitoring data from 2004–2018 suggest small SNYLF populations persist in both areas. However, the population sizes have remained low for years and biologists have consistently observed a small number of dead SNYLF in the Mount Pleasant area. Additionally, SNYLF populations in Bucks Lake Wilderness are part of a genetic clade at high risk of extirpation (Vredenburg et al. 2007). Therefore, these populations are of particular conservation concern to CDFW and Plumas National Forest (PNF). CDFW has designated both areas as Native Species Reserves (NSRs) in the Aquatic Biodiversity Management Plan for the Bucks Lake Wilderness Management Unit (ABMP; CDFW 2015; Figure 2).

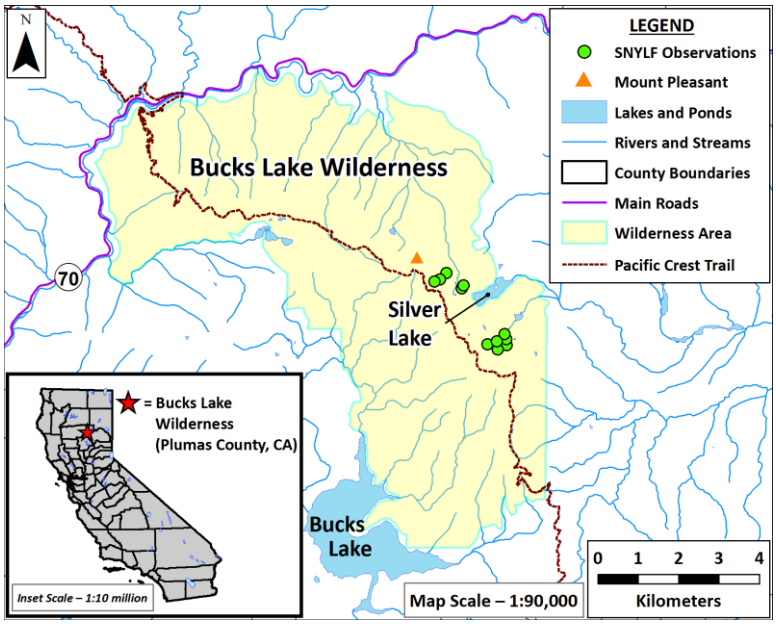


Figure 1: Bucks Lake Wilderness, Plumas County, CA. Green dots show *Rana sierrae* (SNYLF) detections by CDFW staff during visual encounter surveys (VES) between 2004 and 2018.

The Interagency Conservation Strategy for Mountain Yellow-legged Frogs in the Sierra Nevada (hereafter "Strategy"; USFWS 2018) highlights fish removal and reintroductions as principal methods for SNYLF recovery. In 2015, CDFW began Brook Trout (*Salvelinus fontinalis*; BK) removal at Gold Lake to benefit the relictual SNYLF population in the area. As of 2018, CDFW removed the entire population of 254 BK from Gold Lake. In September 2018, PNF staff from the Mount Hough Ranger District collected 64 larval and metamorphic SNYLF for captive rearing at the San Francisco Zoo. Zoo staff are raising the SNYLF to maturity, after which PNF and CDFW staff will release the adult frogs back into the Gold Lake and Mount Pleasant NSRs during summer 2019. Additionally, CDFW and PNF staff will continue annual amphibian monitoring to document SNYLF response to reintroductions and BK removal.

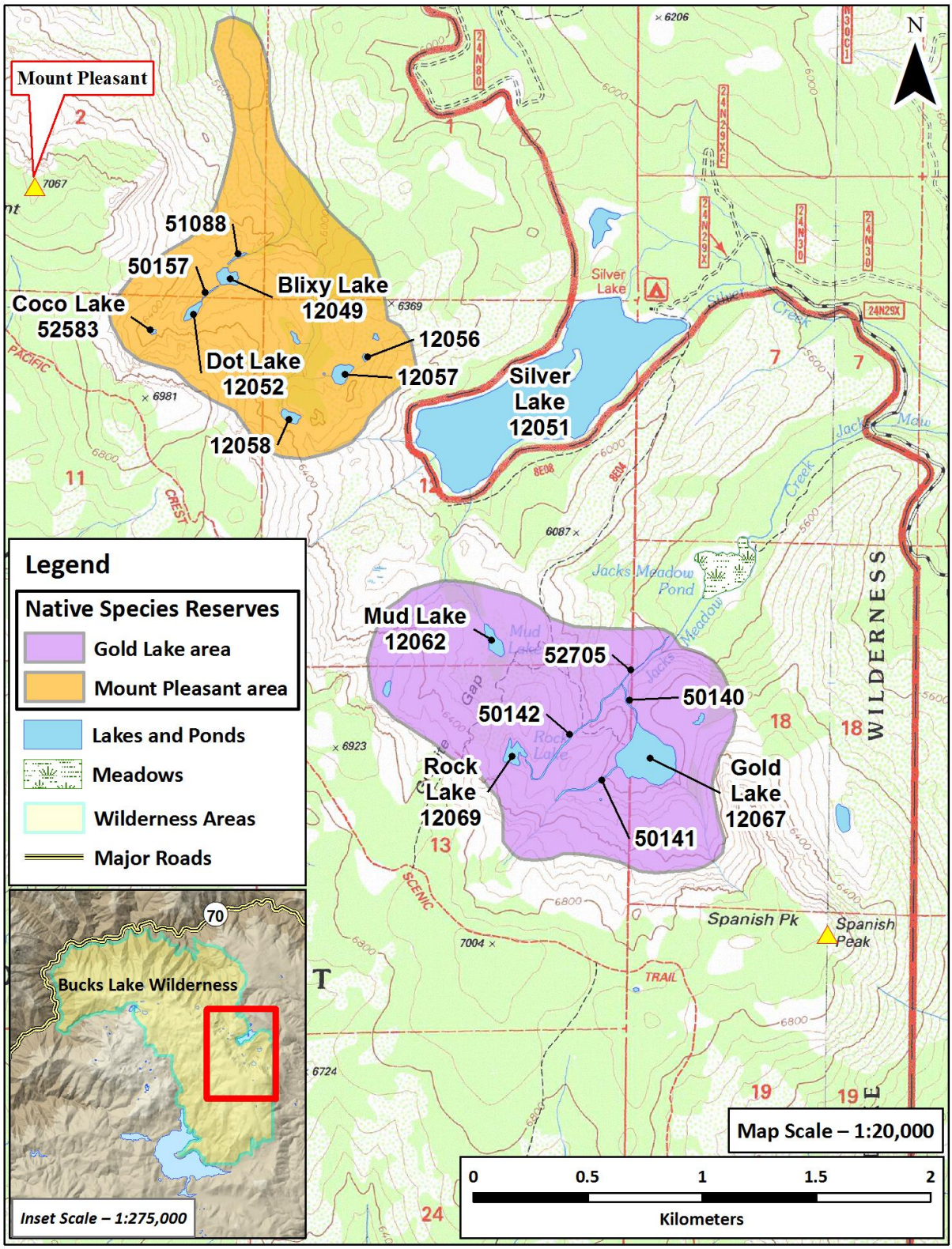


Figure 2: Focal areas for Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) management by California Department of Fish and Wildlife (CDFW) and Plumas National Forest (PNF) in Bucks Lake Wilderness, Plumas County, CA. The orange area highlights the Mount Pleasant Native Species Reserve (NSR). The purple area highlights the Gold Lake NSR. CDFW and PNF regularly monitor SNYLF populations in both areas. Numbers displayed are CDFW site IDs.

MANAGEMENT BACKGROUND

Gold Lake (Figure 3) is the only fish removal project to benefit SNYLF undertaken by CDFW in Plumas County. For detailed background on aquatic ecosystem management in Bucks Lake Wilderness (Figure 1), see the ABMP (CDFW 2015). The ABMP identifies Gold Lake as one of the few, and possibly only, feasible habitat restoration opportunities available in Plumas and Sierra Counties (CDFW 2015). CDFW selected Gold Lake because 1) the site exhibits the physical habitat characteristics beneficial to state threatened and federally endangered SNYLF, 2) CDFW environmental scientists determined that BK eradication using mechanical methods is feasible, and 3) there is an extant SNYLF population in close proximity to Gold Lake.

Figure 3. Gold lake (site ID 12067) on 5 June 2018 (CDFW). California Department of Fish and Wildlife (CDFW) removed 254 non-native Brook Trout (*Salvelinus fontinalis*) from 2015–2018. Plumas National Forest (PNF) staff observed two adult Sierra Nevada Yellow-legged Frogs (*Rana sierrae*; SNYLF) at Gold Lake in 2018. PNF and CDFW staff also observed SNYLF adults in the outlet stream just below the lake.

Gold Lake is a popular day-hike and recreation destination, easily accessible from Silver Lake. Members of the local community strongly opposed the BK removal project. However, CDFW is mandated to conserve threatened and endangered species (Fish & G. Code, § 2050 et seq.), and Gold Lake offered the only feasible option known in Plumas County to improve habitat for an extant SNYLF population by mechanically removing non-native trout. Additionally, several other lakes are available for trout fishing in the vicinity, including Silver Lake, Lost Lake, Lower Three Lakes, Bucks Lake, Lower Bucks Lake, and Grizzly Forebay. Complete details regarding fish removal at Gold Lake may be found in the 2018 Gold Lake area survey memo (CDFW 2018). Final BK removal results are discussed below in the *Gold Lake Fish Removal* section.

During a 2004 baseline visual encounter survey (VES) for SNYLF at Rock Lake (site ID 12069), CDFW observed eight adults, seven juveniles, and 21 larvae – the only sign of SNYLF breeding in the drainage (Figure 4). An 8-hour gill net set at Rock Lake yielded no fish. However, a 9-hour net set at nearby Gold Lake captured eight BK and indicated a self-sustaining fishery. Incidentally, Gold Lake is the only deep-water habitat in Bucks Lake Wilderness (29 m maximum recorded depth). Based on extensive surveys during the summers of 2002–2005, Rock Lake contains one of only three documented lake-based SNYLF populations in Plumas County. In accordance with the CDFW mission statement to balance native species diversity and recreational opportunity, Gold Lake (site ID 12067; Figure 4) was identified as a potential restoration site for SNYLF.

The Mount Pleasant SNYLF population is one of only a few populations remaining at the northern extent of the species' range. Additionally, this population is one of even fewer lake-based populations in Plumas County. In 2004, CDFW conducted a baseline VES, during which staff observed: adult, subadult, and larval SNYLF at Dot Lake (site ID 12052); and adult SNYLF at Blixy Lake (site ID 12049; Figure 5). In 2013, PNF staff surveyed the Mount Pleasant area and observed adult frogs in all wetted habitat, including eight adult SNYLF in Coco Lake (Figure 5; CDFW 2015).

THREATS

- ***Marginal Habitats*** – VES data show the Gold Lake and Mount Pleasant area SNYLF populations are currently reproducing in Rock and Dot Lakes, respectively, both of which are small, isolated, and shallow. Any disturbance, natural or otherwise, that threatens overwintering habitats presents a potential extirpation risk. Among the risks to the population are habitat disturbance by humans, possible exposure to severe winter conditions, and desiccation from drought conditions (e.g., the 2012–2015 drought, which lowed water levels in many small ponds throughout the Sierra Nevada), any one of which could eliminate these small SNYLF populations.

- ***Introduced Fish*** – Gold Lake formerly contained a self-sustaining BK population. However, in 2015, CDFW initiated physical trout removal using gill nets. CDFW field staff have not observed BK in Gold Lake since July 2016. During summer 2018, CDFW field staff observed BK in isolated pools along the Gold Lake outlet stream. These pools are below the Gold Lake streamflow maintenance dam, which provides a barrier to upstream fish movement (see *Gold Lake Fish Removal* below). Trout may have been precluding SNYLF from successful breeding and recruitment in Gold Lake, which is the only deep-water habitat near the breeding SNYLF site at Rock Lake. Furthermore, Speckled Dace (*Rhinichthys osculus*; hereafter "dace") are present in Gold Lake and Blixy Lake. Dace may compete with, or directly harm, smaller life stages of SNYLF (e.g., eggs and larvae). However, little information is available regarding effects of dace on SNYLF (see *Discussion* below).

- ***Disease*** – All SNYLF populations in Plumas County are chytrid fungus (*Batrachochytrium dendrobatidis*; *Bd*) positive. In 2008, 2010, and 2011, SNYLF captured at Rock Lake, Dot Lake, and Blixy Lake were genetically sampled by epithelial swabs for the presence of *Bd.* Twenty seven swabs were collected and screened for the presence of *Bd* DNA using real-time quantitative polymerase chain reaction (qPCR) analysis. Results for all three years indicated very light to moderate *Bd* zoospore loads. In 2018, PNF analyzed 20 additional swabs collected from SNYLF at Dot Lake (n=14) and Rock Lake (n=6). Most of the swabbed frogs at Dot Lake were recent metamorphs, which typically are the most susceptible to *Bd* (Rachowicz et al. 2006). In contrast, four of the six swabs from Rock Lake were collected from adults.

  Results from the swabs collected in 2018 indicated moderate to high *Bd* zoospore loads. However, high *Bd* loads are typical for recent SNYLF metamorphs, even in populations persisting with *Bd* (Ellison et al. 2019; R. Knapp, pers. comm.). CDFW and PNF staff have consistently observed low numbers of dead SNYLF of various life stages at Dot Lake during VES, including: 2004, 2005, 2010, 2015, 2017, and 2018. These observations suggest that there may be consistent *Bd*-induced mortality in this population. CDFW and PNF staff have not observed any recent signs of *Bd* epizootic events in the Gold Lake or Mount Pleasant areas. However, VES results suggest that the Mount Pleasant population may have experienced a major die-off during a *Bd*-induced epizootic event sometime between 2005 and 2008 (Figure 8). A similar die-off may have occurred around the same time in the Gold Lake area, but perhaps not as pronounced as the decline at Mount Pleasant (Figure 6). The Gold Lake and Mount Pleasant SNYLF populations may have been naïve to *Bd* prior to these potential outbreaks.

- ***Loss of Genetic Diversity*** – The Bucks Lake Wilderness SNYLF populations are part of a unique genetic unit (known as Clade 1; Vredenberg et al. 2007, USFWS 2018). Clade 1 is by far the most threatened of the three currently recognized genetic clades as determined by mitochondrial DNA analysis (Vredenburg et al. 2007), due to few remaining extant populations, marginal habitats, and potential threats from multiple land uses (USFWS 2018). Clade 1 also includes some of the lowest elevation SNYLF populations in the range of the species. Additionally, populations in Clade 1 are widely separated from one another, which limits potential for gene flow between populations and increases risk for local extirpation. This 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 (Frankham et al. 2009).

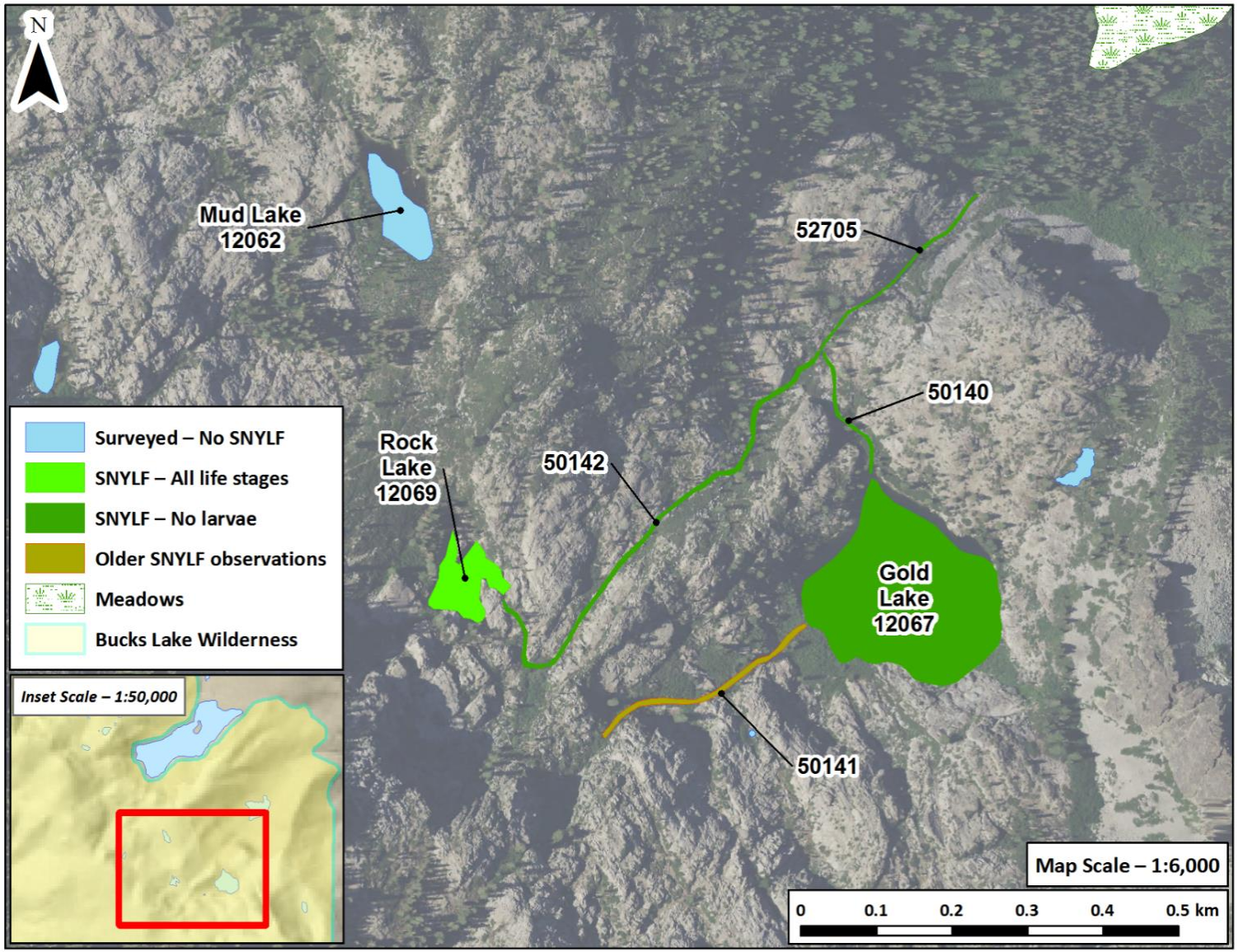


Figure 4: Gold Lake Native Species Reserve (NSR) in Bucks Lake Wilderness, Plumas County, CA. Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) observations occurred during visual encounter surveys (VES) between 2004 and 2018. In 2005, CDFW staff observed two SNYLF in the Gold Lake inlet (site ID 50141), but no SNYLF have been subsequently observed during VES of that tributary. In 2015, CDFW field staff observed two adult SNYLF at the northwest edge of Gold Lake. The most recent SNYLF observations at Gold Lake were two adults observed by a PNF biologist in September 2018. Rock Lake is the only known SNYLF breeding location in the drainage. Numbers displayed are CDFW site IDs.

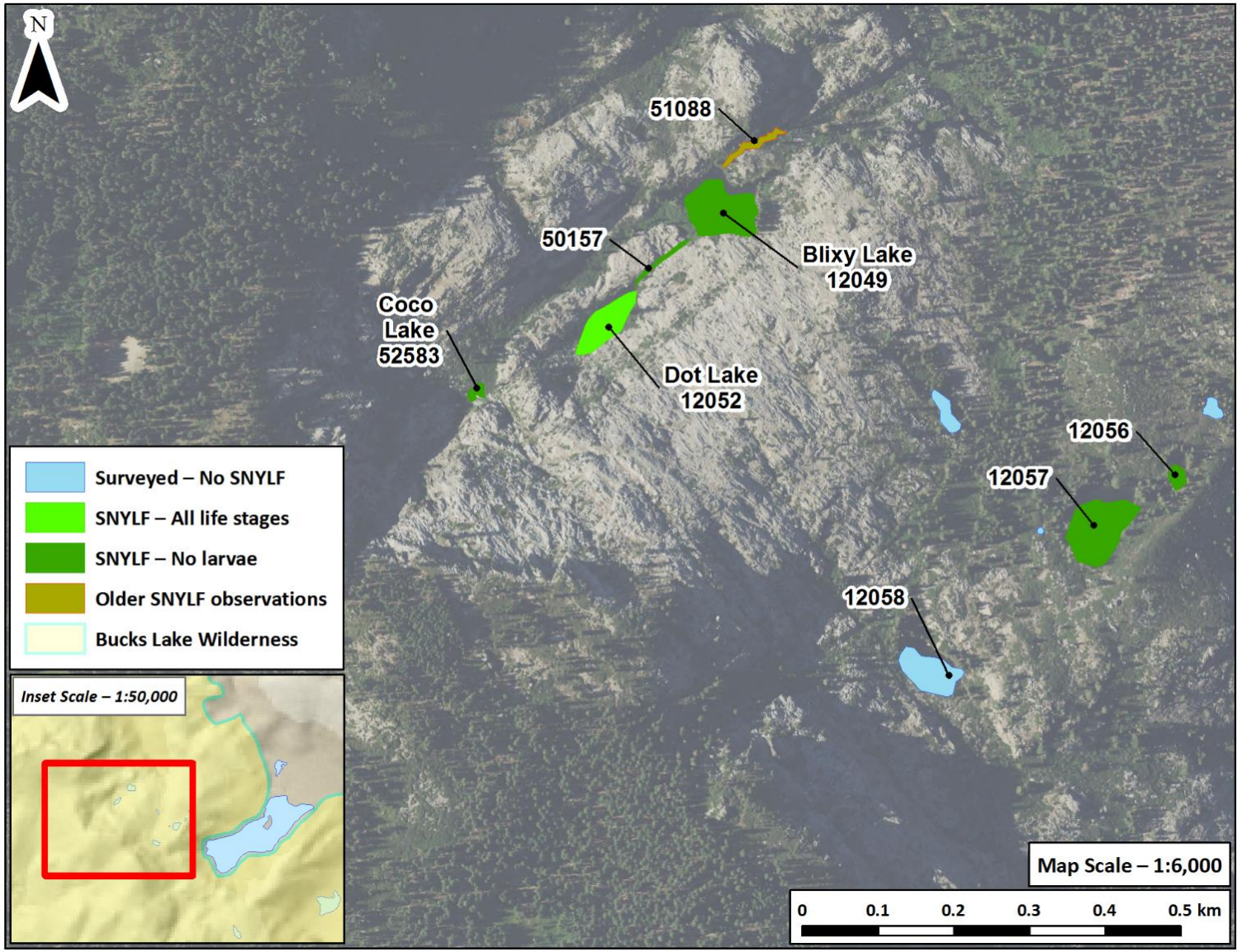


Figure 5: Mount Pleasant Native Species Reserve (NSR) in Bucks Lake Wilderness, Plumas County, CA. Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) observations occurred during visual encounter surveys (VES) between 2004 and 2018. Dot Lake (site ID 12052) is a consistent breeding site for SNYLF, whereas no egg masses or tadpoles have been observed in Blixy Lake (site ID 12049), which contains dace (*Rhinichthys osculus*). Before 2018, CDFW staff had no SNYLF records from Coco Lake (site ID 52583), Pond 12056 (U.S. Forest Service detection in 2018), or Pond 12057. Numbers displayed are CDFW site IDs.

GOLD LAKE FISH REMOVAL

CDFW began BK eradication at Gold Lake in June 2015 and continued through 2018. Soon after CDFW set gill nets in Gold Lake, BK catch per gill net hour (catch per unit effort; CPUE) was high (Table 1). However, CPUE dramatically declined soon after initial net sets. Between June 2015 and June 2018, gill nets were fishing in Gold Lake year round, almost continuously. When accounting for all nets (up to nearly 30 nets set at any one time), the total fishing effort at Gold Lake was 434,993 gill net hours - the equivalent of one net being set for 50 years. During that time, gill nets captured 254 BK and 7,866 dace in Gold Lake (Table 1).

CDFW staff removed the overwinter gill nets from Gold Lake on 6 June 2018 and found no BK. During VES on 21 August 2018, CDFW field staff observed BK and dace in several isolated pools located in the Gold Lake outlet stream (site ID 50140; Figure 4). A streamflow maintenance dam separates the stream from Gold Lake. However, given the close proximity of Gold Lake to the fish-containing outlet pools, and to limit the risk of BK movement into the lake during high water, CDFW staff decided to remove any BK found in stream segment 50140. On 27–28 August 2018, CDFW staff used a backpack electrofishing unit to remove 50 BK located in remnant pools in the Gold Lake outlet. While targeting BK, CDFW staff also shocked numerous dace in the outlet stream pools. As an added precaution, staff set two gill nets in the northern cove of Gold Lake to monitor for BK.

On 24 September 2018, a PNF biologist thought he observed a small BK in Gold Lake. However, the biologist did not definitively identify the fish species. Additionally, the fish he observed was the size of an adult dace. CDFW staff returned on 26 September 2018 to remove the two gill nets and conduct one more round of electrofishing in the outlet stream. The two gill nets captured zero BK, but each net contained approximately 100 dace, respectively. CDFW staff positively identified all fish captured. During the visit on 26 September, no water remained in stream segment 50140. One small pool was located in stream segment 52705, which is below a natural fish barrier, and staff removed one small BK from the pool. Summer 2018 was dry throughout the northern Sierra Nevada, with almost no appreciable rainfall after early summer (NOAA 2018). Summer 2018 may have been the first time the outlet stream went dry since BK removal began in Gold Lake. During subsequent VES trips to the area, CDFW staff will continue overnight gill net surveys at Gold Lake to monitor for BK.

Table 1. Monthly and overwinter summary statistics from gill nets deployed for Brook Trout (*Salvelinus fontinalis*; BK) removal in Gold Lake. Speckled Dace (*Rhinichthys osculus*; "dace"), which are also present in Gold Lake, were not targeted for eradication. Number of nets is an average because the number of summer nets varied within a given month (e.g., when nets needed to be pulled for repair and then reset).

Date	Average # Nets	Net Hours	BK (n)	Dace (n)
Jun-2015	15	2,513	172	357
Jul-2015	29	3,876	12	537
Aug-2015	29	1,919	8	106
Sep-2015	23	1,528	19	854
Oct-2015	25	5,775	21	753
Winter 2015–2016	12	50,825	17	213
May-2016	12	2,289	3	439
Jun-2016	18	13,899	1	927
Jul-2016	25	21,131	1	404
Aug-2016	25	7,313	0	201
Sep-2016	25	22,817	0	224
Oct-2016	24	21,583	0	575
Winter 2016–2017	26	143,154	0	755
Jun-2017	19	3,683	0	263
Jul-2017	23	5,024	0	75
Aug-2017	21	16,544	0	152
Sep-2017	21	15,404	0	230
Oct-2017	21	18,949	0	415
Winter 2017–2018	12*	75,334*	0	186*
27 Aug–26 Sept 2018	2	1,433	0	~200
TOTAL		**434,993**	**254**	**7,866**

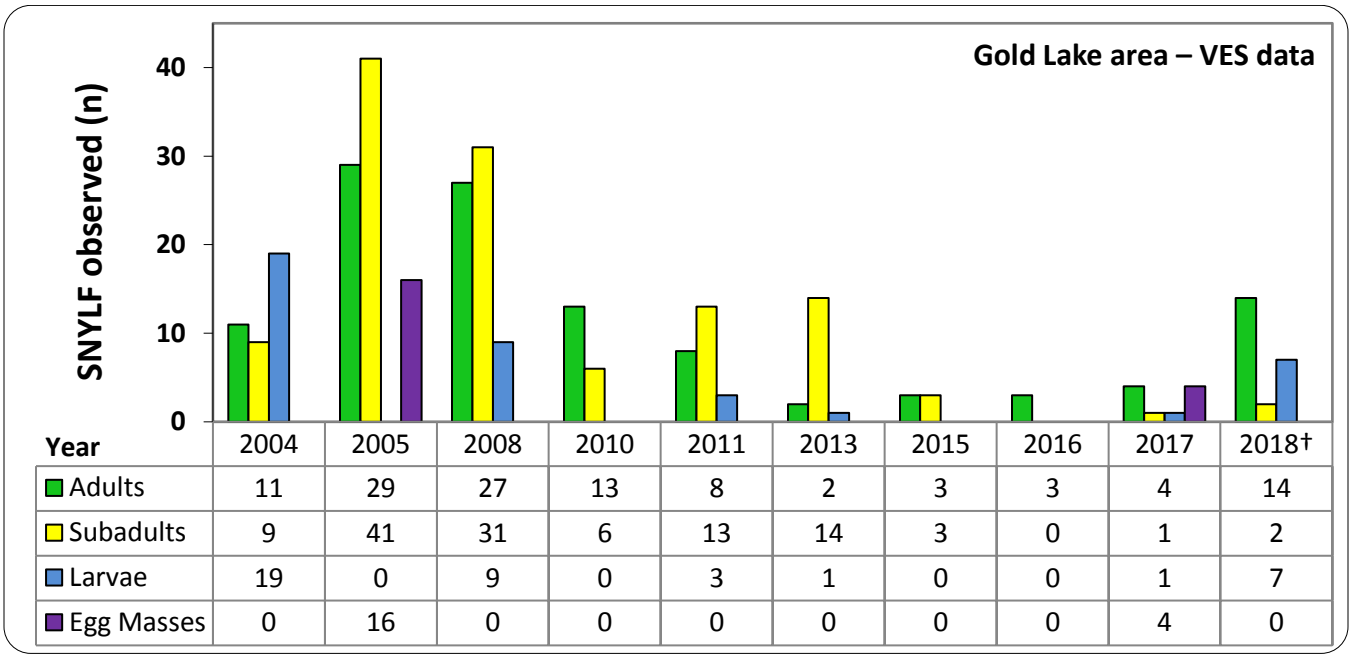
***** *One net was stuck in the lake from October 2016 until June 2018 (14,254 net hours; 7 dace). This net is included in the winter 2017 total.*

VES IN THE GOLD LAKE NSR

CDFW performed the baseline VES in the Gold Lake NSR in 2004, during which staff encountered a small breeding SNYLF population. Fourteen years of monitoring data suggest that this population may be slowly declining (Figure 6). Most signs of breeding have occurred in Rock Lake (site ID 12069; Figure 7). SNYLF detections of all life stages have remained relatively consistent, albeit low, since 2010. Observer bias, variation in survey conditions, and the low number of detections all make deriving trends difficult.

For several years, PNF and CDFW field staff have been marking newly captured adult SNYLF (>40 mm snout-to-urostyle length [SUL]) in the Gold Lake NSR with passive integrated transponder (PIT) tags, which provide a unique identifier for keeping track of individuals. Staff first scan each captured adult with a PIT tag reader, which displays a unique identification code when a PIT tag is detected, to determine if the frog is marked (i.e., a recapture). Field staff then record the global positioning system (GPS) point and the frog's sex. If the adult is a recapture, staff release the frog without further processing. For new adult captures, staff insert an 8 x 1.4 mm PIT tag under the dorsal skin using methods recommended by McAllister et al. (2004), scan and recorded the PIT tag number, and release the frog at the point of capture.

In 2018, field staff from both CDFW and PNF surveyed the Gold Lake NSR on several occasions. Based on scans of adult SNYLF captured during VES, staff detected eight individual SNYLF adults in Gold Lake and the outlet stream. Additionally, PNF staff detected an additional six individual SNYLF adults in Rock Lake. Therefore, at least 14 adult SNYLF were present in the Gold Lake NSR during summer 2018. Both agencies will continue surveying the NSR at least once each year, keeping records on the location and identity of recaptured adult SNYLF, and PIT tagging any newly captured adults. These data will help CDFW better understand the status and trends of the Gold Lake NSR SNYLF population.



Year	2004	2005	2008	2010	2011	2013	2015	2016	2017	2018†
Adults	11	29	27	13	8	2	3	3	4	14
Subadults	9	41	31	6	13	14	3	0	1	2
Larvae	19	0	9	0	3	1	0	0	1	7
Egg Masses	0	16	0	0	0	0	0	0	4	0

Figure 6: Histogram of Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) detections during visual encounter surveys (VES) by life stage and year in the Gold Lake NSR. Survey data include SNYLF detections at Rock Lake (site ID 12069), Gold Lake (site ID 12067), and the associated stream segments (site IDs 50140, 50141, 50142, and 52705). Most detections have occurred at Rock Lake and the outlet stream in close proximity to Rock Lake. SNYLF detections at Gold Lake and the connected streams have been primarily adults. If more than one VES was conducted in a given year (2015, 2016, and 2018), the data shown are from the survey day resulting in the highest number of SNYLF detections.

CDFW only conducted VES at the following sites during the years listed: Gold Lake during all years shown except 2008; Site 50140 in 2005, 2010–2013, 2016, and 2018; Site 50141 in 2005, 2010–2011, and 2018; and Site 50142 in 2011–2013 and 2016–2018.

†CDFW did not add stream segment 52705 (the segment below the confluence of the Rock and Gold Lake outlets) until 2018.

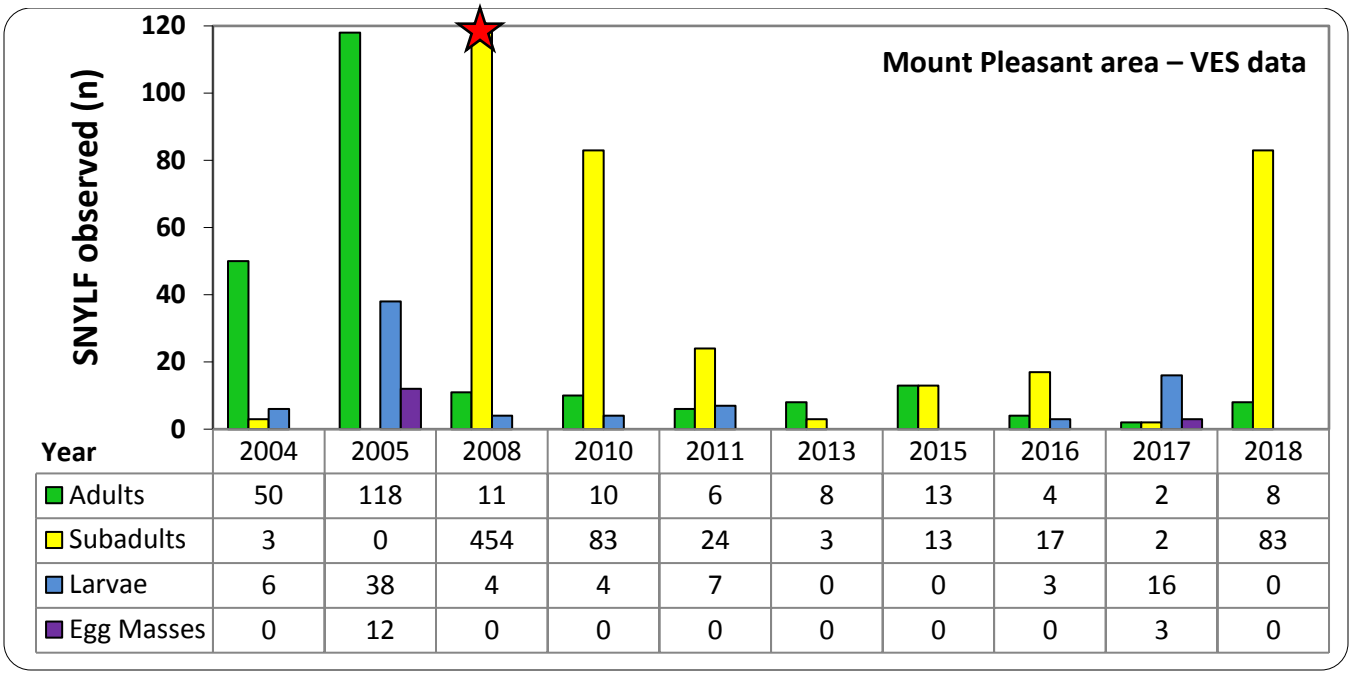
Figure 7. Rock Lake (site ID 12069) on 21 August 2018. (CDFW). Most signs of Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) breeding, including observations of egg masses, larvae, and recent metamorphic SNYLF, in the Gold Lake NSR have occurred at this site.

VES IN THE MOUNT PLEASANT NSR

CDFW performed the baseline VES in the Mount Pleasant NSR in 2004, during which staff encountered a small breeding SNYLF population. Fourteen years of monitoring data suggest this population is declining (Figure 8). Most signs of breeding, including observations of egg masses, larvae, and recent metamorphic SNYLF, have occurred in Dot Lake (site ID 12052; Figure 9). However, similarly to the Gold Lake NSR SNYLF population, detections have remained relatively consistent, albeit low, since 2010. In part due to these low detections, PNF and CDFW staff have undertaken the same adult SNYLF PIT tagging methods described above in the *VES in the Gold Lake NSR* section.

The consistent low number of SNYLF detections in the Mount Pleasant and Gold Lake NSRs has been concerning to both CDFW and PNF. During VES in August 2018, CDFW field staff observed very few SNYLF in both the Mount Pleasant and Gold Lake NSRs. Although observer bias and variation in survey conditions can affect the number of SNYLF detected during any given VES, the low numbers were troubling, especially when observed in already threatened populations. In response to these observations and long-term trends, PNF personnel, in collaboration with CDFW and the U.S. Fish and Wildlife Service (USFWS), undertook a collection of early life stage SNYLF from Dot Lake (site ID 12052; Figures 5 and 9) and Rock Lake (site ID 12069; Figures 4 and 7) for captive rearing at the San Francisco Zoo. The Strategy highlights captive rearing as one of the primary actions to restore SNYLF populations (USFWS 2018, pgs. 19–21). CDFW mentions the potential for translocations (which are one of the methods, along with captive rearing, broadly considered under "Reintroductions" in the Strategy) in the Mount Pleasant area in the Bucks Lake Wilderness ABMP (CDFW 2015, pg. 20).

PNF field staff surveyed the Mount Pleasant and Gold Lake NSRs again on 5–6 September 2018. Encouragingly, PNF staff observed more SNYLF of various life stages than seen during the August 2018 surveys by CDFW. However, SNYLF detections were still low, and most of the frogs observed were very young, suggesting that the PNF surveys coincided with the recent metamorphosis of late stage SNYLF tadpoles. Additionally, as discussed in the *Disease* section above, recent metamorphs can be highly susceptible to *Bd*-induced mortality. Therefore, PNF staff collected 60 recent SNYLF metamorphs at Dot Lake (Figures 5 and 9), plus four early life stage SNYLF at Rock Lake (Figures 4 and 7). On 6 September 2018, PNF staff transported the 64 SNYLF to the San Francisco Zoo. Once at the zoo, staff treated all recently metamorphosed SNYLF with an antifungal drug called Itraconazole, which clears *Bd* infection. Once raised to maturity at the zoo, PNF and CDFW staff plan to release all captive-reared SNYLF back to the Mount Pleasant and Gold Lake NSRs during summer 2019.



Year	2004	2005	2008	2010	2011	2013	2015	2016	2017	2018
Adults	50	118	11	10	6	8	13	4	2	8
Subadults	3	0	454	83	24	3	13	17	2	83
Larvae	6	38	4	4	7	0	0	3	16	0
Egg Masses	0	12	0	0	0	0	0	0	3	0

Figure 8: Histogram of Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) detections during visual encounter surveys (VES) by life stage and year in the Mount Pleasant area. Survey data includes SNYLF detections at Blixy Lake (site ID 12049), Dot Lake (site ID 12052), Coco Lake† (site ID 52583), two nearby ponds (site IDs 12056 and 12057), and the associated stream segments (site IDs 50157 and 50158). The red star over the subadult count in 2008 indicates an outlier above the y-axis scale (see table). The high subadult counts during VES in 2008, 2010, and 2018 may be due to survey timing coinciding with late stage SNYLF tadpoles metamorphosed into young subadult frogs. Only a small subset of these young frogs typically survive to sexual maturity and are very susceptible to mortality from chytridiomycosis, the disease caused by the fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*). These factors could explain why the VES detections were low in subsequent years, despite the large number of subadults seen.
CDFW field staff surveyed Dot Lake during every year shown. CDFW only conducted VES at the following sites during the years listed: Blixy Lake during all years shown except for 2005; Site 50157 in 2005, 2010–2013, and 2016–2017; sites 12056 and 12057 in 2012 and 2018; and Site 51088 in 2011, 2015, and 2016.
†CDFW did not add Coco Lake, which Plumas National Forest staff have occasionally monitored, until 2018.

Figure 9. Dot Lake (site ID 12052) on 21 August 2018. (CDFW). Most signs of Sierra Nevada Yellow-legged Frog (*Rana sierrae*; SNYLF) breeding, including observations of egg masses, larvae, and recent metamorphic SNYLF, in the Mount Pleasant NSR have occurred at this site.

DISCUSSION

The Gold Lake fish removal project has been successful in removing BK using monofilament gill nets. The BK population was small at Gold Lake: only about 250 trout were removed from the lake after nearly constant gill-netting efforts for over three years. Based on present data, CDFW removed BK from Gold Lake in approximately one year (June 2015–July 2016). Removing a non-native predatory fish from the deepest lake in Bucks Lake Wilderness is highly desirable for the SNYLF population in this basin, especially given that few remaining lake-based SNYLF populations exist in Plumas County. Gold Lake will potentially supply additional foraging and overwintering habitat for SNYLF that immigrate from the Rock Lake drainage.

Gold Lake and Blixy Lake continue to contain robust dace populations. CDFW does not know what affect dace may have on SNYLF breeding (e.g., potential for dace to prey on or damage egg masses and early life stage tadpoles). Blixy Lake provides some circumstantial evidence for dace limiting SNYLF breeding because SNYLF eggs and tadpoles have not been observed. Conversely, Goose Lake, located at the southern edge of Plumas National Forest in Sierra County, contains an abundant dace population sympatric with SNYLF, and VES results suggest that the SNYLF population in the Goose Lake area appears to be doing well. Therefore, the presence of dace clearly does not preclude successful SNYLF breeding. However, little quantitative data are available regarding direct interactions between dace and early life stage SNYLF.

There is evidence that other cyprinids can cause reduced survival and growth in amphibians. For example, a mesocosm study found that Fathead Minnows (*Pimephales promelas*) reduced the survival and growth rates of salamander larvae through competition and inflicting injury (Pearson and Goater 2009). Other small fish species have been linked with sublethal effects on amphibians, including Mosquitofish (*Gambusia* sp.; Pyke and White 2000; studies summarized in Kats and Ferrer 2003). Experimental evidence has shown that Three-spined Sticklebacks (*Gasterosteus aculeatus*) cause limb and tail damage in larval Western Toads (*Anaxyrus boreas*) identical to damage observed in the field (Bowerman et al. 2010). Undoubtedly, numerous fish species can affect amphibian larvae in different ways, and many of those effects may be deleterious, if not necessarily lethal (Wells 2007, pgs. 657–659).

The evidence for other common aquatic predators affecting larval amphibians further complicates isolating potential effects of minnows. For example, various species of dragonfly nymphs are voracious predators of amphibian larvae (See Table 14.2 in Wells 2007; Ballengée and Sessions 2009, Bowerman et al. 2010). Additionally, other amphibian larvae found in the northern Sierra Nevada are known to prey on conspecifics (e.g., *Ambystoma macrodactylum*; Wildy et al. 1998, Wildy et al. 2001).

In light of these complications and unknowns regarding interactions between minnows and SNYLF, CDFW and PNF will continue to monitor the Gold Lake and Blixy Lake populations to monitor for evidence of recruitment (particularly tadpoles), and observe potential interactions between minnows and SNYLF. This site, in combination with aforementioned SNYLF populations in the Goose Lake area, Sierra County, could provide a unique opportunity for CDFW to study the ecological interactions of native cyprinids and early life stage SNYLF.

Given the close proximity and hydrologic connection of Gold Lake and Rock Lake, CDFW is not planning to conduct short distance translocations of SNYLF from the Rock Lake drainage to Gold Lake. CDFW observations in 2018 have already shown an increase in SNYLF observations in the Gold Lake drainage. SNYLF will likely continue migrating into Gold Lake via the streams connecting to Rock Lake. Now lacking predatory non-native BK, Gold Lake is more likely to provide suitable deep-water habitat for SNYLF.

RECOMMENDATIONS

CDFW will continue monitoring the Gold Lake and Mount Pleasant NSR SNYLF populations every year to assess population status (i.e., determine relative abundance, look for signs of continued breeding and recruitment, and assess distribution of SNYLF on the landscape). Staff will focus on locating SNYLF that may be moving out of Rock Lake and into Gold Lake or its tributaries. This will require thorough VES in challenging terrain, such as stream channels with dense willow growth and steep, rocky substrates with abundant refugia for SNYLF.

Additionally, CDFW may work with local zoo and university partners to develop a research project (e.g., a graduate research masters study) on the interactions between cyprinids and SNYLF, especially early life stages, such as eggs and recently hatched larvae. The interactions of large predatory fish (e.g., trout) and SNYLF are well-studied, but there is much less currently known about the interactions of smaller forage fish and amphibians, especially studies investigating potential sublethal effects (e.g., limited breeding success, reduced size at metamorphosis, limb damage) on frog populations.

If results from captive rearing in 2018–2019 are encouraging, CDFW may also work with PNF and zoo partners to collect additional early life stage SNYLF for future captive rearing efforts. Success of captive rearing efforts may be determined in several ways, including staff observing, 1) released adult SNYLF persisting after the first winter following release, 2) additional signs of breeding (higher counts of egg masses, tadpoles, and/or metamorphs), and 3) evidence of new recruitment into the adult population. Augmenting these populations through captive rearing, and enhancing deep-water habitat through the successful removal of introduced trout, has increased the odds of long-term SNYLF persistence in Bucks Lake Wilderness.

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