State of California

Memorandum

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

GOLD LAKE FISH REMOVAL AND ROCK LAKE *RANA SIERRAE* MONITORING.

Brook trout removal activities are complete in the Gold Lake drainage (Figure 1); California Department of Fish and Wildlife (CDFW) staff removed 254 brook trout to benefit Sierra Nevada yellow-legged frogs (*Rana sierrae*, SNYLF). Amphibian monitoring data from 2012 through 2017 suggest a very small but stable SNYLF population; because of its size, this population remains extremely vulnerable to extirpation. CDFW will continue amphibian monitoring the in area to document SNYLF response to fish removal.

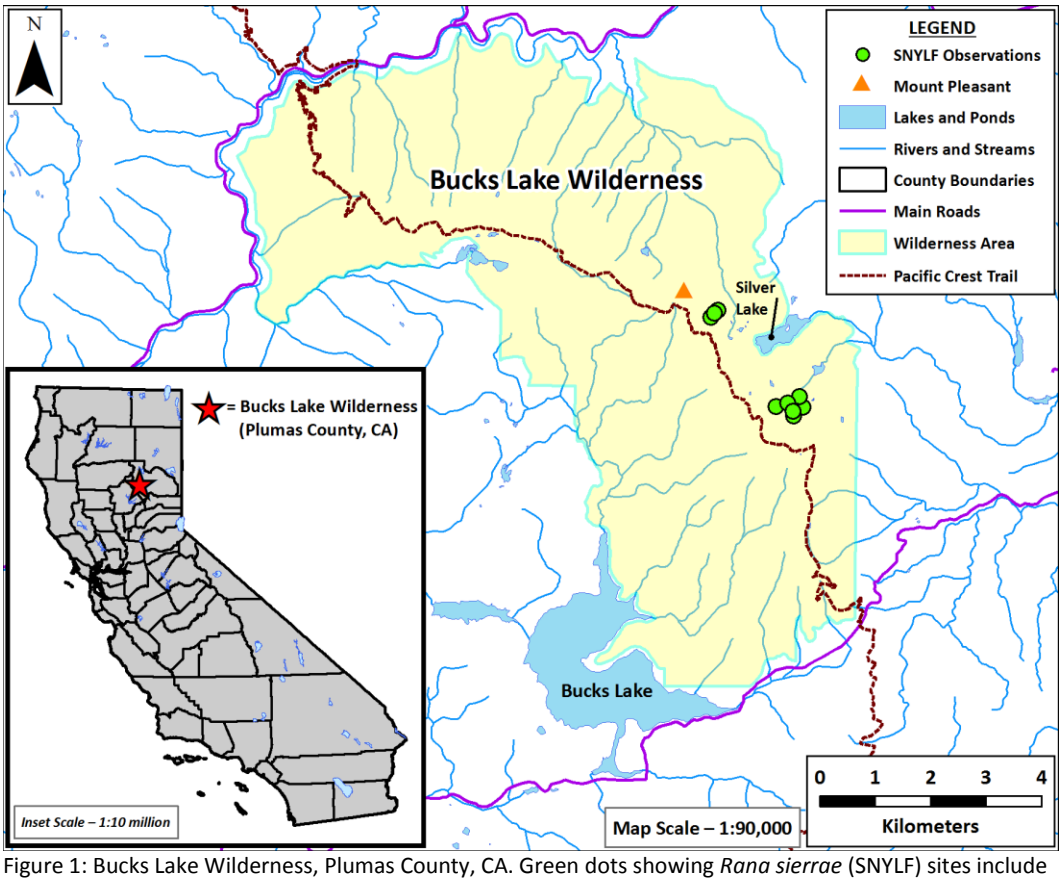


Figure 1: Bucks Lake Wilderness, Plumas County, CA. Green dots showing *Rana sierrae* (SNYLF) sites include positive detections by CDFW staff during visual encounter surveys (VES) between 2004 and 2017.

ENVIRONMENTAL SETTING

Bucks Lake Wilderness is located in western Plumas County, south of Interstate 70 and north of Bucks Lake Reservoir, and consists of 9,695 hectares. The Pacific Crest Trail bisects the wilderness from north to south, and local elevations range from around 2,400 feet (730 meters [m]) above mean sea level near the northern border along the Feather River, to 7,067 feet (2,154 m) at the summit of Mount Pleasant. CDFW crews observed two SNYLF populations in Bucks Lake Wilderness while conducting baseline surveys in 2003 and 2004. Surveys conducted in the intervening years have revealed one SNYLF population south of Silver Lake in the Rock Lake drainage; and a second population persisting in a small drainage with two ponds southeast of Mount Pleasant.

INTRODUCTION

Gold Lake represents the only fish removal project to benefit SNYLF undertaken by CDFW in Plumas County. For detailed background on aquatic ecosystem management in the Bucks Lake Wilderness (Figure 1), see the Aquatic Biodiversity Management Plan (ABMP) for the Bucks Lake Wilderness Management Unit (CDFW 2015; available online via the publicly accessible CDFW document library at https://nrm.dfg.ca.gov/documents/DocViewer.aspx). The Bucks Lake 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 brook trout eradication using mechanical methods is feasible, and 3) there is an extant SNYLF population in close proximity to Gold Lake.

Fish removal was complicated by Gold Lake being a popular recreational destination easily accessible from Silver Lake. Members of the local community strongly opposed the action. 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 fish. 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. There are numerous other fishing opportunities in Plumas County, including the Mount Hope area of Lassen National Forest to the west of Bucks Lake Wilderness, and approximately 20 different locations in Plumas County that are regularly stocked by CDFW.

During a 2004 baseline visual encounter survey (VES) for SNYLF at Rock Lake (CA Lake ID 12069), CDFW observed eight adults, seven juveniles, and 21 larvae – the only sign of breeding within the area (Figure 2). An 8-hour gill net set at Rock Lake yielded no fish. However, a 9-hour net set at nearby Gold Lake (Figure 3), which includes the only deep water (29 m maximum recorded depth) lake habitat in Bucks Lake Wilderness located close to the Rock Lake SNYLF population, captured eight brook trout and indicated a self-sustaining fishery. While potentially offering foraging and basking habitat to adult SNYLF, Mud Lake is likely too shallow and homogeneous to provide breeding habitat. Additionally, Mud Lake is not hydrologically connected to Rock and Gold Lakes. Both Gold and Rock Lakes are beautiful northern Sierra lakes easily accessible via a short hike from Silver Lake trailhead, all factors that make for heavy recreational use of the area. Based on extensive surveys during the summers of 2002–2005, the small SNYLF population at Rock Lake is one of only three documented lake-based populations in Plumas County. In accordance with the CDFW mission statement to balance native species diversity and recreational opportunity, Gold Lake (Figure 4) was identified as a potential restoration site for *Rana sierrae*.

THREATS

- ***Marginal Habitats*** – These frog populations are persisting in Rock Lake and its tributary. Rock Lake is small, isolated, and has a maximum recorded depth of 3.9 m. 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 resulted in low water levels in Rock Lake), any one of which could eliminate these small SNYLF populations.

- ***Introduced Fish*** – Gold Lake (Figure 4) formerly contained a self-sustaining brook trout population.

However, in 2015, CDFW initiated fish removal efforts. No brook trout have been observed in Gold Lake since July 2016. In 2004 and 2005, CDFW staff observed adult SNYLF in the tributaries of Gold Lake, and staff also observed two adult SNYLF at Gold Lake in 2015 (Figure 5). Additionally, CDFW regularly observes SNYLF in Rock Lake and its outlet, which is located adjacent to Gold Lake (Figures 2 and 3). Trout may have been precluding SNYLF from successful breeding and recruitment in Gold Lake, which is the only additional deep water habitat near the breeding SNYLF site at Rock Lake. Furthermore, dace (*Rihinichthys* spp.) are present in Gold 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).

- ***Disease*** – All SNYLF populations in Plumas County are chytrid fungus (*Batrachochytrium dendrobatidis*; *Bd*) positive. In 2008, 2010, and 2011, Rock Lake and unnamed ponds 12049 and 12052 were genetically sampled by epithelial swabs for the presence of *Bd.* A total of 27 swabs were collected and results for all three years indicate light to very light *Bd* zoospore loads at all sites. CDFW field staff have not yet observed any signs of *Bd* outbreak in the Gold or Rock Lake drainages. If *Bd*-induced die-offs occurred in these populations, the disease outbreaks likely took place many years ago when SNYLF populations may have been much larger and individuals were naïve to the disease.

- ***Loss of Genetic Diversity*** – The Bucks Lake Wilderness SNYLF populations represent 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 (e.g., small streams), 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).

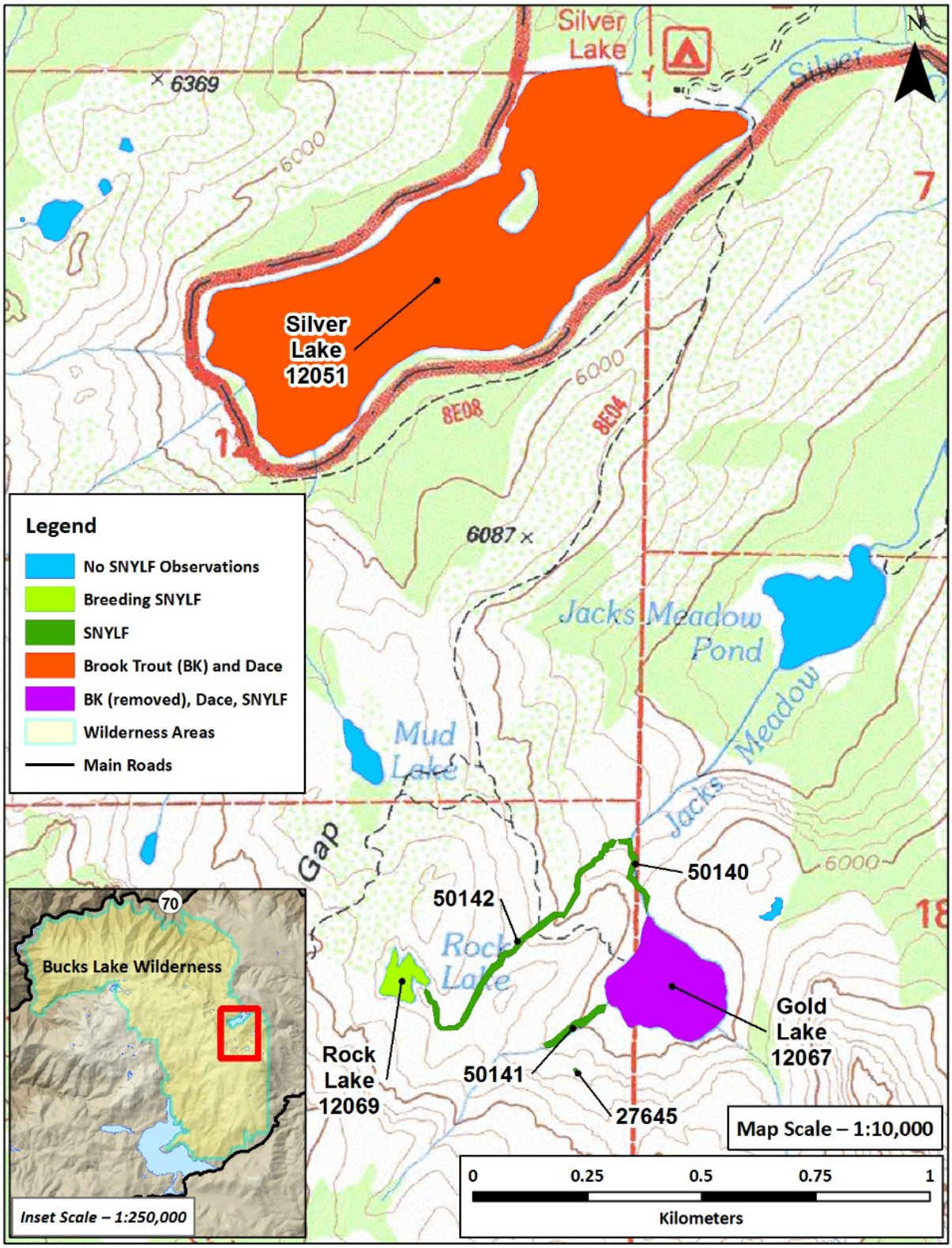


Figure 2: Gold and Rock Lakes restoration area in Bucks Lake Wilderness, Plumas County, CA. *Rana sierrae* (SNYLF) observations occurred during visual encounter surveys (VES) between 2004 and 2017. In 2015, CDFW staff observed two adult SNYLF in Gold Lake. Rock Lake is the only known SNYLF breeding location in the Gold Lake drainage. CDFW staff had 10–30 gill nets set in Gold Lake between 2015 and 2018. No brook trout captures have occurred since July 2016. Gill nets are set in Gold Lake through early summer 2018. If gill nets set overwinter in Gold Lake during 2017-18 capture no brook trout, CDFW will remove all gill nets. CDFW staff will undertake occasional visual surveys to monitor native amphibian populations and set overnight gill nets to add evidence of fish absence. Dace are still present in Gold Lake.

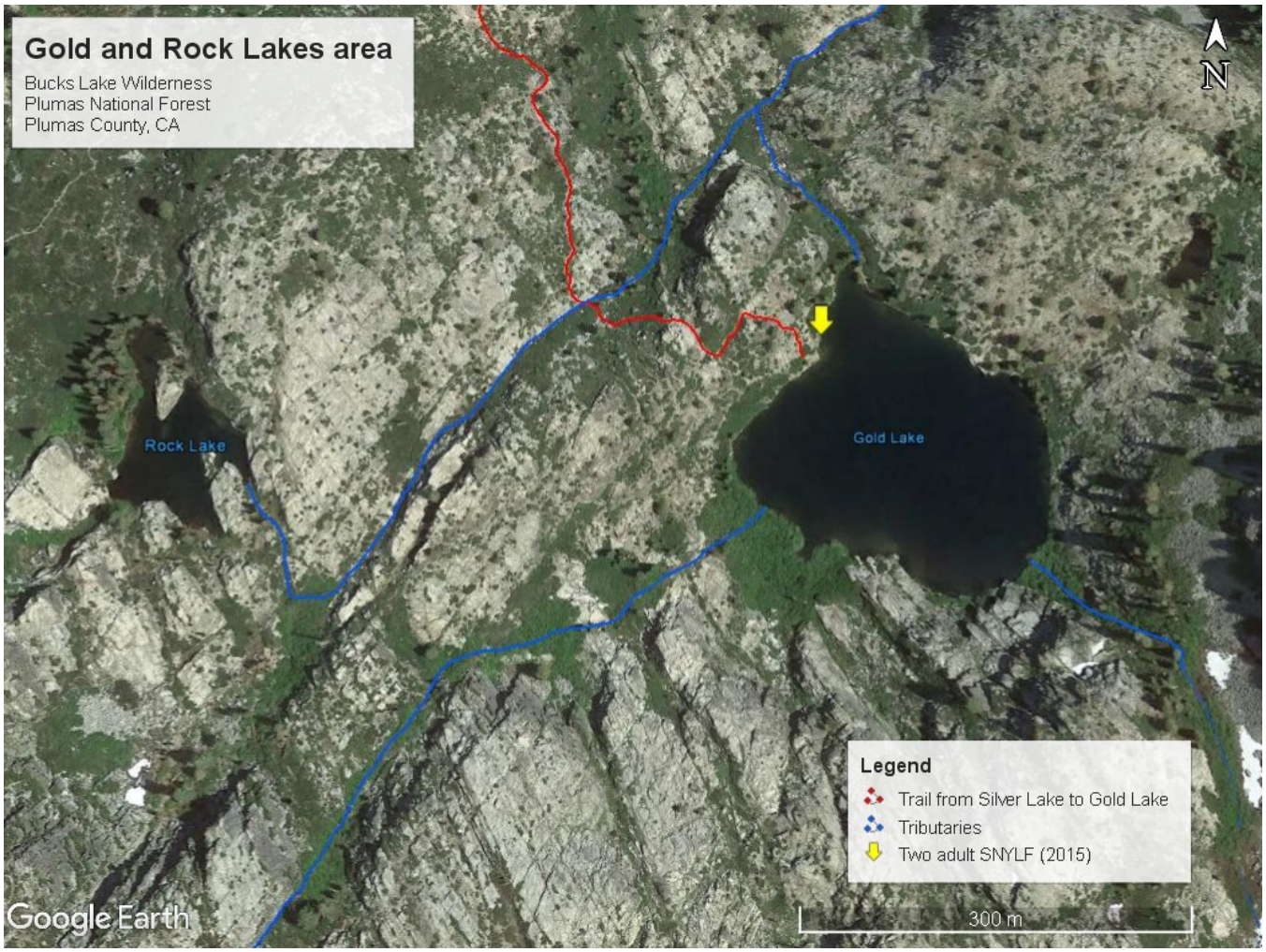


Figure 3. Aerial image of Gold and Rock Lake areas, taken on 2 July 2017 (Google Earth). CDFW staff have observed most SNYLF, including egg masses and tadpoles, in Rock Lake. However, CDFW has also frequently observed adults and subadults in the upper portions of the Rock Lake outlet, which flows past the hiking trail from Silver Lake to Gold Lake. Staff have also seen SNYLF in the southwest inlet to Gold Lake, although there have been fewer visual encounter surveys (VES) in this drainage. In October 2015, CDFW staff observed two adult SNYLF basking in a rock crevice along the northwest shoreline of Gold Lake (yellow arrow). This observation was the first time CDFW staff had detected SNYLF in the Gold Lake vicinity since 2004, when staff observed three adults in the Gold Lake outlet stream.


Figure 4. Gold Lake (CA Lake ID 12067) in October 2016, looking east. (CDFW)

Figure 5. Two adult *Rana* sierrae (SNYLF) basking in a rock crevice along the northwestern shore of Gold Lake in October 2015. (CDFW)

FISH REMOVAL AT GOLD LAKE

PROJECT TIMELINE

In 2013, CDFW applied for Traditional Section 6 funding from the U.S. Fish and Wildlife Service to remove brook trout from Gold Lake and restore habitat for SNYLF and other native species. The grant was awarded in February 2014. Public outreach for the Gold Lake fish removal project began on April 3, 2014, when the plan was introduced at the Plumas County Fish and Game commission meeting. CDFW filed the California Environmental Quality Act (CEQA) Notice of Exemption on April 21, 2014 (CEQA Clearinghouse # 2014048177). On May 6, 2014, CDFW staff attended the Plumas County Board of Supervisors (BOS) meeting to discuss the project with the board and the public. In May 2015, CDFW completed the Bucks Lake Wilderness Management Unit Aquatic Biodiversity Management Plan (CDFW 2015), which identified Gold Lake for habitat restoration to benefit SNYLF and other native species. Prior to initiating fish removal, CDFW staff met with the BOS and the public on June 2, 2015 to provide updates on the project. Fish removal officially commenced in June 2015.

METHODS

CDFW staff used monofilament gill nets to remove brook trout from Gold Lake and associated stream pools. Gill nets are 36 m long, 1.8 m high, and composed of six 6-m-long panels of mesh with increasing diameters (10 millimeters [mm]–38 mm). Gill nets contain a float line on top and a weighted line on bottom. The entire net sinks to the lake bottom, but the float line allows the net to remain upright in the water column to capture fish effectively. Gill nets are set perpendicular to shore, with one side of the net anchored to land via paracord, and the other end stretched offshore and anchored in deep water. Small mesh panels are placed near shore to catch smaller fish in the littoral zone, and the larger mesh farther out in deeper water to target larger fish.

To remove any brook trout observed in the associated stream habitats of Gold Lake, CDFW crews planned to use 24-volt backpack electrofishing units. Backpack electrofishing units create an electrical circuit through the water column between an anode pole and flexible metal cathode wire. This electric current temporarily stuns the fish and allows crew members to capture the immobilized fish using dip nets. In addition, crews planned to disturb

any redds (gravel nests of trout eggs) detected in streams in the restoration areas to minimize the number of brook trout eggs that would successfully hatch.

Between June 16, 2015 and October 17, 2017, CDFW staff deployed between 10 and 30 variable-mesh monofilament gill nets at a time in Gold Lake. The number of nets set depended on time of year (i.e., CDFW typically deployed more nets in the summer when crews regularly visited the site) and net availability. Initially, staff checked nets every day, after which net checks became less frequent as the rate of brook trout captures declined. Therefore, crews had gill nets deployed almost constantly, and checked the nets every day (early in the project) up to once per month (later in the project) to remove fish during the field season. From late October to early May, crews left gill nets set in the lake to capture fish throughout the winter. Due to access restrictions and lake ice, crews did not check the nets during the winter season.

Crews recorded the time and date of each net set and pull to calculate deployment time (used to determine catch per unit effort; CPUE). CPUE is calculated as the number of fish caught per "net hour," which is a unit denoting a single gill net set for one hour. All captured fish were euthanized, identified to species, and tallied. Crews monitored the inlet and outlet streams at Gold Lake for any brook trout. Due to consistent drought conditions during eradication efforts, the inlet and outlet streams to Gold Lake dried completely in 2015. Therefore, CDFW staff did not observe any brook trout in the stream segments, and no electrofishing was necessary.

OUTREACH AND PUBLIC RELATIONS

Throughout the project, CDFW displayed signs at the Silver Lake information kiosk to alert members of the public of restoration activities at Gold Lake. Additionally, the anchor point of each gill net contained a laminated sign, which included contact information for the CDFW Environmental Scientist leading the project. CDFW crews also avoided placing gill nets below the popular swimming areas, such as the prominent rock outcrops on the west and north shore of the lake.

FISH REMOVAL RESULTS

Fish eradication began in June 2015 and has continued through 2018. Soon after gill nets were set in Gold Lake, CPUE for brook trout were high. However, CPUE dramatically declined soon after initial net sets (Figure 6). After the initial summer of gill netting (2015), very few brook trout were captured (Table 1). Since June 2015, gill nets have been deployed in Gold Lake almost constantly. Therefore, when accounting for all nets (up to nearly 30 nets set at any one time), the total gill net hours as of October 2017 is 358,224, or about 40 net years. During that time, CDFW staff caught 254 brook trout and 7,480 dace (Table 1).

CDFW has not observed any brook trout in the fish removal area since July 27, 2016. Currently, eleven gill nets are set overwinter to provide final confirmation that brook trout are eradicated from the lake. CDFW will inspect the overwinter gill nets in early summer 2018. If the gill nets have not captured any brook trout, CDFW will declare brook trout removal complete. CDFW will occasionally (e.g., once/year or every other year) set one or two gill nets over a single night to provide additional evidence of brook trout absence. CDFW will also conduct VES at Gold Lake and its tributaries, and the nearby aquatic habitats (Rock Lake drainage), to monitor SNYLF population status and trends, and attempt detecting any frogs that may move into Gold Lake andsociated tributaries.

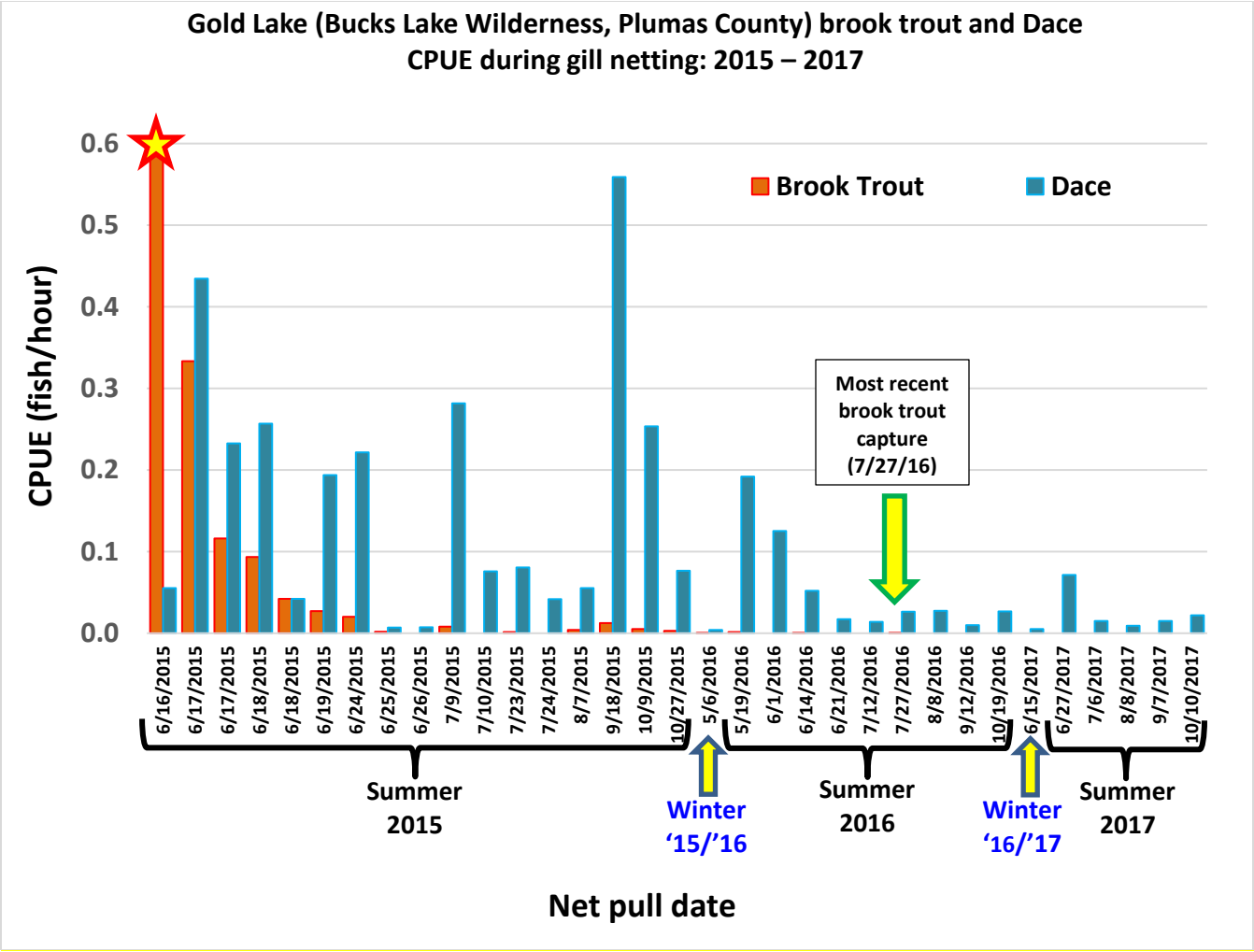


Figure 6. Catch per unit effort (CPUE) of brook trout and dace captured from gill nets set in Gold Lake (CA Lake ID 12067) between 6/2015 and 10/2017. The star indicates a much higher brook trout CPUE (2.6 fish/hour) from the first net set than what is shown on the graph. Scale was set to show more detail of CPUEs during subsequent gill net pulls. brook trout CPUE was very high during the initial gill net sets in June 2015. CPUE rapidly declined by the end of June, after which brook trout captures remained consistently low (as measured by CPUE) until the last brook trout capture in July 2016. CPUE for dace has been highly variable since CDFW began gill netting in Gold Lake. However, there appears to be a general downward trend in dace captures. Dace CPUE has been consistently below 0.01 fish/hour since mid-June 2016. Gill netting is not an effective method for eradicating a small, abundant, highly fecund minnow species.

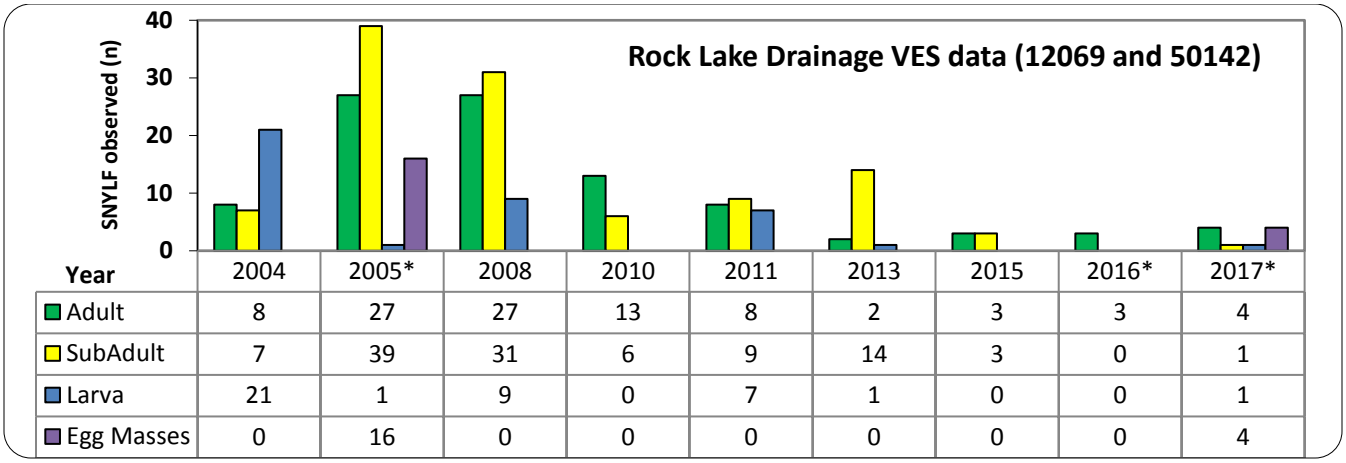
Table 1. Monthly summary statistics from gill nets deployed for brook trout removal in Gold Lake from Jun 2015–Oct 2017.

Date	Average # Nets	Net Hours	Brook trout (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	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	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	11	Deployed	N/A	N/A
TOTAL		**358,224**	**254**	**7,480**

VES IN THE ROCK LAKE DRAINAGE

CDFW performed the baseline visual encounter survey at Rock Lake (12069; Figure 7) in 2004, during which surveyors detected eight adult *Rana sierrae,* seven juveniles and 21 larvae. Fourteen years of monitoring data suggest that this population is slowly declining (Figure 8). However, 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. CDFW will continue to survey the site at least every other year to monitor SNYLF population trends over time.

Figure 7. Rock Lake (CA Lake ID 12069) in June 2017. (CDFW)



Year	2004	2005*	2008	2010	2011	2013	2015	2016*	2017*
Adult	8	27	27	13	8	2	3	3	4
SubAdult	7	39	31	6	9	14	3	0	1
Larva	21	1	9	0	7	1	0	0	1
Egg Masses	0	16	0	0	0	0	0	0	4

Figure 8: Visual encounter survey data by life stage and year at Rock Lake. If more than one VES was conducted in a given year (2015 and 2016), the data shown are from the survey day resulting in the highest number of SNYLF detections.
*50142 was only surveyed in 2005, 2016, and 2017.

DISCUSSION

The Gold Lake fish removal project has been successful at mechanically removing brook trout using monofilament gill nets. The brook trout population was small at Gold Lake: only about 250 trout were removed from the lake after nearly constant gill-netting efforts for over two years. Based on present data, brook trout were removed from Gold Lake in approximately one year (June 2015–July 2016). Removing a non-native predatory fish from the closest deep water lake to Rock Lake 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 continues to contain a robust dace population. 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). Some circumstantial evidence for dace limiting SNYLF breeding is provided by Pond 12049, which also contains dace, and in which 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. CDFW and U.S. Forest Service staff regularly monitor Goose Lake and the other waterbodies in the drainage east of Gold Lake reservoir. During recent surveys, in addition to observations of SNYLF adults and subadults, staff have observed egg masses in 2010, 2016, and 2017. CDFW crews observed nine SNYLF egg masses during the recent surveys in 2017, and crews detected 17 egg masses in 2010. CDFW is not aware of additional fishless deep water breeding habitat in the Goose Lake area, and VES results suggest that the SNYLF population in this 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 some evidence that other cyprinids can cause reduced survival and growth in amphibians. For example, a study involving the use of mesocosms and aquaria to investigate potential effects of fathead minnows (*Pimephales promelas*) on egg masses and larval southern long-toed salamanders (*Ambystoma macrodactylum sigillatum*) found that minnows reduced the survival and growth rates of salamander larvae (Pearson and Goater 2009). The minnows did not appear to actively consume recent hatchling salamander larvae, but minnows did attack limbs and cause other sublethal effects (e.g., smaller size at metamorphosis and increased time spent in refugia). Fathead minnows were also hypothesized to have outcompeted salamander larvae for zooplankton, on which both species will feed (Pearson and Goater 2009). Other small, often highly abundant, fish species have also been linked with sublethal effects on amphibians, including mosquitofish (*Gambusia* sp.), which have been shown to cause injuries, reduced size at metamorphosis, and decreasing activity in larval anurans (Pyke and White 2000; plus, see studies summarized in Kats and Ferrer 2003). Three-spined sticklebacks (*Gasterosteus aculeatus*) have also been demonstrated during experiments to cause limb and tail damage in larval western toads (*Anaxyrus*

boreas) identical to damage observed in the field (Bowerman et al. 2010). Although some researchers dispute drawing conclusions from experimental trials using unnatural aquarium and mesocosm settings (e.g., Skelly and Benard 2010), others have argued that these experiments are extremely useful, especially when combined with multiple lines of evidence from field-based observations and experiments (Johnson and Bowerman 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 causing damage and mortality in larval amphibians further complicates isolating potential effects of dace. 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 dace and SNYLF, CDFW will need to monitor the Gold Lake area to document SNYLF response to brook trout removal and observe potential interactions between dace and SNYLF. This site also 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 any SNYLF life stages from the Rock Lake drainage to Gold Lake. Over time, SNYLF will likely migrate into Gold Lake via the streams connecting the two areas. If future surveying reveals that the Rock Lake SNYLF population has grown substantially, CDFW anticipates that post-metamorphic SNYLF will likely expand to new areas, and Gold Lake provides hydrologically connected deep-water habitat.

RECOMMENDATIONS

CDFW should continue monitoring the Rock and Gold Lakes 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 especially focus on locating any SNYLF that may be moving out of Rock Lake and into Gold Lake or its tributaries. These efforts will require thorough VES in challenging terrain, such as stream channels with dense willow growth and steep, rocky substrates with many possible sources of 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.

LITERATURE CITED

Ballengée, B., and S.K. Sessions. 2009. Explanation for missing limbs in deformed amphibians. Journal of Experimental Zoology (Molecular Development and Evolution) 312B:770–779.

Bowerman, J., P.T.J. Johnson, and T. Bowerman. 2010. Sublethal predators and their injured prey: linking aquatic predators and severe limb abnormalities in amphibians. Ecology 91:242–251.

California Department of Fish and Wildlife (CDFW). 2015. Aquatic Biodiversity Management Plan for the Bucks Lake Wilderness Management Unit. North Central Region, Rancho Cordova.

Frankham, R., J.D. Ballou, and D.A. Briscoe. 2009. Introduction to Conservation Genetics. Cambridge University Press, New York, NY, USA.

Johnson, P.T.J., and J. Bowerman. 2010. Do predators cause frog deformities? The need for an eco-epidemiological approach. Journal of Experimental Zoology (Molecular Development and Evolution) 314B:515–518.

Kats, L.B., and R.P. Ferrer. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distributions 9:99–110.

Pearson, K.J., and C.P. Goater. 2009. Effects of predaceous and non-predaceous introduced fish on the survival, growth, and antipredation behaviors of long-toed salamanders. Canadian Journal of Zoology 87:948–955.

Pyke, G.H., and A.W. White. 2000. Factors influencing predation on eggs and tadpoles of the endangered green and golden bell frog *Litoria aurea* by the introduced plague minnow *Gambusia holbrooki*. Australian Zoologist 31:496–505.

Skelly, D., and M. Benard. 2010. Mystery unsolved: missing limbs in deformed amphibians. Journal of Experimental Zoology (Molecular Development and Evolution) 314B:179–181.

U.S. Fish and Wildlife Service, U.S. Department of the Interior (USFWS). 2018. Interagency Conservation Strategy for Mountain Yellow-legged Frogs in the Sierra Nevada (*Rana sierrae* and *Rana muscosa*). Administrative Draft.

Vredenburg, V.T., R.A. Knapp, T.S. Tunstall, and C.J. Briggs. 2010. Dynamics of an emerging disease drive large-scale amphibian population extinctions. Proceedings of the National Academy of Sciences 107:9689–9694.

Wells, K. 2007. The ecology and behavior of amphibians. The University of Chicago Press, Chicago, Illinois.

Wildy, E.L., D.P. Chivers, J.M. Kiesecker, and A.R. Blaustein. 1998. Cannibalism enhances growth in larval long-toed salamander, (*Ambystoma macrodactylum*). Journal of Herpetology 32:286–289.

Wildy, E.L., D.P. Chivers, J.M. Kiesecker, and A.R. Blaustein. 2001. The effects of food level and conspecific density on biting and cannibalism in larval long-toed salamanders, *Ambystoma macrodactylum*. Oecologia 128:202–209.