



Foothill Yellow-legged Frog Monitoring at Little Carson Creek and Big Carson Creek, Mt. Tamalpais Watershed 2018-2019

January 2020



Prepared for:

Marin Municipal Water District
220 Nellen Avenue
Corte Madera, CA 94925



Prepared by:

Garcia and Associates
2601 Mission Street, Suite 600
San Francisco, CA 94110



NATURAL & CULTURAL RESOURCE CONSULTANTS

GANDA

FOOTHILL YELLOW-LEGGED FROG MONITORING
AT LITTLE CARSON CREEK AND BIG CARSON CREEK,
MT. TAMALPAIS WATERSHED,
2018 - 2019

Prepared For:

Marin Municipal Water District
220 Nellen Avenue
Corte Madera, CA 94925

Prepared By:

Garcia and Associates
2601 Mission Street, Suite 600
San Francisco, CA 94110

January 2020



Executive Summary

Since 2004, Garcia and Associates has conducted annual monitoring of foothill yellow-legged frogs (*Rana boylei*) on Marin Municipal Water District land within the Mt. Tamalpais Watershed, Marin County, California. This report includes monitoring results from spring and fall of 2018 and 2019. Monitoring was performed at: 1) Little Carson Creek, and 2) Big Carson Creek and its two tributaries. Study objectives were to locate breeding sites, identify breeding periods, record egg masses, tadpoles, metamorphs (young-of-the-year), juveniles, and adults, and assess population trends. Surveys for egg masses, tadpoles, juveniles, and adults were conducted from March to late May and surveys for young-of-the-year (YOY) were conducted in October and early November.

In 2018, 17 egg masses were observed at Little Carson Creek and 30 egg masses at Big Carson Creek and its two tributaries. In 2019, 12 egg masses were observed at Little Carson Creek and 14 egg masses were observed at Big Carson Creek and its two tributaries. The breeding period at Little Carson Creek occurred from March 30 to April 16 in 2018 and from March 18 to April 28 in 2019. In Big Carson Creek and its two tributaries, the breeding period occurred from March 31 to April 28 in 2018 and from March 18 to April 26 in 2019. From 2008-2019, nearly half of the 151 total egg masses recorded on Little Carson Creek were located within Pool 3 at Carson Falls; during the same period, more than half of the 221 total egg masses recorded on Big Carson Creek were found near Pine Mountain Road. In 2018, eight egg masses were totally or partially scoured from Little Carson Creek breeding pools, apparently due to three rain events during the breeding period. At Big Carson Creek in 2018, four egg masses (two in the mainstem; two in Tributary 2) were also scoured during these rain events. In 2019, four rain events occurred during the breeding period resulting in two egg masses scoured from Pool 2 at Little Carson Creek. In Big Carson Creek, seven egg masses in 2018 and four egg masses in 2019 laid in the Pine Mountain Road crossing were relocated immediately downstream and hatched successfully.

During fall metamorph surveys at Little Carson Creek, no YOY were observed in 2018 and only a single YOY was observed in 2019. At Big Carson Creek, 48 YOY were observed in 2018 and four were observed in 2019. Although fewer observations were made over the last two seasons, annual metamorph recruitment continues to be higher for the Big Carson Creek population compared to the Little Carson Creek population. This may be caused by high predation rates by newts which are abundant in the breeding pools on Little Carson Creek and apparently absent in Big Carson Creek.

During breeding surveys at Little Carson Creek, 115 adult or juvenile frogs were observed in 2018 and 88 were observed in 2019. At Big Carson Creek, 306 adult or juvenile frogs were observed in 2018 and 267 were observed in 2019. Since 2008, a total of 567 individual adult frogs (246 from Little Carson Creek [103 females, 143 males] and 321 from Big Carson Creek [94 females, 227 males]) have been identified using mark-recapture techniques by photographic matching of chin mottling patterns. One male (BCC M-9), captured every year from 2008-2017, was recaptured again in 2019, and is estimated to be at least 14 years of age.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	i
INTRODUCTION.....	1
METHODS	4
RESULTS	7
EGG MASSES	7
ANNUAL EGG MASS COUNTS (2004-2019).....	16
BREEDING PERIOD	17
BREEDING SITE CHARACTERISTICS	19
WATER TEMPERATURES AND PRECIPITATION	20
TADPOLES	21
YOUNG-OF-THE-YEAR (YOY).....	22
ADULTS AND JUVENILES.....	23
PREDATORS	34
DISCUSSION	35
RECOMMENDATIONS.....	40
LITERATURE CITED	42

List of Tables

Table 1. FYLF survey results at Little Carson Creek, 2018-2019.....	8
Table 2. FYLF survey results at Big Carson Creek and its tributaries, 2018-2019.....	11
Table 3. Total egg mass counts at Little Carson Creek and Big Carson Creek and its tributaries, 2004-2019.	16
Table 4. FYLF breeding periods, Mt. Tamalpais Watershed, 2007-2019.	19
Table 5. Summary of FYLF oviposition site habitat parameters in Little Carson Creek and Big Carson Creek and tributaries, 2018-2019.....	20
Table 6. Mean daily water temperatures at Little Carson Creek, Big Carson Creek, and Cataract Creek from March 20 to October 22, 2018-2019.	21
Table 7. Summary of 2018 FYLF metamorph surveys on Little Carson Creek and Big Carson Creek and tributaries.....	22
Table 8. Summary of 2019 FYLF metamorph surveys on Little Carson Creek and Big Carson Creek and tributaries.....	23
Table 9. Number of FYLF YOY observations on Little Carson Creek and Big Carson Creek and tributaries, 2009-2019.....	23
Table 10. Summary of adult capture/recapture data for Little Carson Creek and Big Carson Creek and tributaries (2008-2019).....	27
Table 11. Summary of egg masses oviposited within Pine Mountain Road crossings at Big Carson Creek and tributaries, 2008-2019.....	37

List of Figures

Figure 1. Current distribution of FYLF, Marin Municipal Water District.	3
Figure 2. Gosner staging table for determining developmental stages of FYLF egg masses (Duellman and Trueb 1986).	5
Figure 3. Example of chin photographs of adult male FYLF (M1, M11 and M13) captured between 2008 and 2010 on the Mt. Tamalpais Watershed (Marlow et al. 2016).	6
Figure 4. Distribution of egg masses in Little Carson Creek breeding pools, 2008-2019 (N=151).	9
Figure 5. Distribution of egg masses in Little Carson Creek, 2018 and 2019.	10
Figure 6. Distribution of egg masses in Big Carson Creek, 2008-2019 (N=221).	14
Figure 7. Distribution of egg masses in Big Carson Creek, 2018 and 2019.	15
Figure 8. Annual egg mass counts for the Little Carson Creek and Big Carson Creek FYLF populations, 2004-2019. Dashed lines represent moving averages during the same period.	17
Figure 9. Breeding period (shaded areas), mean daily water temperatures, and precipitation at Little Carson Creek (purple shaded area) and Big Carson Creek (blue shaded area), 2018.	18
Figure 10. Breeding period (shaded areas), mean daily water temperatures, and precipitation at Little Carson Creek (purple shaded area) and Big Carson Creek (blue shaded area), 2019.	18
Figure 11. Percentage of recaptured frogs observed in Little Carson Creek and Big Carson Creek, 2009-2019.	28
Figure 12. Recapture and movement for Little Carson female (F68), 2013 to 2016.	29
Figure 13. Recapture and movement for Little Carson male (M80), 2013 to 2019.	30
Figure 14. Recapture and movement for Big Carson female (F1), 2009 to 2015.	31
Figure 15. Recapture and movement for Big Carson male (M9), 2008 to 2019.	32
Figure 16. Annual number of egg masses versus total number of female FYLF of breeding size present based on mark-recapture on Little Carson Creek, 2008-2019.	34
Figure 17. Annual number of egg masses versus total number of female FYLF of breeding size present based on mark-recapture on Big Carson Creek, 2008-2019.	34
Figure 18. Seep on Pine Mountain Road (left) and culverted pool in unnamed tributary to Big Carson Creek mainstem (right). Juveniles were observed in these two areas on March 28, 2018 and adults were observed in the tributary pool on March 19, 2019. ..	38
Figure 19. Unidentified adult FYLF in unnamed tributary to Tributary 1 near Big Carson Creek. This observation was made by David Greenberger on May 19, 2019.	40

Appendices:

Appendix A: Representative Photographs, 2018-2019

Introduction

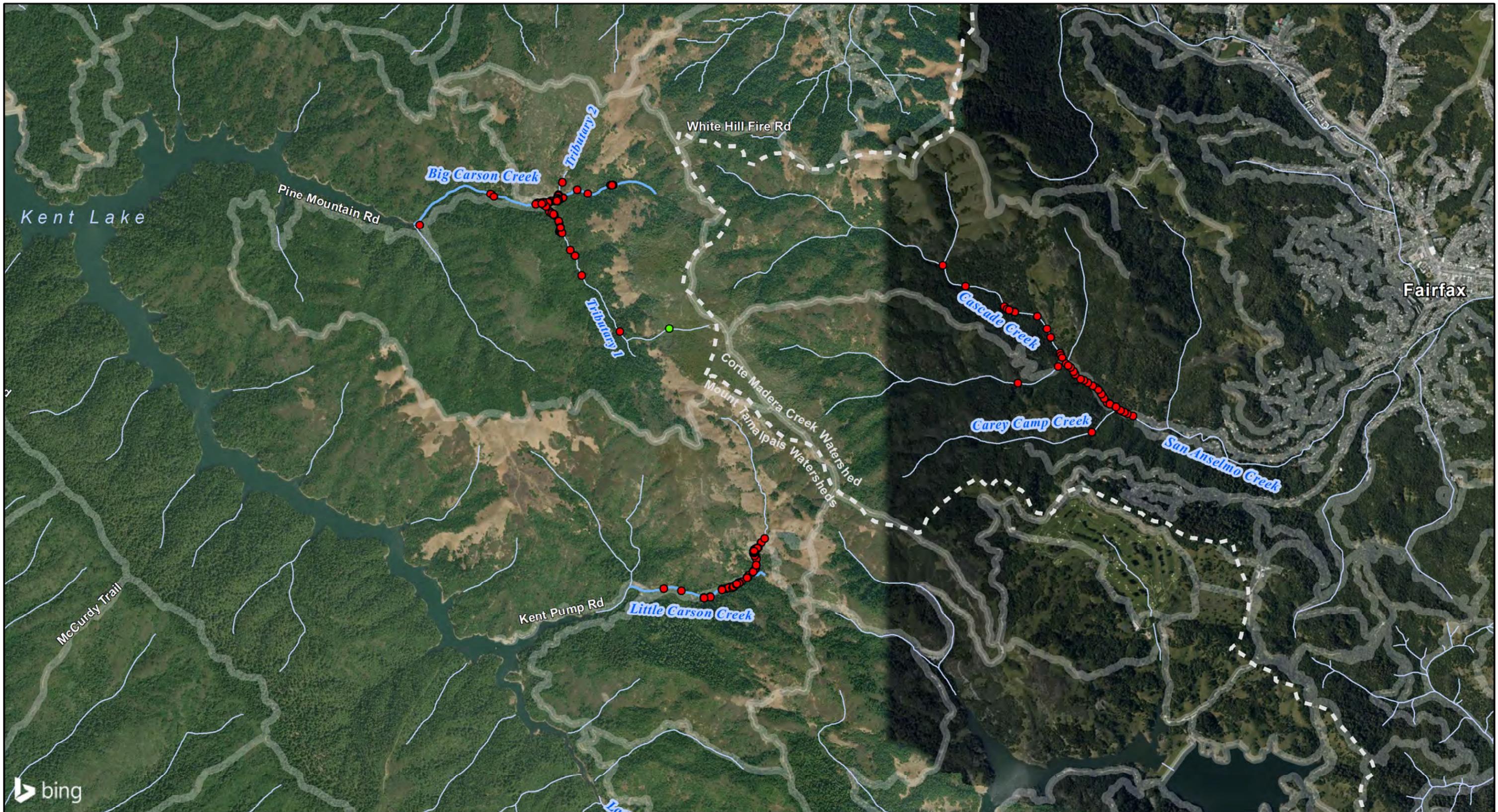
The Marin Municipal Water District (MMWD) has operated reservoirs within the Mt. Tamalpais Watershed since 1872, providing a major source of domestic water for its customers. In addition, the watershed is a valuable natural resource and is held in trust as a natural wildland, scenic open space, and an area for daytime recreational use for the residents of Marin County and the San Francisco Bay Area. Currently, MMWD operates five reservoirs within the watershed at Lagunitas Lake, Phoenix Lake, Alpine Lake, Bon Tempe Lake, and Kent Lake. As part of MMWD's *Mt. Tamalpais Watershed Road and Trail Management Plan* and *One Tam's Measuring the Health of the Mountain: A Report on Mount Tamalpais' Natural Resources*, MMWD has committed to best management practices to reduce road and trail impacts on water quality and to implement programs to monitor many special-status plant and animal species, including the foothill yellow-legged frog (FYLF; *Rana boylei*) (MMWD 2008; One Tam 2016).

Since 2004, Garcia and Associates (GANDA) has conducted annual population monitoring of FYLF in the Mt. Tamalpais Watershed for MMWD. This report provides the methods and results of monitoring efforts conducted during 2018 and 2019 and evaluates them within the context of previous years' data to assess population trends.

The FYLF is designated as a Federal Species of Concern and a Forest Service Sensitive species. On December 11, 2019, five of six genetic clades of *R. boylei* were listed as threatened or endangered under the California Endangered Species Act (CESA). The California Department of Fish and Wildlife (CDFW) voted to protect the Southern Sierra, Central Coast, and South Coast clades of the frog as endangered; and the Northern Sierra and Feather River clades as threatened. The CDFW also determined that FYLF in California's North Coast do not currently warrant state listing and remain a California Species of Special Concern. Foothill yellow-legged frogs are highly aquatic amphibians, spending most or all of their life in, or near, streams and rivers with rocky substrate and open, sunny banks, in forests, chaparral, and woodlands (CDFW 2019). They typically attach their egg masses to rocky substrates in open, sunny microhabitats with flowing water. Adult FYLF are primarily diurnal with strong site fidelity and typically occupy small home ranges, but adults and juveniles may move several hundred meters (m) or more to access breeding sites or refugia during the non-breeding season (CDFW 2019).

Monitoring sites for FYLF are located at the two known breeding sites within the Mt. Tamalpais Watershed, Little Carson Creek and Big Carson Creek (and its two tributaries) (Figure 1). Both creeks flow into Kent Lake, a reservoir along what was previously Lagunitas Creek. Little Carson Creek is a relatively small creek with a substrate primarily composed of bedrock, boulder, and gravel. Big Carson Creek is a larger creek with substrate primarily composed of gravel, cobble, and boulder. Along both creeks, tree canopy is generally dense in the lower reaches and becomes more open in the upper reaches, especially at Carson Falls on Little Carson Creek where there are few trees. Breeding areas in the upper reaches of Big Carson Creek have sections of dense tree canopy cover interspersed with more open canopy and sunny areas where most breeding sites are found.

The Mt. Tamalpais Watershed and surrounding region has a Mediterranean climate characterized by hot, dry summers and cool, wet winters. The dominant plant community of the watershed is mixed evergreen forest, interspersed with shrubland, chaparral, and grassland. The mixed evergreen forest surrounding the five reservoirs includes coast redwood (*Sequoia sempervirens*), Douglas fir (*Pseudotsuga menziesii*), tan oak (*Notholithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), coast live oak (*Quercus agrifolia*), canyon live oak (*Quercus chrysolepis*), black oak (*Quercus kelloggii*), California bay (*Umbellularia californica*), and California buckeye (*Aesculus californica*).



	 <p>Project Location</p>	<ul style="list-style-type: none"> ● Foothill yellow-legged frog observations ● FYLF observation (DG 05-31-19) Watershed Boundary 	<p>0 0.25 0.5 1 Mile</p> <p>0 0.5 1 2 Kilometer</p>		<p>Figure 1. Current Distribution of FYLF, Marin Municipal Water District</p> <p>Marin County, CA</p>
-------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----------------------------------------------------	---------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------------

Methods

Surveys were conducted at Big Carson Creek and two of its unnamed tributaries near Pine Mountain Road, and at Little Carson Creek near Kent Lake. Surveys were conducted following *A Standardized Approach for Habitat Assessments and Visual Encounter Surveys for the Foothill Yellow-Legged Frog (Rana boylei)* (Seltenrich and Pool 2002). Surveys were conducted by GANDA biologists Karla Marlow and Kevin Wiseman.

In 2018 and 2019, a total of twelve breeding surveys were conducted on Little Carson and Big Carson creeks, one every six to 10 days (\bar{x} =8.6 days) from March 28 to May 10, 2018, and one every six to 29 days (\bar{x} =11.7 days) from March 19 to May 28, 2019.

On Little Carson Creek, the standard survey area focused on known breeding areas, from Pool 0 to Pool 6. On Big Carson Creek, the standard survey area began approximately 80 m downstream of the Tributary 1 confluence upstream to the Pine Mountain Road crossing; Tributary 1 was surveyed from the Big Carson Creek confluence to approximately 250 m upstream; and, Tributary 2 was surveyed from the Big Carson Creek confluence to approximately 50 m upstream.

For each egg mass observed, a standard list of parameters were measured and recorded. These parameters included: location; attachment substrate; distance from shore; depth of egg mass and maximum depth at the egg mass; velocity at the egg mass; surface velocity; microhabitat; stream substrate; water temperature; egg mass shape; egg mass color; egg mass size; and, Gosner developmental stage (Gosner 1960; Figure 2). In addition, several individual embryos from each egg mass were collected for genetic analyses.

To determine when egg masses were laid, the stage of development of each egg mass was recorded following Gosner's (1960) table of anuran development (Figure 2). Based on previous work evaluating rates of development (GANDA 2006) and data from Zweifel (1955), it was determined that egg masses at these sites develop at an average rate of four Gosner stages during the first two days following oviposition (stages 1-8) and two Gosner stages per day thereafter. Because rates of development vary between sites based on water temperatures and exposure to sunlight, backdating with this method is an approximation of the breeding period. The breeding period of FYLF were estimated using this method from 2007-2019.

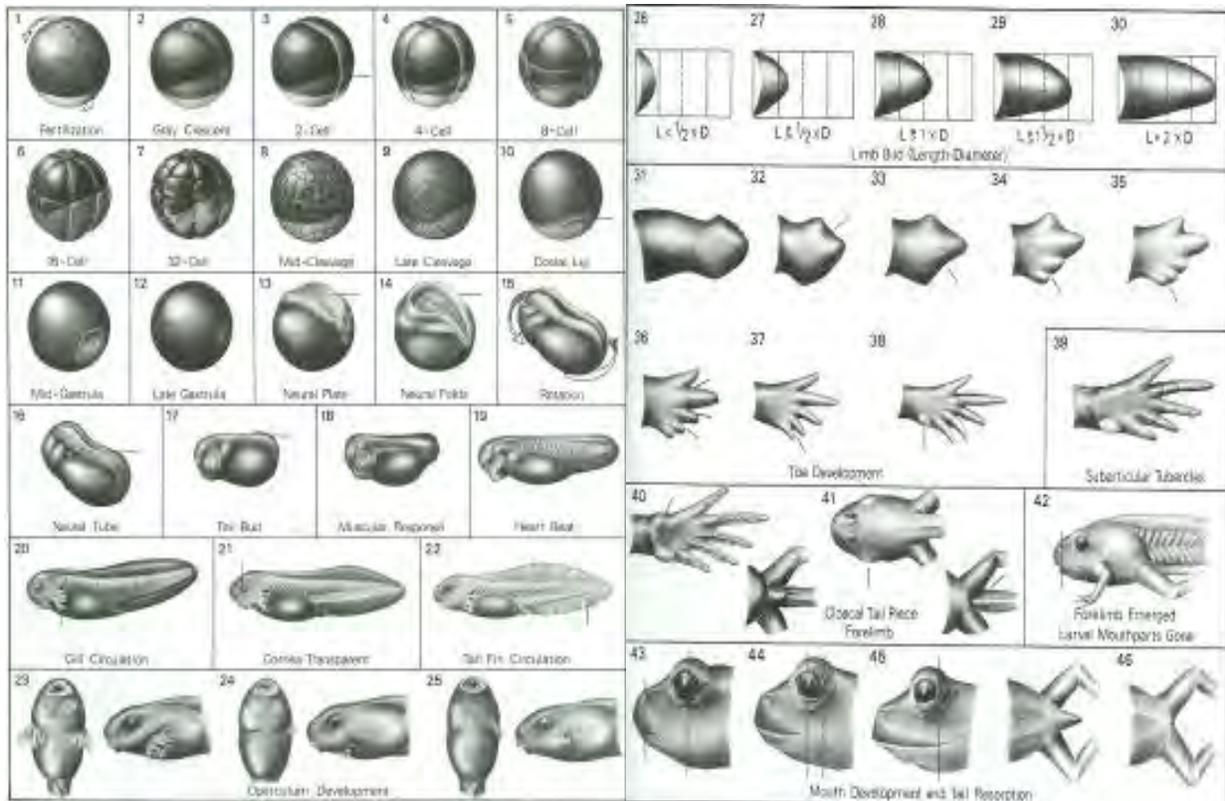


Figure 2. Gosner staging table for determining developmental stages of FYLF egg masses (Duellman and Trueb 1986).

Although surveys focused on locating egg masses, all life stages of frogs (egg masses, tadpoles, juveniles, and adults) encountered were documented and appropriate data sheets were completed. Occurrences were recorded using a Global Positioning System (GPS) unit and/or by noting the linear distance location within the survey site. Data collected for captured frogs included location; sex; snout-urostyle length (SUL, millimeters [mm]); weight (grams); condition (gravid or spent); activity; habitat and microhabitat type; and, dominant substrate. In addition to these parameters, skin swab samples were obtained of captured adults and juveniles to be used for future DNA and chytrid fungus analyses. We also recorded notes of any frogs with injuries or deformities. Uncaptured frogs were also recorded and data collected to the extent possible. During all surveys, an attempt was made to remove any non-native bullfrogs (*Lithobates catesbeianus*) or signal crayfish (*Pacifastacus leniusculus*) encountered.

Annual comparisons of egg mass counts, egg mass distribution, and metamorph (young-of-the-year [YOY]) recruitment varies in the range of data used for the analysis based upon available and/or comparable data (e.g. prior to 2008, egg mass locations were not always assigned to a specific breeding pool or tributary).

For each adult or juvenile frog captured during 2008 to 2019, a photograph of the chin was taken using a digital camera. Photographs were then used to identify individual frogs by matching their unique patterns of mottling (Figure 3).

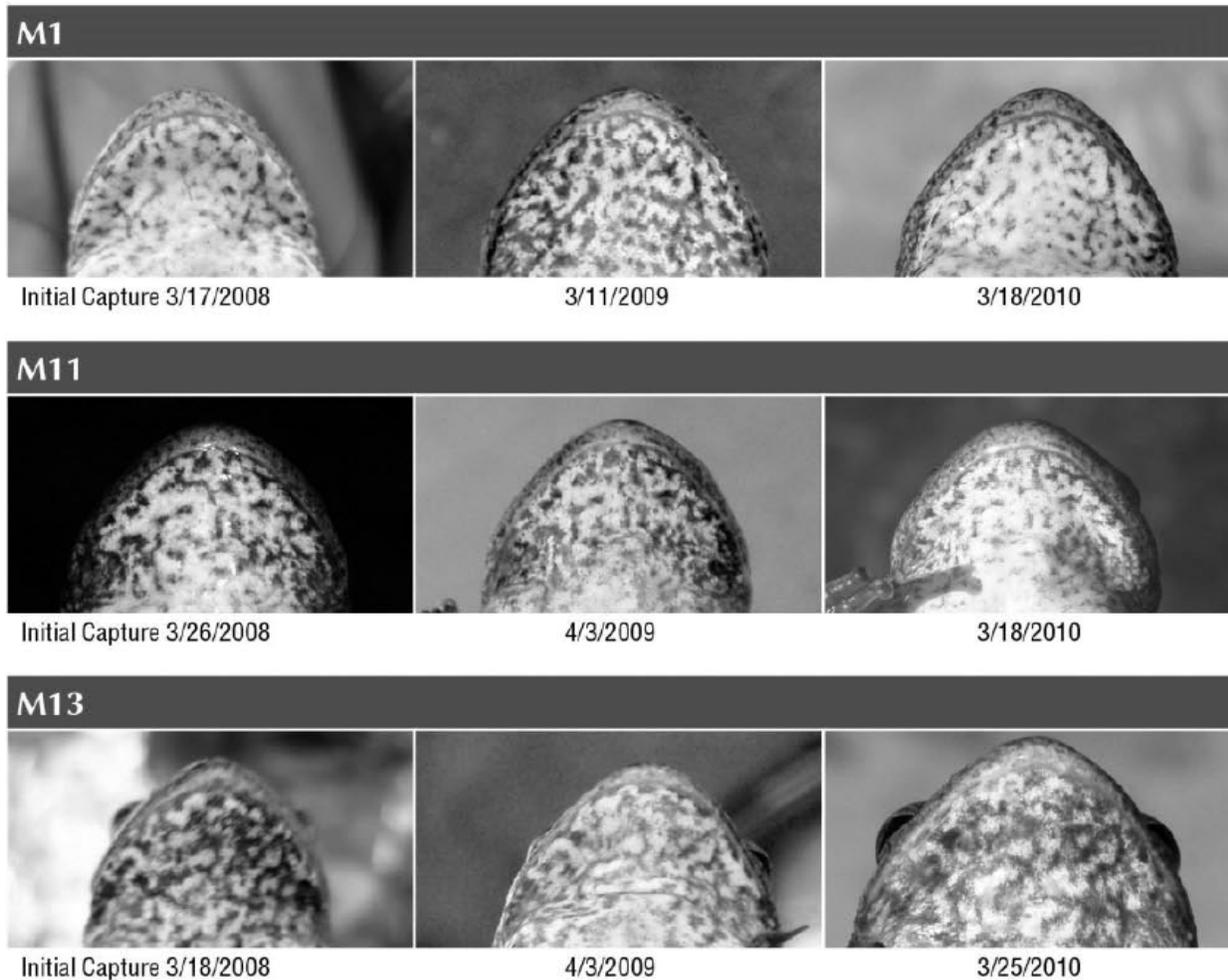


Figure 3. Example of chin photographs of adult male FYLF (M1, M11 and M13) captured between 2008 and 2010 on the Mt. Tamalpais Watershed (Marlow et al. 2016).

Chin photographs were later compared to others from the same creek and each frog was assigned a unique identification number, including frogs with no match. Chin photographs were also compared between years (2008-2019) within each creek and between tributaries to Big Carson Creek. Based upon recapture data collected from 2008-2013, site fidelity, movement, and annual reproduction of individual frogs was analyzed (GANDA 2013). This extensive analysis was not repeated from 2014 to 2019. Individual females were considered to have bred only if observed both in a gravid and spent condition during the breeding period of a given year.

Metamorph surveys were performed on October 15, 2018 and on November 5, 2019. Survey areas were the same as those surveyed during breeding surveys for Big Carson Creek (and its tributaries) and Little Carson Creek during both years.

To obtain mainstem channel water temperatures in 2018-2019, Onset Stowaway TidbiT[®] temperature recording loggers were installed in breeding habitats located in Little Carson Creek and Big Carson Creek; an additional logger was installed at Cataract Creek, a potential FYLF reintroduction site (GANDA 2010). Loggers were inserted into perforated PVC pipes and attached to edgewater vegetation with a small diameter plastic-coated metal cable. Temperature loggers were set to record at hourly intervals. Loggers were installed during the first breeding survey of the year and were removed during the last metamorph survey.

Results

Egg Masses

Little Carson Creek

Similar to previous years, FYLF breeding at Little Carson Creek occurred in the pools at Carson Falls. In 2018, a total of 17 egg masses were observed in pools 1, 2, 3, and 4 (Table 1; Figures 4-5). Eight of 11 egg masses, originally found on April 3, were found completely or partially scoured away on April 12, apparently as a result of over 4.6 inches of rain that fell between April 5 and April 12 (Figure 9). All other egg masses appeared to hatch successfully.

In 2019, 12 egg masses were observed in three of the seven breeding pools at Carson Falls (pools 2, 3, and 4) (Table 1; Figures 4-5). Two egg masses, originally observed on March 19, were observed on April 2 to have been almost completely scoured from Pool 2 (photos 5-6, Appendix A). These scour events likely occurred during high flows resulting from 4.3 inches of rain that fell between March 20-27, 2019 (Figure 10).

From 2008-2019, a total of 151 egg masses were observed in Little Carson Creek. Of these, 65 (43.0%) were located within Pool 3 at Carson Falls, 43 (28.5%) in Pool 2, 19 (12.6%) in Pool 4, and the remainder in pools 0, 1, and 6. Egg masses have not been observed in Pool 5 since 2004 (Figure 4).

Table 1. FYLF survey results at Little Carson Creek, 2018-2019.

Date	Subsite	H2O Temp* (°C) (range)	AD ¹ Male	AD ¹ Female Condition ²			AD UNK ³	JUV ¹	TAD ¹	EM ¹	Comments
				G	S	U					
3/28/2018	LCC	14.0 (14-15.5)	7	5	0	0	10	8	0	0	Five gravid females observed. One pair in amplexus. No egg masses observed.
4/3/2018	LCC	8.0 (8.0-10.0)	9	2	2	0	2	6	0	11	Eleven egg masses and two gravid females observed in pools 1, 2, 3, and 4.
4/12/2018	LCC	13.0 (12.5-13.5)	4	1	1	0	2	0	0	1	One new egg mass, one gravid female observed. Eight previous egg masses completely or partially scoured. Three previous egg masses intact.
4/20/2018	LCC	10.5	6	2	0	1	2	3	0	2	Two new egg masses and two gravid females observed.
4/30/2018	LCC	12.5 (12.5-15)	6	0	1	1	10	6	0	3	Three new egg masses observed in Pool 2.
5/10/2018	LCC	12.0 (12.5-13.5)	6	0	3	2	7	0	317	0	No new egg masses observed. Previous egg masses hatched or hatching.
2018 Total			38	10	7	4	33	23	317	17	
3/19/2019	LCC	13	7	3	1	0	4	1	0	2	Two fresh egg masses observed in Pool 2. One amplexing pair.
4/2/2019	LCC	11.5 (11.5-12)	9	5	1	0	3	1	0	0	No new egg masses observed. Two previous egg masses scoured. Three amplexing pairs in pools 1, 2, 3.
4/8/2019	LCC	14.5	5	3	1	0	5	1	0	3	Three new egg masses observed in pools 2 and 3. Two amplexing pairs observed in pools 2 and 4.
4/18/2019	LCC	11.5 (12-12.5)	9	0	2	2	1	4	0	3	Three new egg masses observed in Pool 2.
4/29/2019	LCC	10.5 (11-11.5)	6	0	5	0	2	1	300	4	Four new egg masses observed (one inferred from tadpole group). One dead male FYLF was observed in Pool 3 and collected for analysis.
5/28/2019	LCC	15.5 (15-16.5)	1	0	0	0	3	2	1	0	No new egg masses. Scouring from high flows seems likely with only one tadpole observed in egg mass areas.
2019 Total			37	11	10	2	18	10	301	12	

*Mainstem water temperature taken in Pool 0 at start of survey. Parentheses indicate temperature range of all breeding pools.

¹ Life Stage: AD=Adult, JUV=Juvenile; TAD=Tadpole; EM=Egg mass; Adult and Juvenile totals may include repeat captures over several surveys.

² Condition: G=Gravid; S=Spent (i.e. eggs laid); U=Breeding condition undetermined

³ UNK=Unknown: Unknown adults were frogs that were not captured.

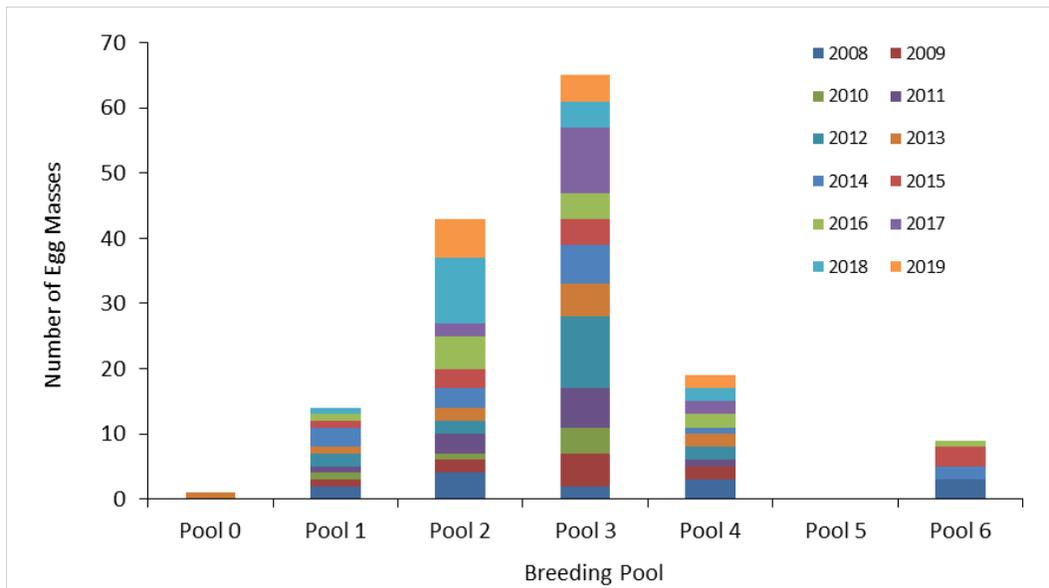


Figure 4. Distribution of egg masses in Little Carson Creek breeding pools, 2008-2019 (N=151).



- 2018 FYLF Egg Mass
- 2019 FYLF Egg Mass

bing

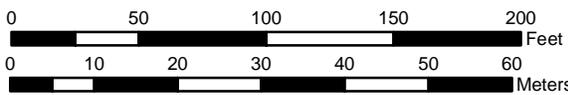


Figure 5.
Distribution of Egg Masses
in Little Carson Creek,
2018 and 2019.

Marin County, CA

Big Carson Creek

Similar to previous years, FYLF breeding in 2018 and 2019 was concentrated along Big Carson Creek near the road crossing of Pine Mountain Road. In 2018, a total of 30 egg masses were observed at Big Carson Creek and one of its tributaries (24 egg masses in the mainstem, and six in Tributary 2; Table 2; Figures 6-7). Three previously observed egg masses and one new egg mass were found scoured in Big Carson Creek and Tributary 2 on April 12, apparently resulting from 4.6 inches of rain that fell between April 5 and April 12, 2018 (Figure 9). A total of seven egg masses oviposited in the Pine Mountain Road crossing area of Big Carson Creek were relocated several meters downstream to avoid being disturbed by activity within the road crossing. These egg masses were subsequently observed to have hatched successfully.

In 2019, a total of 14 egg masses were observed at Big Carson Creek and Tributary 2 (12 in the mainstem and 2 in Tributary 2; Table 2; Figures 6-7). Four egg masses laid in the Pine Mountain Road crossing area were relocated immediately downstream; all appeared to have hatched successfully. No egg masses appeared to be scoured in the Big Carson system in 2019, however, low tadpole numbers in Tributary 2 during the final survey on May 28 indicate that some tadpoles may have been flushed downstream of egg mass sites after 5.9 inches of rain fell between May 6 and May 21 (Figure 10). Since 2008, a total of 221 egg masses have been observed in the Big Carson Creek system; 145 (65.6%) were located within the mainstem of Big Carson Creek, 68 (30.8%) were found in Tributary 2, and the remaining eight (3.6%) were located in Tributary 1 (Figure 6).

Table 2. FYLF survey results at Big Carson Creek and its tributaries, 2018-2019.

Date	Subsite	H2O Temp * (°C)	AD ¹ Male	AD ¹ Female Condition ²			AD UNK ³	JUV ¹	TAD ¹	EM ¹	COMMENTS
				G	S	U					
3/28/2018	BCC	10.0	8	0	0	0	6	25	0	0	No egg masses observed.
4/3/2018	BCC	11.0	11	1	2	0	8	27	0	8	Eight egg masses and one gravid female observed. Three egg masses in road crossing were relocated to protected area downstream.
4/12/2018	BCC	10.0	6	1	0	0	8	17	0	6	Six new egg masses, one gravid female observed. Two previous egg masses completely scoured. Three new egg masses in road crossing were relocated to protected area downstream.
4/20/2018	BCC	10.5	16	0	1	0	2	24	0	6	Six new egg masses. One new egg mass in road crossing was relocated to protected area downstream.
4/30/2018	BCC	10.0	4	0	0	0	4	20	0	4	Four new egg masses.

Date	Subsite	H2O Temp * (°C)	AD ¹ Male	AD ¹ Female Condition ²			AD UNK ³	JUV ¹	TAD ¹	EM ¹	COMMENTS
				G	S	U					
5/10/2018	BCC	13.5	3	0	0	0	2	18	1363	0	No egg masses observed.
BCC 2018 Subtotals			48	2	3	0	30	131	1363	24	
3/28/2018	BCC- Trib 1	9.5	0	0	0	0	0	4	0	0	No egg masses observed.
4/3/2018	BCC- Trib 1	11.0	0	1	1	0	0	7	0	0	One gravid female observed. No egg masses observed.
4/12/2018	BCC- Trib 1	9.0	0	1	0	0	0	1	0	0	One gravid female observed. No egg masses observed.
4/20/2018	BCC- Trib 1	11.5	0	0	2	0	0	7	0	0	Two spent females observed. No egg masses observed.
4/30/2018	BCC- Trib 1	10.0	0	0	0	0	0	2	0	0	No adult frogs observed. No egg masses observed.
5/10/2018	BCC- Trib 1	13.0	1	0	1	0	1	9	0	0	No egg masses observed.
Trib 1 2018 Subtotals			1	2	4	0	1	30	0	0	
3/28/2018	BCC- Trib 2	11.0	1	0	0	0	0	21	0	0	Twelve juveniles along small seep on Pine Mountain Road uphill from Trib 2 and 8 juveniles in small culverted pool on road are included in count. No egg masses observed.
4/3/2018	BCC- Trib 2	12.5	0	1	0	0	0	12	0	5	Five egg masses and one gravid female observed. Two juveniles observed in culvert pool on road included in count.
4/12/2018	BCC- Trib 2	11.0	1	0	0	0	0	5	0	1	One new egg mass observed, but was mostly scoured. Approximately 50 eggs remaining. One previous egg mass partially scoured.
4/20/2018	BCC- Trib 2	11.5	0	1	0	0	0	3	0	0	No new egg masses observed. One gravid female observed.
4/30/2018	BCC- Trib 2	11.0	0	0	0	0	0	5	0	0	No new egg masses observed.
5/10/2018	BCC- Trib 2	14.0	0	0	0	0	0	4	522	0	No new egg masses observed. Previous egg masses hatched or hatching.
Trib 2 2018 Subtotals			2	2	0	0	0	50	522	6	
BCC Population 2018 Totals			51	6	7	0	31	211	1885	30	

Date	Subsite	H2O Temp * (°C)	AD ¹ Male	AD ¹ Female Condition ²			AD UNK ³	JUV ¹	TAD ¹	EM ¹	COMMENTS
				G	S	U					
3/19/2019	BCC	10.0	14	1	0	0	10	11	0	0	No egg masses observed.
4/1/2019	BCC	11.0	19	2	0	0	12	3	0	4	Four egg masses observed. One egg mass found in road crossing and moved downstream. One pair in amplexus. One gravid female and one juvenile in culverted pool on Pine Mountain Road.
4/8/2019	BCC	12.5	20	0	0	0	15	10	0	4	Four new egg masses observed. Three egg masses found in road crossing and moved downstream.
4/18/2019	BCC	10.5	16	1	0	0	9	10	0	2	Two new egg masses observed.
4/29/2019	BCC	12.0	16	0	0	0	3	8	1900	2	Two new egg masses observed (one inferred from tadpole group).
5/28/2019	BCC	11.0	8	0	1	0	4	11	170	0	No new egg masses. Some scouring from high flows, but several tadpole groups in areas of egg mass sites.
BCC 2019 Subtotals			93	4	1	0	53	53	2070	12	
3/19/2019	BCC-Trib 1	10.5	1	0	0	0	0	1	0	0	No egg masses observed.
4/1/2019	BCC-Trib 1	10.5	0	0	0	0	0	0	0	0	No FYLF or egg masses observed.
4/8/2019	BCC-Trib 1	12.0	1	0	0	0	0	2	0	0	No egg masses observed.
4/18/2019	BCC-Trib 1	10.0	3	0	0	0	0	2	0	0	No egg masses observed.
4/29/2019	BCC-Trib 1	12.0	4	0	1	0	1	1	0	0	No egg masses observed.
5/28/2019	BCC-Trib 1	10.5	1	0	0	0	1	0	0	0	No egg masses observed.
Trib 1 2019 Subtotals			10	0	1	0	2	6	0	0	
3/19/2019	BCC-Trib 2	12.5	5	1	0	0	1	3	0	1	2 adults (1 gravid female, 1 male) in small culverted pool on Pine Mountain Road uphill; one new egg mass observed.
4/1/2019	BCC-Trib 2	12.5	5	2	0	0	2	3	0	1	One new egg mass observed.
4/8/2019	BCC-Trib 2	13.5	6	0	0	0	1	4	0	0	No new egg masses observed.

Date	Subsite	H2O Temp * (°C)	AD ¹ Male	AD ¹ Female Condition ²			AD UNK ³	JUV ¹	TAD ¹	EM ¹	COMMENTS
				G	S	U					
4/18/2019	BCC-Trib 2	11.5	1	0	0	0	1	2	20	0	No new egg masses observed.
4/29/2019	BCC-Trib 2	13.5	1	0	0	0	0	4	200	0	No new egg masses observed.
5/28/2019	BCC-Trib 2	12.5	0	0	0	0	0	2	2	0	No new egg masses observed. Scouring from high flows seems likely with only two tadpoles observed in trib.
Trib 2 2019 Subtotals			18	3	0	0	5	18	222	2	
BCC Population 2019 Totals			121	7	2	0	60	77	2292	14	

¹ Life Stage: AD=Adult, JUV=Juvenile; TAD=Tadpole; EM=Egg mass; Adult and Juvenile totals may include repeat captures over several surveys.

² Condition: G=Gravid; S=Spent (i.e. eggs laid); U=Breeding condition undetermined

³ UNK=Unknown: Unknown adults were frogs that were not captured.

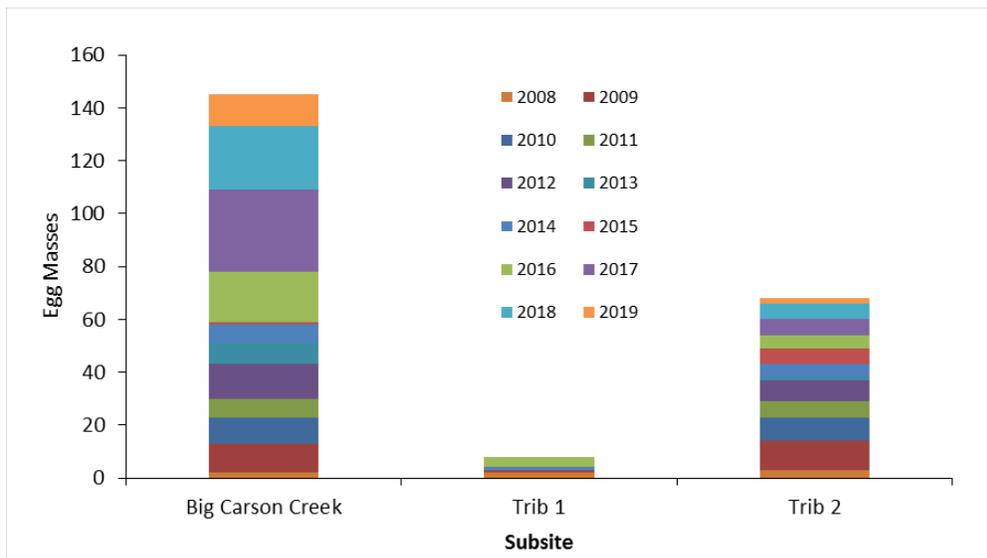


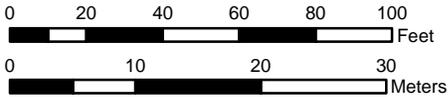
Figure 6. Distribution of egg masses in Big Carson Creek, 2008-2019 (N=221).



bing



Project Location



1 inch = 50 feet

Figure 7.
Distribution of Egg Masses
in Big Carson Creek,
2018 and 2019.

Marin County, CA

Annual Egg Mass Counts (2004-2019)

The total number of egg masses observed at Little Carson Creek in both 2018 (n=17) and 2019 (n=12) was slightly higher than the moving mean number of egg masses from 2004-2019 (\bar{x} =11.8; Table 3; Figure 8). The total number of egg masses observed at Big Carson Creek in 2018 (n=30) was much higher than the moving mean (\bar{x} =16.5) number of egg masses observed from 2004-2019 and dipped below that mean in 2019 (n=14; Table 3; Figure 8).

Table 3. Total egg mass counts at Little Carson Creek and Big Carson Creek and its tributaries, 2004-2019.

Site	Number of Egg Masses per Year															
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
LCC	12	7	4	14	14	10	6	11	17	11	15	11	13	14	17	12
BCC	13	9	11	5	2	11	10	7	13	8	1	1	19	31	24	12
BCC Trib 1	*	*	*	0	2	1	0	0	0	0	5	0	4	0	0	0
BCC Trib 2	*	*	*	5	3	11	9	6	8	1	7	6	5	6	6	2
BCC Total	13	9	11	10	7	23	19	13	21	9	13	7	28	37	30	14
Total Egg Masses	25	16	15	24	21	33	25	24	38	20	28	18	41	51	47	26

Overall, total counts in 2018 and 2019 were close to average or higher for Little Carson Creek since surveys began in 2004 (Table 3; Figure 8) and remained stable in both years. Egg mass numbers in the Big Carson population in 2018 were much higher than average, and the second highest recorded, but then showed a considerable decrease in 2019 (Figure 8).

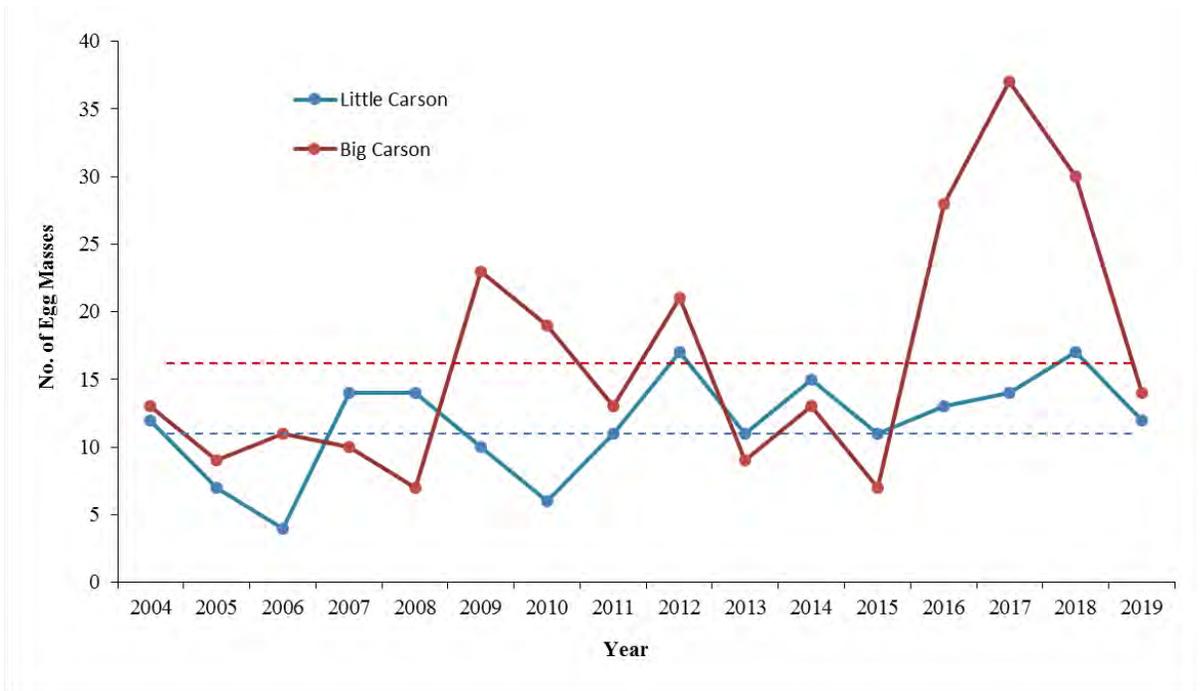


Figure 8. Annual egg mass counts for the Little Carson Creek and Big Carson Creek FYLF populations, 2004-2019. Dashed lines represent moving averages during the same period.

Breeding Period

The FYLF breeding period for Little Carson Creek occurred from March 30 to April 16 in 2018 and from March 18 to April 28 in 2019 (Figures 9-10; Table 4). For Big Carson Creek, the breeding period occurred from March 31 to April 28 in 2018 and from March 18 to April 26 in 2019 (Figures 9-10; Table 4). Mean daily water temperatures at Cataract Creek, a proposed reintroduction site for FYLF, were also recorded and are shown on figures 9 and 10 for reference.

Since 2007, breeding periods have been generally shorter on Little Carson Creek (\bar{x} =32.6 days) versus Big Carson Creek (\bar{x} =41.2 days) (Table 4). The average onset of breeding has been generally similar between populations, March 26 and 23, respectively, with the earliest onset in Little Carson Creek on March 13 and in Big Carson Creek on February 16, both in 2015. Cessation of breeding tends to be earlier on Little Carson Creek (mean date=April 27) than on Big Carson Creek (mean date=May 3); the breeding season has extended as late as May 7 (2011) on Little Carson Creek and May 23 (2016) on Big Carson Creek (Table 4).

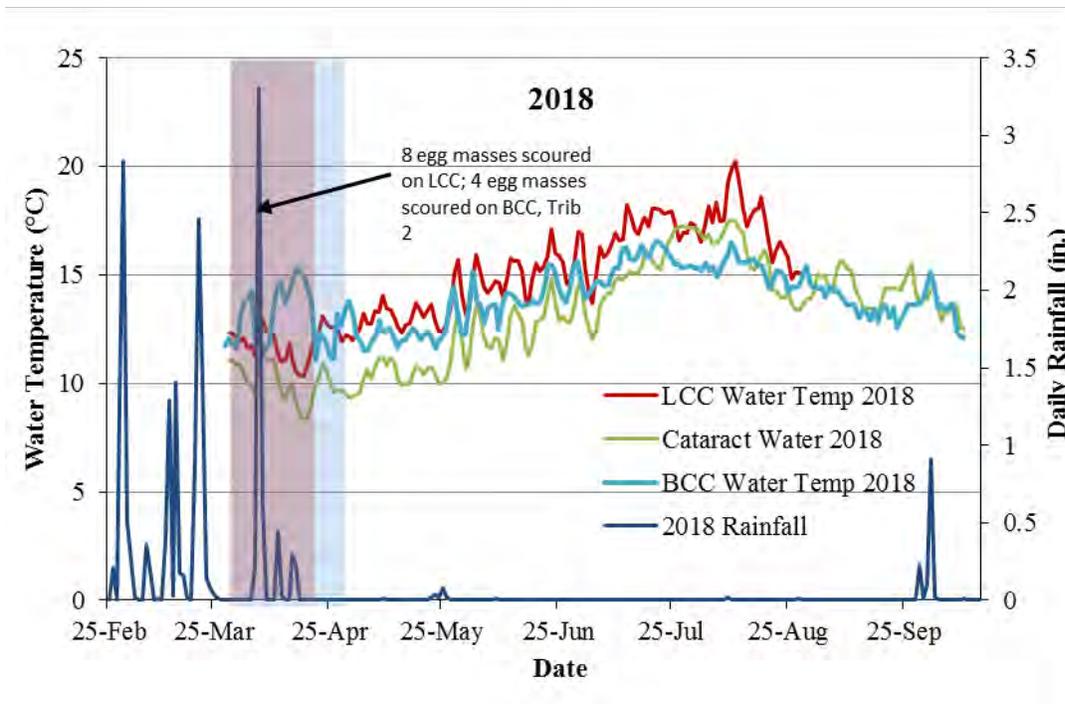


Figure 9. Breeding period (shaded areas), mean daily water temperatures, and precipitation at Little Carson Creek (purple shaded area) and Big Carson Creek (blue shaded area), 2018.

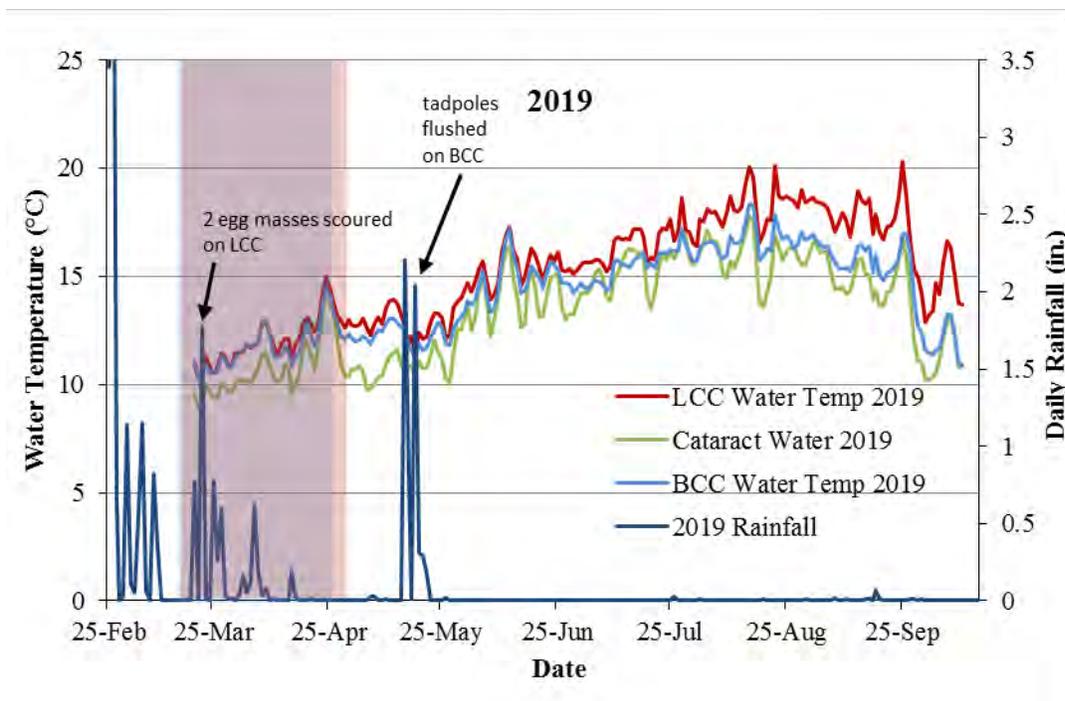


Figure 10. Breeding period (shaded areas), mean daily water temperatures, and precipitation at Little Carson Creek (purple shaded area) and Big Carson Creek (blue shaded area), 2019.

Table 4. FYLF breeding periods, Mt. Tamalpais Watershed, 2007-2019.

Little Carson Creek														
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean (all years)
First Egg Mass Date	3/27	3/17	4/1	4/7	4/4	4/14	3/24	3/21	3/13	3/24	3/18	3/30	3/18	3/26
Last Egg Mass Date	4/30	4/18	4/22	5/3	5/7	5/3	4/25	5/5	4/22	5/5	4/29	4/16	4/28	4/27
Breeding Period (days)	34	32	21	26	33	19	32	45	40	42	42	17	41	32.6
Mean Breeding Date	4/4	4/9	4/14	4/23	4/17	4/20	4/5	4/15	3/27	4/1	3/28	4/8	4/10	4/9
Big Carson Creek														
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean (all years)
First Egg Mass Date	3/18	3/23	4/1	3/22	4/5	4/13	4/3	3/19	2/16	3/22	3/18	3/31	3/18	3/23
Last Egg Mass Date	4/28	5/11	5/15	5/8	4/28	5/5	4/25	5/15	4/4	5/23	5/11	4/28	4/26	5/3
Breeding Period (days)	41	49	44	47	23	22	22	57	47	62	54	28	39	41.2
Mean Breeding Date	4/2	5/4	4/24	4/21	4/15	4/21	4/7	4/7	3/14	4/29	4/21	4/9	4/5	4/13

Breeding Site Characteristics

Breeding site characteristics were generally the same in 2018 and 2019 as in previous years (2004-2017; GANDA 2018). In both creeks, breeding occurs in portions of the creek that are relatively open, with little canopy cover. Characteristics of each breeding site vary slightly between Little Carson Creek and Big Carson Creek. During these two years, egg masses at Little Carson Creek were generally laid in more exposed areas, slightly closer to shore, and in slightly deeper water than those in Big Carson Creek and its tributaries (Table 5).

At Little Carson Creek, the breeding area has small-to-medium sized pools (approximately 1-20 square meters [m²]) and the substrate is mostly composed of bedrock. During the 2018-2019 breeding seasons, females attached egg masses mostly to bedrock at the bottom or sides of pools. Egg masses were found at pools 1, 2, 3, and 4 (Figures 4-5). In both years combined, egg masses were located between zero and two meters from shore (\bar{x} =0.4 m) and were laid at depths ranging from three to 27 centimeters (cm) (\bar{x} =13.0 cm). Water velocity at egg masses ranged from zero to five cm per second (cm/s), with a mean velocity of 1.2 cm/s. Most egg masses laid in Little Carson Creek were located within Pool 3 (Figure 4). Several were laid within a bubble curtain at the base of a waterfall where water velocities are difficult to measure and thus excluded from the descriptive statistics presented in Table 5. Egg masses ranged from five to eight centimeters in width, with a mean width of 6.6 cm (Table 5).

At Big Carson Creek, the substrate is mostly composed of gravel, pebble, cobbles, and boulder. During the 2018 and 2019 breeding seasons, females attached egg masses mostly to boulders and cobbles, and egg masses were found in pools used in previous years along Big Carson Creek and in Tributary 2 (Figures 6-7). In both years combined, egg masses were located between zero and 1.4 meters from shore (\bar{x} =0.5 m) and laid at depths ranging from three to 29 cm (\bar{x} =12.3 cm). Water velocity at egg masses ranged from zero to eight cm/s, with a mean velocity of 1.6 cm/s. Egg masses ranged in size from two to eight cm in width (\bar{x} =6.3 cm) (Table 5).

Table 5. Summary of FYLF oviposition site habitat parameters in Little Carson Creek and Big Carson Creek and tributaries, 2018-2019.

		Distance from Shore (m)	Egg Mass Depth (cm)	Maximum Water Depth (cm)	Velocity * at Egg Mass (cm/s)	Surface Velocity* Above Egg Mass (cm/s)	Egg Mass Width (cm)	Water Temp at Egg Mass (°C)	Water Temp at Main Channel (°C)
LCC N=29	Mean	0.4	13	16.3	1.2	2.6	6.6	11.5	10.6
	SD	0.5	7.1	8.7	1.4	2.8	0.9	2.1	2.3
	Range	0-2	3-27	0.2-33	0-5	0-10	5-8	9-15	8-14.5
BCC N=44	Mean	0.5	12.3	16.9	1.6	2.6	6.3	11.5	11.9
	SD	0.5	5.9	6.2	1.7	2.3	1.2	1.1	1.0
	Range	0-1.4	3-29	6-34	0-8	0-7	2-8	10-13.5	10-12.5

*Excludes LCC egg masses located below waterfall in Pool 3 where velocities could not be measured accurately.

Water Temperatures and Precipitation

2018

From March 28 to October 22, 2018, mean daily water temperatures at Little Carson Creek averaged 15.4°C and ranged from 10.3°C to 20.2°C, and at Big Carson Creek mean daily water temperatures averaged 14°C and ranged from 11.1°C to 16.7°C (Figure 9; Table 6). The estimated breeding period was March 30 to April 16 at Little Carson Creek, during which hourly water temperatures averaged 11.8°C and ranged from 10.5°C to 12.9°C; onset of oviposition on Little Carson Creek occurred on March 30, when the daily mean water temperature was 12.3°C. At Big Carson Creek, the estimated breeding period was March 31 to April 28, during which hourly water temperatures averaged 13.1°C and ranged from 11.1°C to 15.3°C; onset of oviposition on Big Carson Creek occurred on March 31, when the daily mean water temperature was 11.8°C.

During the 2018 water year (July 1, 2017-June 30, 2018), approximately 39 inches of rainfall was recorded, which is below average annual rainfall (52 inches; MMWD 2019). Three rain

events occurred during the FYLF breeding period, resulting in eight egg masses being scoured on Little Carson Creek and four on Big Carson Creek and Tributary 2 (Figure 9).

2019

From March 20 to October 22, 2019, mean daily water temperatures at the Little Carson Creek breeding sites averaged 15.2°C and ranged from 10.3°C to 20.3°C. During the same period, mean daily water temperatures at Big Carson Creek averaged 14.0°C and ranged from 10.1°C to 18.4°C (Figure 10).

The estimated breeding period was March 18 to April 28 at Little Carson Creek, during which hourly water temperatures averaged 12.0°C and ranged from 10.3°C to 15.0°C. At Big Carson Creek, the estimated breeding period was March 18 to April 26 during which hourly water temperatures averaged 11.7°C and ranged from 10.3°C to 14.6°C.

During the 2019 water year (July 1, 2018-June 30, 2019), a total of 74 inches of rainfall occurred, which is above average annual rainfall (52 inches; MMWD 2019). Four rain events occurred during the FYLF breeding period, which resulted in two egg masses being scoured in Little Carson Creek (Figure 10). In addition, a late-season rain event in mid-May of over five inches of rain apparently flushed tadpoles downstream from breeding sites on Big Carson Creek (Figure 10).

Table 6. Mean daily water temperatures at Little Carson Creek, Big Carson Creek, and Cataract Creek from March 20 to October 22, 2018-2019.

Site	Mean Daily Water Temp. (range, °C)	
	2018	2019
Little Carson Creek	15.4 (10.3-20.2)	15.2 (10.3-20.3)
Big Carson Creek	14.0 (11.1-16.7)	14 (10.1-18.4)
Cataract Creek	13.1 (8.4-17.8)	13.2 (8.9-17.8)

During 2018 and 2019, mean water temperatures were highest at Little Carson, with Big Carson Creek and Cataract Creek (a potential FYLF reintroduction site) having cooler temperatures (Figures 9-10; Table 6). On average, Cataract Creek is typically about 2°C cooler than Little Carson Creek and 1°C cooler than Big Carson Creek, a pattern observed consistently since 2014 when water temperature monitoring began at Cataract Creek (GANDA 2016).

Tadpoles

Little Carson Creek

In 2018, tadpoles were first observed on May 10 and the total estimated number of tadpoles was approximately 317 (Table 1). Tadpoles were only observed during the final field visit on May 10. In 2019, the first tadpoles were observed on April 29 and the total estimated number of

tadpoles was approximately 300. Only a single additional tadpole was observed in Pool 3 during the final survey on May 28 (Table 1).

Big Carson Creek

In 2018, tadpoles were first observed in Big Carson Creek on May 10 and the total estimated number of tadpoles was approximately 1,885 between the mainstem and Tributary 2 (Table 2). Tadpoles were found in areas where egg masses were documented and were only observed during the final field visit on May 10 (Photo 7, Appendix A; Table 2). In 2019, the first tadpoles were observed along Tributary 2 on April 18 adjacent to egg mass areas and the estimated number of tadpoles was approximately 20. The estimated total number of tadpoles observed in 2019 between Big Carson mainstem and Tributary 2 was approximately 2,292, observed on April 18, April 29, and May 28 (Photo 8, Appendix A; Table 2).

Young-of-the-Year (YOY)

Little Carson Creek

In 2018, no YOY were observed during a survey conducted on October 15 (Table 7). In 2019, a single YOY was observed in Pool 1 during a survey conducted on November 5 (Table 8); surveys were not conducted downstream of Pool 0 in either year.

Big Carson Creek

In 2018, a total of 48 YOY were observed in Big Carson Creek and Tributary 2 during a survey conducted on October 15 (Table 7). Thirty-nine YOY were located in the mainstem of Big Carson Creek and nine in Tributary 2 near the confluence with Big Carson Creek. No YOY were observed in Tributary 1. In 2019, a total of four YOY were observed during a survey conducted on November 5 (Table 8). All YOY were located in the mainstem of Big Carson Creek (Photo 9, Appendix A).

Table 7. Summary of 2018 FYLF metamorph surveys on Little Carson Creek and Big Carson Creek and tributaries.

DATE	SUBSITE	H2O TEMP* (°C)	AD ¹ MALE	AD FEMALE	AD UNK ²	JUV ³	YOY ⁴	COMMENTS
10/15/2018	LCC	12	1	2	2	0	0	No YOY observed.
10/15/2018	BCC	11	0	0	3	2	39	YOY observed near egg mass areas.
10/15/2018	BCC Trib 1	12	3	2	2	5	0	No YOY observed.
10/15/2018	BCC Trib 2	15	0	0	0	0	9	YOY observed near egg mass areas.
2018 Fall Survey Totals			4	4	7	7	48	

¹AD= adult; ²Unk= unknown: unknown adults were frogs that were not captured; ³Juv= juvenile; ⁴YOY= young-of-the-year

Table 8. Summary of 2019 FYLF metamorph surveys on Little Carson Creek and Big Carson Creek and tributaries.

DATE	SUBSITE	H2O TEMP* (°C)	AD ¹ MALE	AD FEMALE	AD UNK ²	JUV ³	YOY ⁴	COMMENTS
11/5/2019	LCC	12	0	4	2	0	1	One YOY observed in Pool 3.
11/5/2019	BCC	9.5	2	3	1	0	4	YOY observed near egg mass areas.
11/5/2019	BCC Trib 1	9.5	0	0	0	0	0	No YOY or other FYLF observed.
11/5/2019	BCC Trib 2	10	0	0	1	0	0	No YOY observed.
2019 Fall Survey Totals			2	7	4	0	5	

¹AD= adult; ²Unk= unknown: unknown adults were frogs that were not captured; ³Juv= juvenile; ⁴YOY= young-of-the-year

Annual YOY Counts (2009-2019)

With the exception of 2012, young-of-the-year observations continue to be higher for the Big Carson Creek population compared to the Little Carson Creek population (Table 9).

Table 9. Number of FYLF YOY observations on Little Carson Creek and Big Carson Creek and tributaries, 2009-2019.

Site	2009 Survey		2010 Survey		2011 Survey		2012	2013	2014	2015	2016	2017	2018	2019
	1	2	1	2	1	2	Single Survey							
Little Carson Creek	3	4	0	5	4	2	32	6	3	2	13	7	0	1
Big Carson Creek	26	13	59	30	20	10	11	97	64	27	97	61	39	4
BCC - Tributary 1	2	3	0	0	0	0	0	10	13	0	4	7	0	0
BCC - Tributary 2	5	5	5	5	5	6	2	15	16	18	21	4	9	0

Adults and Juveniles

Overall, more adult and juvenile FYLF were observed at Big Carson Creek and its tributaries than at Little Carson Creek in both years (tables 1 and 2). In both creeks, total observations of adults and juveniles during breeding surveys were higher in 2018 (n=421) compared to 2019 (n=355), and a slightly higher number of female frogs were observed in 2018 (n=34) versus 2019

(n=32) during breeding surveys. Total observations of juveniles were greater in 2018 than in 2019 (2018 n=234; 2019 n=87).

Little Carson Creek

In 2018, a total of 92 adult and 23 juvenile FYLF were observed on Little Carson Creek during the breeding period. The highest number of FYLF observed during a single breeding survey in 2018 (n=30) occurred on March 28 when seven males and five females (all gravid), 10 unidentified frogs, and eight juveniles were recorded (Table 1). One observation of amplexus was recorded in 2018 at Little Carson Creek also during the survey on March 28. A total of 21 females (10 gravid, 7 spent, and 4 unknown condition) were observed during the 2018 breeding period, which likely includes repeat observations of the same individuals (Table 1). During the metamorph survey conducted on October 15, 2018, two females, one male, and two unidentified adult FYLF were found in pools 5 and 6 (Table 7).

In 2019, a total of 78 adult and 10 juvenile FYLF were observed on Little Carson Creek during the breeding period. The highest number of FYLF observed during a single breeding survey in 2019 (n=19) occurred on April 2 when nine males, six females (5 gravid, 1 spent), three unidentified adults, and one juvenile FYLF were observed (Table 1). Six observations of amplexus were recorded during the 2019 breeding period on Little Carson Creek during surveys on March 19, April 2, and April 8 (Photo 2, Appendix A). A total of 23 females (11 gravid, 10 spent, 2 unknown condition) were observed during surveys, which likely includes repeat observations of the same individuals (Table 1). In addition to these observations, one adult male FYLF was found dead in Pool 3 on April 29 and was collected for analysis. During a single metamorph survey on November 5, six adults (4 females, 2 unknown) were observed (Table 8). No survey was conducted downstream of Pool 0.

During 2018-2019, adult males and females congregated at Carson Falls to breed on Little Carson Creek, a seasonal pattern found in previous years (GANDA 2018). Since surveys in both years were focused on the breeding pools where egg masses are laid, the distribution of adult observations are biased towards the breeding pools; however, a single survey conducted in the fall of 2016 (and in previous years) demonstrated that many adult frogs migrate downstream from the breeding pools following the breeding season (Figure 1). As expected, YOY were only observed within close proximity or downstream of the breeding pools.

Big Carson Creek

In 2018, a total of 95 adult and 211 juvenile FYLF were observed in Big Carson Creek and its two tributaries. The highest number of FYLF adults (n=71) observed during a single breeding survey in 2018 occurred on April 3. During this survey, 11 males, six females (3 gravid, 3 spent), eight unidentified adults, and 46 juveniles were observed between the three sites (Table 2). At Big Carson Creek and both tributaries, a total of six gravid and seven spent females were observed during the 2018 breeding period (Table 2). Observations of amplexus were not recorded in 2018. On March 28 while en route to the survey area, incidental observations of 12 juveniles were recorded along a small seep draining onto Pine Mountain Road just uphill from Tributary 2 and another eight juveniles were observed in an unnamed, culverted tributary to the mainstem, also just uphill from Tributary 2 along Pine Mountain Road (Figure 18). These juveniles are included in the total counts presented here. During a metamorph survey conducted on October 15, 2018, 10 adults (2 females, 3 males, and 5 unidentified) and seven juveniles were observed (Table 7). Adults were located near the breeding areas on Big Carson Creek and Tributary 2, as well as upstream on Tributary 1.

In 2019, a total of 190 adult and 77 juvenile FYLF were observed in Big Carson Creek and its two tributaries. The highest number of FYLF observed during a single breeding survey (n=59) in 2019 occurred on April 8 (Table 2). During this survey, 27 males, 16 unidentified adults, and 16 juvenile FYLF were observed between the three sites. Seven gravid and two spent females were observed during breeding surveys in 2019, some of which were likely repeat observations of the same individuals. One observation of amplexus was recorded on April 1 (Photo 1, Appendix A). On March 19, a check of the unnamed tributary (Figure 18) to the mainstem was conducted while en route to the survey area and one gravid adult female and one adult male were observed. These adults are included in the total counts presented here. During a metamorph survey conducted on November 5, two adult males, three females, and two unidentified FYLF were observed near the breeding areas on the mainstem and Tributary 2 (Table 8). No juvenile frogs were observed during the metamorph survey.

During 2018-2019, adult frogs were concentrated at the breeding areas located in a glide section upstream of the Tributary 1 confluence and within and around the Pine Mountain Road crossing on Big Carson Creek. Since surveys were focused on the breeding areas, the distribution of adult observations are biased towards these areas; however, previous surveys conducted in the fall of each year demonstrated that many adult frogs migrate up- and downstream on the mainstem of Big Carson Creek as well as to the upstream portions of tributaries 1 and 2 following the breeding season (GANDA 2018). As expected, YOY and most juveniles were also observed within close proximity of known breeding sites.

Mark-Recapture

During 12 years of surveys from 2008 to 2019, a total of 567 individual adult frogs were identified (Table 10). These 567 adult frogs included 246 from Little Carson Creek (103 females, 143 males) and 321 from Big Carson Creek (94 females, 227 males). A total of 88 females and 309 males were recaptured one or more years within both Little Carson and Big Carson creeks

(Table 10). Among all years, total recaptures were higher for females in Little Carson Creek (n=51) versus Big Carson Creek (n=37), whereas for males the reverse was true—total recaptures were higher in Big Carson Creek (n=194) compared to Little Carson Creek (n=115) (Table 10; Figure 11).

Total recaptures for females in 2018 and 2019 were higher than the previous two years (Table 10). On Little Carson Creek, three females were recaptured in 2018 and one recaptured in 2019. On Big Carson Creek, three females were recaptured in 2018 and two recaptured in 2019. Twenty-two males were recaptured in 2018 (4 from Little Carson Creek and 18 from the Big Carson system) and 24 males were recaptured in 2019 (9 in Little Carson and 15 in Big Carson). The oldest male recaptured across all years (2008 to 2019) is BCC-M9, who was captured every year from 2008-2017 and again recaptured in 2019 on the Big Carson Creek mainstem (Figure 15). Based on size at first capture (41 mm SUL) in 2008, this male is estimated to be at least 14 years of age. Several other long-lived males have been captured over the period of these surveys between 2008 and 2017 (GANDA 2018). The oldest female recaptured between 2008 and 2016 (LCC-F80) was estimated to be at least 11 years of age based on size at first capture (64 mm SUL). Recaptures have not yet found any longer-lived individual females on these creeks, however, recapture data from the Feather River has confirmed one female to have survived to the age of at least 15 years. Thus, we expect that females in these creeks have similar longevity compared to the males. The decline in total recaptures from 2017 to 2019 depicted in Figure 11 is partially due to the discontinuation of fall surveys previously conducted downstream of the breeding area on Little Carson Creek and up- and downstream of the breeding areas on Big Carson Creek and the tributaries since 2016. Likewise, total recaptures in 2009 and 2010 were higher due to the inclusion of those areas during breeding surveys as well as fall metamorph surveys.

Table 10. Summary of adult capture/recapture data for Little Carson Creek and Big Carson Creek and tributaries (2008-2019).

FEMALES																									
Total New Captures														Total Recaptures											
Subsite	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2008-2019	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2008-2019*
LCC	17	8	4	12	4	18	1	6	12	4	11	8	103	5	7	8	10	9	4	3	1	0	3	1	51
BCC	8	17	9	11	6	1	1	5	13	8	9	8	94	2	5	4	9	7	4	1	0	0	3	2	37
Total Female	25	25	13	23	10	19	2	11	25	12	20	16	197	7	12	12	19	16	8	4	1	0	6	3	88
MALES																									
Total New Captures														Total Recaptures											
Subsite	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2008-2019	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2008-2019*
LCC	33	4	4	8	2	26	18	19	8	6	14	5	143	13	10	8	12	7	19	12	15	6	4	9	115
BCC	33	11	12	9	4	5	9	32	42	14	10	50	227	19	21	14	16	15	16	15	26	18	18	15	194
Total Males	66	15	16	17	6	31	27	51	50	20	24	55	370	32	31	22	28	22	35	27	41	24	22	24	309
FEMALES AND MALES																									
Total-LCC	50	12	8	20	6	44	19	25	20	10	25	13	246	18	17	16	22	16	23	15	16	6	7	10	166
Total-BCC	41	28	21	20	10	6	10	37	55	22	19	58	321	21	26	18	25	22	20	16	26	18	21	17	231
Total Indivs.	91	40	29	40	16	50	29	62	75	32	44	71	567	39	43	34	47	38	43	31	42	24	28	27	397

*Recaptured one or more times across years

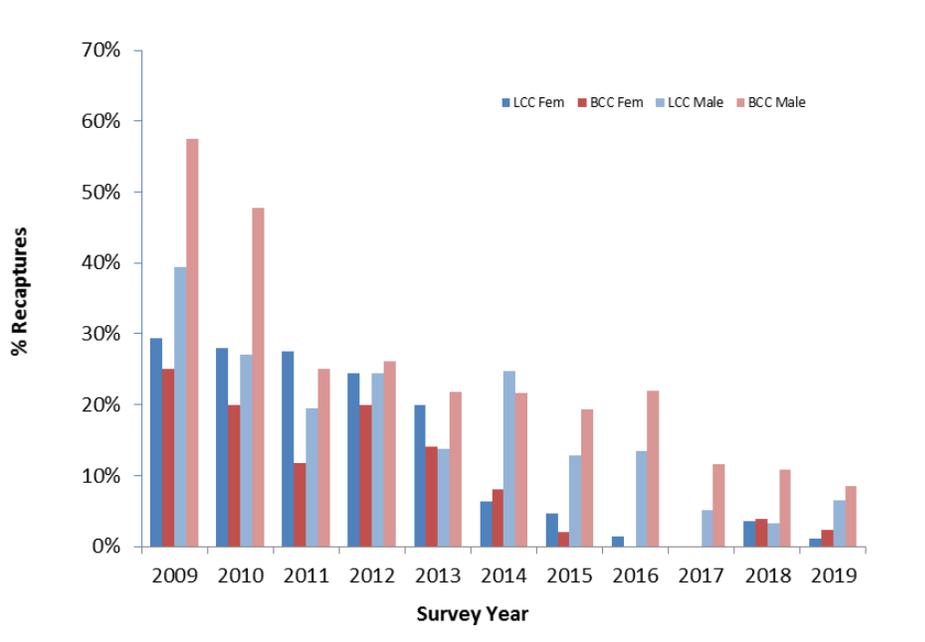
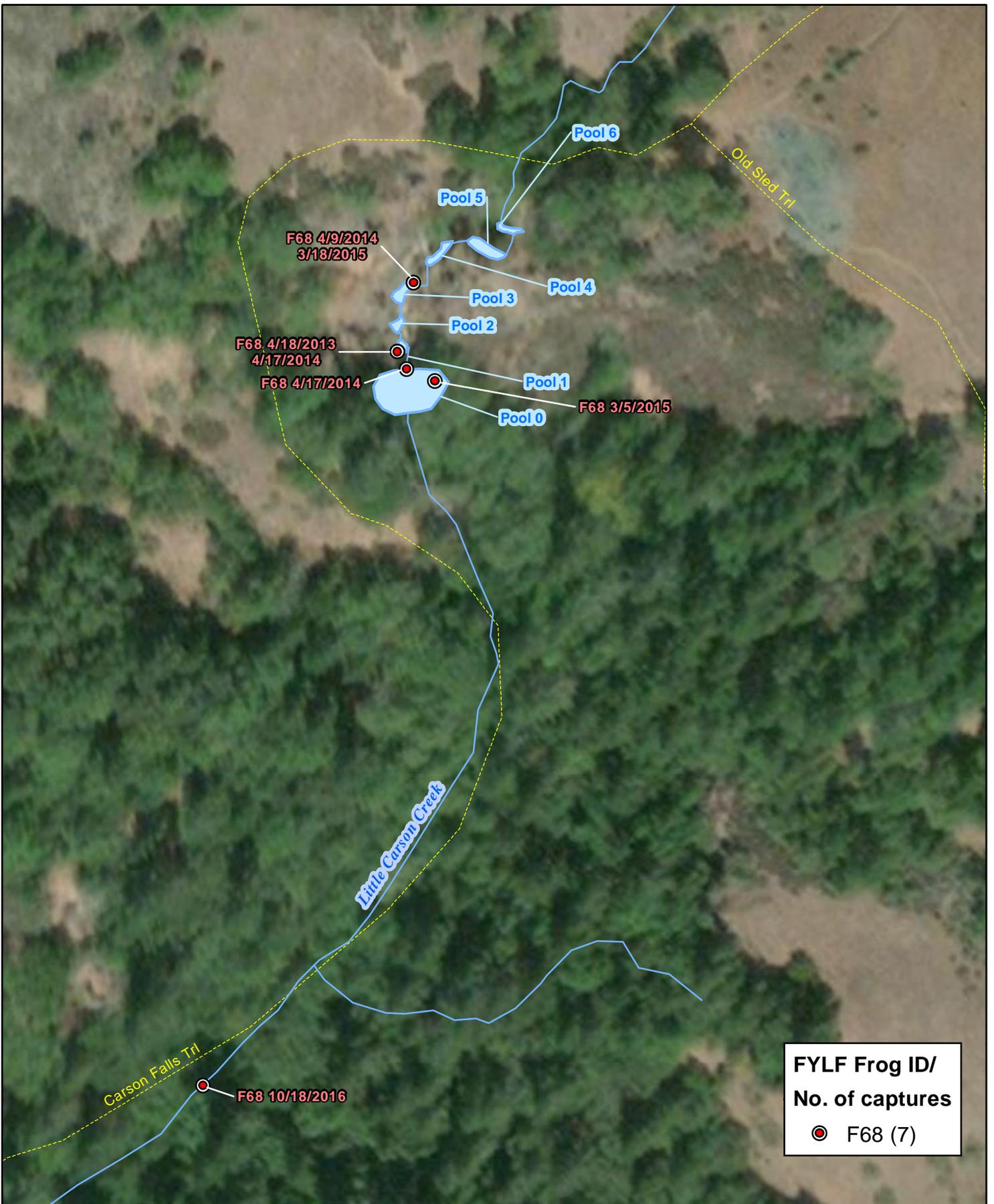


Figure 11. Percentage of recaptured frogs observed in Little Carson Creek and Big Carson Creek, 2009-2019.

Movement

In general, recapture data from 2008-2019 show that both males and females migrate from non-breeding refugia along stream courses to the breeding areas at Little Carson and Big Carson creeks; some frogs may remain in the breeding areas (e.g., Little Carson Creek) throughout the season. Based upon opportunistic recaptures of individual frogs during surveys, single one-way movements were greater for females than males from 2008 to 2013 (GANDA 2013). Diagrams of movement for Little Carson Creek frogs include one female (LCC-F68) and one male (LCC-M80) and are shown in figures 12 and 13, respectively. Diagrams of movement data for Big Carson Creek frogs include one female (BCC-F1) and one male (BCC-M9) and are shown in figures 14 and 15, respectively. Big Carson Creek M9 has been captured every year except 2018 since 2008. Total recaptures for females have been low since 2016, thus movement patterns are demonstrated for LCC-F68 from 2013-2016 and for BCC-F1 from 2009-2015.



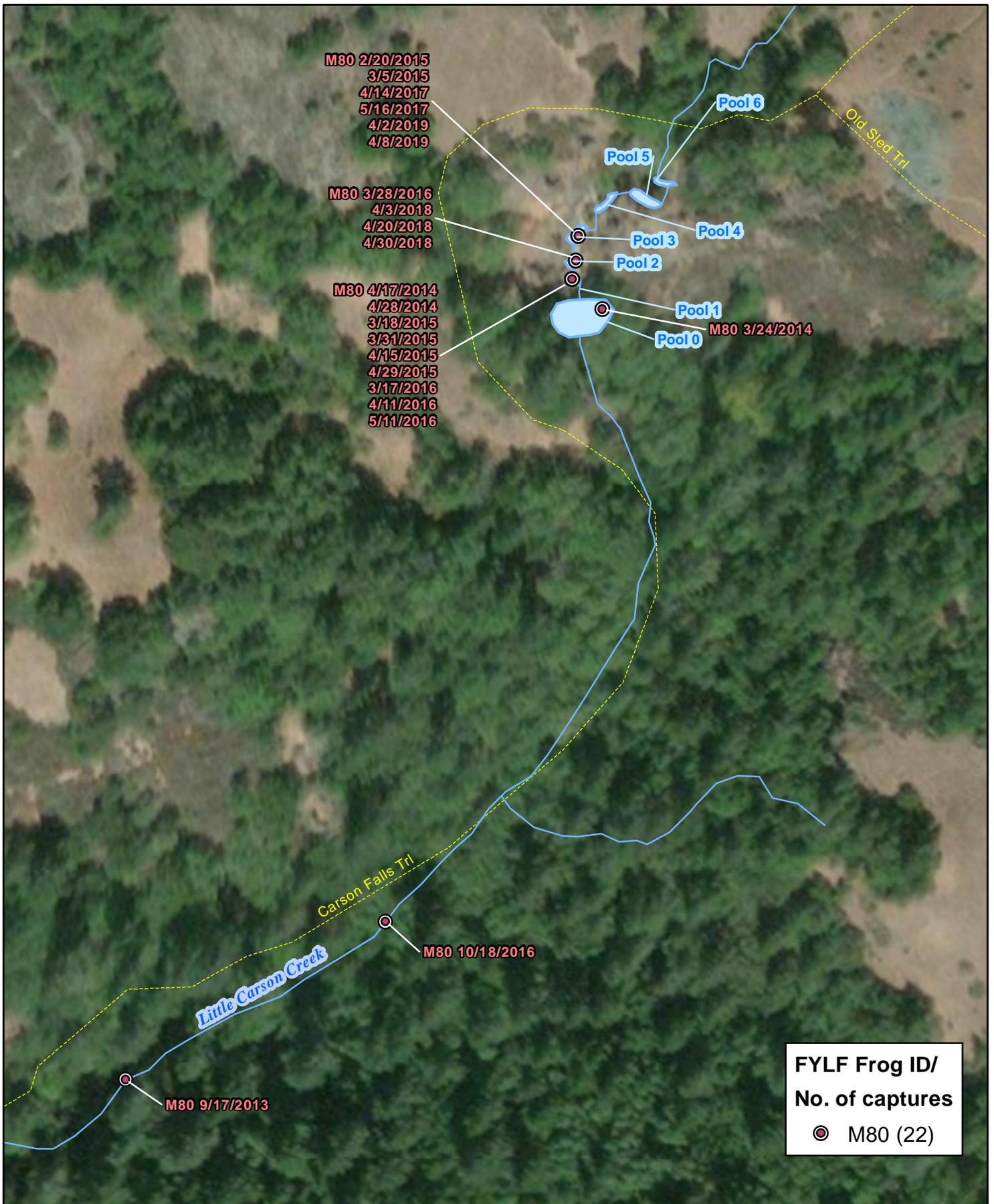
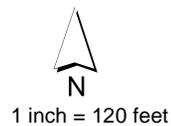


Figure 13. Recapture and Movement for Little Carson Creek male (M80), 2013 to 2019



Marin County, CA



**FYLF Frog ID/
No. of captures**

● F1 (13)

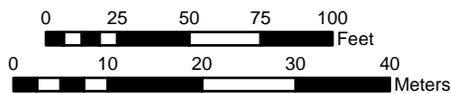


Figure 14. Recapture and Movement for Big Carson Creek female (F1), 2009 to 2015

Marin County, CA



Figure 15. Recapture and Movement for Big Carson Creek male (M9), 2008 to 2019



Annual Reproductive Effort by Individual Frogs

In addition to movement information, a review of chin photograph data on adult female frogs collected during 2008 to 2019 confirms six individuals that bred in multiple years (three in Little Carson and three in Big Carson). Three of these six individuals were observed to breed in two consecutive years (2011-2012) and two of these also bred in 2008 and 2009. LCC-F68 (Figure 12) bred in 2014 and 2015. BCC-F1, captured every year from 2009 to 2015 (Figure 14), was observed to breed over two non-consecutive years (2012 and 2014). One other (BCC-F8) bred in 2009 and 2011. An additional 13 females (seven from Big Carson and six from Little Carson) were observed to have bred in a single year. Females were considered to have bred only if observed both in a gravid and spent condition during the breeding period of a given year. No female has been observed breeding more than once in a year.

These surveys focus on finding egg masses for general population estimates based on the assumption that a female breeds only once per season, laying a single egg mass. In most years, fewer individual females are captured than egg masses observed (Figures 16 and 17). This is partially due to the inherent randomness of observing frogs during visual encounter surveys and the fact that females tend to oviposit and immediately return to their refugia sites. Males by contrast remain at the breeding sites for all or most of the breeding season. Comparing the total number of individual females of breeding size (≥ 48 mm SUL in the spring) to the numbers of egg masses observed, there tend to be more egg masses observed than the estimated number of individual females on Big Carson Creek (Figure 17), with greatest difference between these two numbers occurring in 2017. On Little Carson Creek, these two numbers vary from year to year, but remain similar. The differences between the number of egg masses observed and the estimated number of individual females may be the result of egg masses that were not found or perhaps oviposited upstream of the survey area, individual females not being captured (e.g., 2007 on Big Carson Creek), as well as the reduced survey area in fall metamorph surveys where more females would have likely been detected at downstream refugia sites. Based on these data, it appears that most egg masses in these populations are being counted during surveys and would further support the assumption that females lay a single egg mass per breeding season.

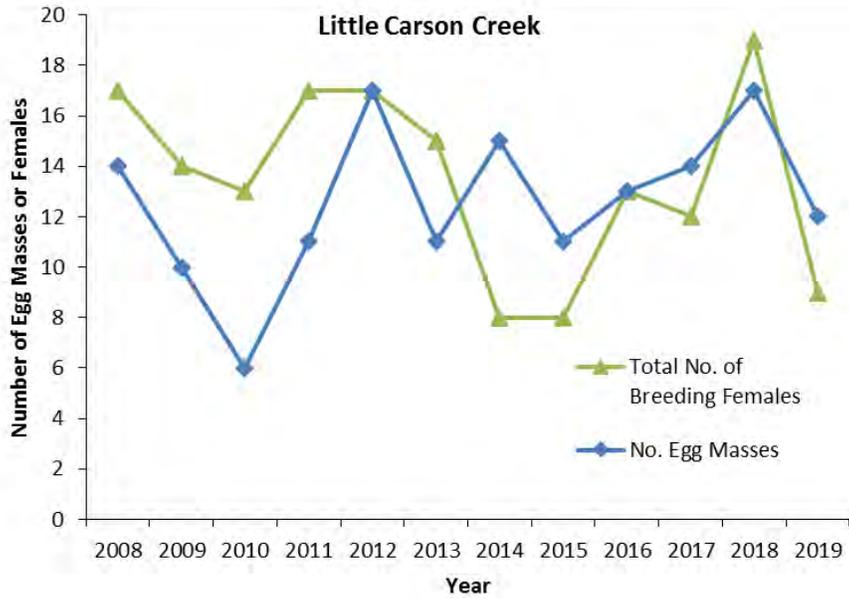


Figure 16. Annual number of egg masses versus total number of female FYLF of breeding size present based on mark-recapture on Little Carson Creek, 2008-2019.

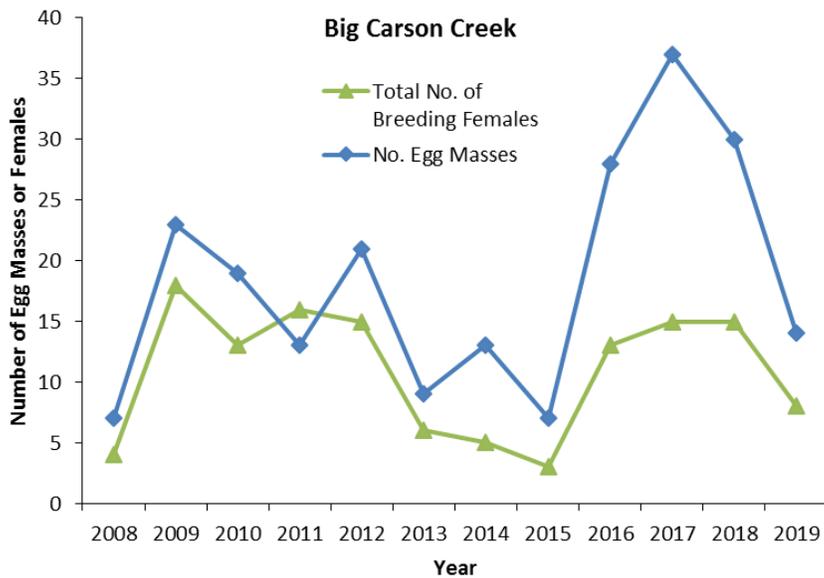


Figure 17. Annual number of egg masses versus total number of female FYLF of breeding size present based on mark-recapture on Big Carson Creek, 2008-2019.

Predators

Predator species encountered in 2018-2019 were similar to those found during previous surveys (GANDA 2013). Known predators of FYLF encountered within both drainages include bullfrogs (Crayon 1998), California giant salamanders (*Dicamptodon ensatus*; Fidenci 2006), signal

crayfish (Wiseman et al. 2005), rough-skinned newts (*Taricha granulosa*; Evenden 1948), California newts (*Taricha torosa*; GANDA 2013), and western aquatic garter snakes (*Thamnophis atratus*; Fitch 1941). Of these predators, only bullfrogs and signal crayfish are non-native, and access Little Carson and Big Carson creeks via Kent Lake.

Bullfrogs were not observed in either creek in 2008, 2009, and 2010. From 2011-2014, a total of 29 bullfrogs were removed from the lower reach of Little Carson Creek downstream of the breeding pools and in the lower reach of Big Carson Creek (GANDA 2016). One bullfrog was observed, but eluded capture, during breeding surveys in 2016 on Little Carson Creek in Pool 0. No bullfrogs were observed during 2017, 2018, or 2019 surveys; however, surveys were conducted only at breeding sites and not in the lower reaches where these predators are usually seen.

California newts and rough-skinned newts are relatively common in Little Carson Creek (particularly in the breeding pools) but are apparently absent in Big Carson Creek. Two California newts collected (for the California Academy of Sciences) in 2013 from Pool 2 in Little Carson Creek had stomach contents which included several FYLF tadpoles (GANDA 2013). No newts were collected for examination in 2018 or 2019.

Signal crayfish are known non-native predators of FYLF egg masses and tadpoles (Wiseman et al. 2005) and are able to migrate up into the creeks from Kent Lake, a perennial source of crayfish. Signal crayfish are often encountered in the lower reaches of Little Carson Creek but appear less common in Big Carson Creek. No signal crayfish were removed from Little Carson Creek in 2018 or 2019 because surveys were conducted only at breeding sites and not in the lower reaches where these predators are usually observed. Since 2008, signal crayfish have not been observed upstream of Pool 0 on Little Carson Creek or adjacent to any egg masses on Big Carson Creek.

Discussion

Ongoing population monitoring of FYLF in Little Carson Creek and Big Carson Creek continues to show that these populations, while small, isolated, and vulnerable, are still relatively stable. Egg mass numbers observed at Little Carson Creek were lower (n=12) in 2019 than in 2018 (n=17) and also lower (n=14) at Big Carson Creek in 2019 than in 2018 (n=30) (Figure 8). Total egg masses in 2017 were the highest recorded (n=51) since surveys began in 2004, but numbers in 2018 (n=47) were only slightly lower and the second highest recorded since 2004. The breeding periods on both creeks were longer in 2019 (LCC=41 days; BCC=39 days) than in 2018. The breeding period on Little Carson Creek in 2018 was just 17 days long, the shortest breeding period recorded since 2004 and just 28 days long on Big Carson Creek, also one of the shorter breeding periods recorded since 2013 (n=22) (Table 4). The trend of higher numbers of egg masses in Big Carson Creek could be the result of opportunistically finding and relocating egg masses from the Pine Mountain Road crossings at the mainstem and Tributary 1 before they become vulnerable to scouring or other damage from vehicles, bicycles, dogs, and other human interference; egg mass relocation from these areas has been in practice since 2008. Moving egg

masses downstream to more protected habitats likely also increases survivorship and recruitment. Vegetation removal and tree trimming that occurred in 2012 may have further helped breeding sites downstream become more productive as a result of increased solar exposure for food production and tadpole growth.

A total of 14 (10 at Little Carson and 4 at Big Carson Creek and Tributary 2) egg masses were scoured from their oviposition sites in 2018 and 2019. Three rain events occurred during the 2018 FYLF breeding period, one of which resulted in eight egg masses being completely or partially scoured in Little Carson Creek (Figure 9, photos 5-6, Appendix A). During the 2018 rainfall year, a total of 39 inches of rainfall occurred, which is below the average annual rainfall (52.7 inches; MMWD 2019). During the 2019 rainfall year, a total of 74 inches of rainfall occurred, higher than average. The highest annual precipitation recorded was 112 inches in 1889. Four rain events occurred during the 2019 FYLF breeding period, one of which resulted in two egg masses being scoured in Little Carson Creek in March and another in mid-May which caused tadpoles to be flushed away in Big Carson Creek (Figure 10).

In 2018 to 2019, a total of 11 egg masses were laid within the Big Carson Creek mainstem crossing at Pine Mountain Road (Table 11), leaving them vulnerable to potential disturbance from vehicles, bicyclists, equestrians, hikers, and dogs. All 11 egg masses were relocated to a protected area downstream, and all hatched successfully. In fall 2012, after seven egg masses were laid in the mainstem crossing, MMWD conducted tree trimming below the road crossing to increase sunlight and enhance breeding habitat outside of the road crossings. This resulted in a short-term trend (2013-2015) with no egg masses laid in the road crossings; however, beginning in 2016, oviposition within the road crossing started to increase again. During 2008 to 2012, prior to the tree trimming, 11 out of 83 (13%) of egg masses were laid in the road crossings and during 2013 to 2019, 21 out of 138 (15%) were laid in the road crossings. In 2018, seven out of 30 (23%) egg masses were laid in the mainstem road crossing. In 2019, four egg masses (29%) were laid in the mainstem road crossing, the second highest percentage recorded, compared to 2012 (33%), suggesting that the tree trimming did not discourage breeding in the road crossing long term. We suspect that one of the reasons there was only a single egg mass laid in the mainstem crossing during 2013 to 2016 was due to low water levels in the crossing during those dry water years. In 2017, by contrast, high flows appeared to scour the road crossing, creating deeper water levels more suitable for egg laying (GANDA 2018).

Table 11. Summary of egg masses oviposited within Pine Mountain Road crossings at Big Carson Creek and tributaries, 2008-2019.

Year	Total Egg Masses BCC and Tributaries	Number of Egg masses in Road Crossing (% of Total)	
		BCC Mainstem	Tributary 1
2008	7	0	2 (29%)
2009	23	0	1 (4%)
2010	19	0	0
2011	13	1 (8%)	0
2012	21	7 (33%)	0
Total 2008-2012	83	8 (10%)	3 (4%)
Tree trimming and vegetation removal conducted in fall 2012			
2013	9	0	0
2014	13	0	1 (8%)
2015	7	0	0
2016	28	1 (4%)	2 (7%)
2017	37	6 (16%)	0
2018	30	7 (23%)	0
2019	14	4 (29%)	0
Total 2013-2019	138	18 (13%)	3 (2%)
Total All Years	221	26 (12%)	6 (3%)

Additional FYLF activity in the area of Pine Mountain Road near Big Carson Creek was first recorded in 2018. While en route to the survey area on March 28, 12 juveniles were found using a small seep draining across Pine Mountain Road just a few meters uphill from Tributary 2 and another eight juveniles were observed in an unnamed, culverted tributary to the mainstem, approximately 15 meters uphill from Tributary 2 on Pine Mountain Road (Figure 18). The seep was dried up in 2019 but, during a check of the culverted pool in the unnamed tributary on March 19, one gravid adult female and one adult male were observed. These observations are included in the total counts presented for Tributary 2 due to its close proximity; however, it is also likely they are traveling down the tributary to breed in the mainstem.



Figure 18. Seep on Pine Mountain Road (left) and culverted pool in unnamed tributary to Big Carson Creek mainstem (right). Juveniles were observed in these two areas on March 28, 2018 and adults were observed in the tributary pool on March 19, 2019.

While YOY numbers on Big Carson Creek and tributaries continue to be higher than Little Carson Creek since these surveys began in 2009 (Table 9), numbers declined in 2018 and 2019 compared to previous years. In 2018, YOY observed in Big Carson Creek were lower (n=39) than the previous two years and in 2019, YOY counts at Big Carson Creek were the lowest recorded (n=4) across all years. No metamorphs were observed at Little Carson Creek in 2018 and just a single YOY was observed in 2019 (Table 9). Fall metamorph surveys are usually conducted in mid-to-late October, but surveys were delayed in 2019 due to a number of red flag fire warning days restricting access to the breeding sites. Thus, YOY counts may have been slightly higher if surveys were not delayed. Additionally, severe drought in recent years (before 2017) and the lingering after effects, followed by three ‘above normal’ water years may be the cause of fluctuating egg mass counts, longer breeding periods, and lower recruitment. Data from the coming years may help shed more light on possible climate change effects to these populations.

Recapture data taken from chin photographs on 567 individual frogs over a twelve-year period has revealed higher recapture rates for males than for females (Table 10). Previous analysis of this data shows a shorter numbers of days between captures for males than females, that females seem to move greater distances than males overall, and that males show a higher rate of site fidelity than females (GANDA 2013). Male and female frogs have been recorded to move hundreds of meters to and from breeding sites and have also been observed to return to the same breeding areas across years (GANDA 2013).

Marin Municipal Water District has had measures in place since 2008 to protect the FYLF breeding sites at Little and Big Carson creeks, including removal of signal crayfish and bullfrogs, translocating egg masses laid in road crossings, and the presence of docents at sensitive FYLF

breeding habitats during the breeding season. During past surveys (2008-2016) in the lower reaches of the creeks, signal crayfish were removed by hand, mostly from the lower reaches of Little Carson Creek, though one signal crayfish was removed from the mainstem of Big Carson Creek in 2017. Bullfrogs found in the lower section of Little Carson Creek were also removed by hand in 2013-2014 and 2016-2017. Surveys of the lower sections of Little and Big Carson creeks were not conducted in 2018 and 2019 and no signal crayfish or bullfrogs were observed in the breeding areas. For the most part, these efforts have proved effective; however, the potential for recreational impacts remains high, with the greatest potential at Pool 3 at Carson Falls and the road crossings at Big Carson Creek and Tributary 1. Pool 3 is a particularly important breeding site, with almost half of the reproductive effort occurring at this location (Figures 4 and 5). At Big Carson Creek, authorized vehicle traffic, equestrians, mountain bikers, and hikers with dogs at the Pine Mountain Road crossings continue to have the potential to negatively impact FYLF and egg masses.

During habitat assessment surveys for the *Feasibility Study for the Reintroduction of the Foothill Yellow-legged Frog (Rana boylei) within the Mt. Tamalpais Watershed, Marin County, California* (GANDA 2010), two incidental observations of FYLF YOY were recorded near the confluence of Big Carson Creek and Kent Lake, suggesting that breeding occurred in this location. One of these was observed slightly upstream in Pine Mountain Tributary. Further surveys were conducted in other creeks within the Mt. Tamalpais Watershed in 2014 at seven previously unsurveyed tributaries near Kent Lake and Alpine Lake (Figure 1) and no FYLF of any life stage were observed during these efforts. However, in December 2017, Finch Klein (son of Janet Klein, former MMWD Natural Resources Program Manager) observed an adult FYLF while hiking above the falls in Cascade Creek (GANDA 2018). This event, along with another local hiker's report of his own FYLF observation in Cascade Creek (GANDA 2018), led Marin County Open Space District to conduct focused surveys in San Anselmo Creek and Cascade Creek in 2018 and 2019. During these surveys, GANDA observed one egg mass in 2018 and 18 egg masses in 2019 in San Anselmo Creek along with numerous adult males, gravid and spent females, and juvenile FYLF. In addition, 15 adult and juvenile FYLF were observed in Cascade Creek in 2019, including five males, four females (2 gravid, 1 spent, 1 unknown condition), five unknown adults, and one juvenile. Another gravid female was observed in Carey Camp Creek, a tributary to San Anselmo Creek (GANDA 2019). An additional new occurrence of FYLF within the watershed occurred on May 31, 2019 when David Greenberger observed an adult FYLF (undetermined sex) while hiking near an unnamed tributary leading to Tributary 1. A photo of this observation (Figure 19) was registered with iNaturalist and reported to MMWD staff (D. Greenberger, email comm. to Eric Ettlinger, MMWD, June 3, 2019). This unnamed tributary is outside of the survey areas referred to in this report. These observations are included in Figure 1 showing the current distribution of FYLF in the Mt. Tamalpais and Corte Madera Creek watersheds.



Figure 19. Unidentified adult FYLF in unnamed tributary to Tributary 1 near Big Carson Creek. This observation was made by David Greenberger on May 31, 2019.

Recommendations

To ensure the long-term viability of FYLF populations in the Mt. Tamalpais watershed, GANDA recommends the following management strategies:

1. Continue to maintain interpretive signs at Carson Falls and the use of docents to educate the public during the breeding season, particularly at Pool 3. Docents could also serve a similar role at the Pine Mountain Road crossing at Big Carson Creek, particularly during large mountain biking events.
2. Continue to monitor FYLF at Little Carson Creek and Big Carson Creek and its tributaries. Consistent population monitoring will allow MMWD to detect changes in population trend and facilitate adaptive management strategies. Breeding surveys should be conducted once every seven to 14 days between March 1 and May 30. Surveys for metamorphs should be conducted at least once in late September or early October. Methodology for monitoring and surveying FYLF should continue to follow that used since 2008 to facilitate analysis of trends.
3. Limit disturbance at Big Carson Creek at the Pine Mountain Road crossing. Interpretive signs and limiting vehicle access during the breeding season could reduce the risk of impacts to frogs, egg masses, and tadpoles. Egg masses laid in the crossing should continue to be translocated immediately downstream. Consider having docents present during the breeding season to reduce impacts from bikers and vehicles crossing the creek. Installing a bridge over this crossing may significantly reduce potential impacts to FYLF.
4. Consider re-surveying the lower reaches of Little Carson Creek and the upper and lower reaches of Big Carson Creek during fall metamorph surveys to determine possible breeding locations outside of known breeding areas and increase and enhance recapture data.
5. Continue to remove invasive signal crayfish and bullfrogs along Little Carson Creek and Big Carson Creek. Bullfrog and crayfish removal should be conducted by a qualified biologist with demonstrated ability to distinguish between FYLF and bullfrogs.
6. Re-survey Cascade Creek and Cataract Creek in 2020-2021 to determine status of FYLF at each creek. For Cascade Creek, continue to determine if FYLF are using the creek for refugia and movement or if they might breed in the creek (most likely upstream of the falls, similar to Little Carson Creek). Since Cataract Creek is recommended as a possible re-introduction site, conduct additional surveys to see if FYLF are present.

Literature Cited

- California Department of Fish and Wildlife (CDFW). 2019. Life history account for Foothill Yellow-legged Frog. Available online at: <https://wildlife.ca.gov/Search-Results?q=rana%20boylii>
- Crayon, J.J. 1998. *Rana catesbeiana* (bullfrog) Diet. Herpetological Review 29(4):232.
- Duellman, W. E. and L. Trueb. 1986. Biology of the amphibians. McGraw-Hill Publishing Company. New York, NY. 670 pp.
- Evenden, F.G. 1948. Food habits of *Triturus granulosus* in Western Oregon. Copeia 1948(3): 219-220.
- Fidenci, P. 2006. *Rana boylei* (Foothill yellow-legged frog) Predation. Herpetological Review 37(2): 208.
- Fitch, H. S. 1941. The feeding habits of California garter snakes. California Department of Fish and Game 27:1-32.
- GANDA. 2006. Identifying Climatic and Water Flow Triggers Associated with Breeding Activities of a Foothill Yellow-legged Frog (*Rana boylei*) Population on the North Fork Feather River, California. California Energy Commission, PIER.
- GANDA. 2009. Foothill yellow-legged frog breeding success and monitoring at Little Carson Creek and Big Carson Creek, Mt. Tamalpais Watershed, 2008. Marin Municipal Water District. 32pp.
- GANDA. 2010. Feasibility Study for the Reintroduction of the Foothill Yellow-legged Frog (*Rana boylei*) within the Mt. Tamalpais Watershed, Marin County, California. 32pp.
- GANDA. 2012. Foothill yellow-legged frog monitoring at Little Carson Creek and Big Carson Creek, Mt. Tamalpais Watershed, Fall 2009 to Fall 2011. 41 pp.
- GANDA. 2013. Foothill yellow-legged frog monitoring at Little Carson Creek and Big Carson Creek, Mt. Tamalpais Watershed, 2012 to 2013. 94 pp.
- GANDA. 2016. Foothill yellow-legged frog monitoring at Little Carson Creek and Big Carson Creek, Mt. Tamalpais Watershed, 2014 to 2015. 39 pp.
- GANDA. 2018. Foothill yellow-legged frog monitoring at Little Carson Creek and Big Carson Creek, Mt. Tamalpais Watershed, 2016 to 2017. 44 pp.

- GANDA. 2019. Marin Open Space District Foothill yellow-legged frog survey results 2019, Marin County, CA, 2019. 22 pp.
- Gosner, K.L. 1960. A simplified table for staging anuran embryos and larvae with notes on identification. *Herpetologica* 16:183-190.
- Marin Municipal Water District (MMWD). 2008. The Mount Tamalpais Watershed Road and Trail Management Plan website:
<http://www.marinwater.org/controller?action=menuclick&id=249>
- Marin Municipal Water District (MMWD). 2019. Daily Rainfall at Lake Lagunitas, Fiscal Years 2017/2018 and 2018/2019. Available online at:
<https://www.marinwater.org/31/Water>
- Marlow, K.R., K.D. Wiseman, C.A. Wheeler, J.E. Drennan, and R.E. Jackman. 2016. Identification of individual foothill yellow-legged frogs (*Rana boylei*) using chin pattern photographs: a non-invasive and effective method for small population studies. *Herpetological Review* 47(2):193-198.
- One Tam. 2016. Measuring the Health of a Mountain: A Report on Mount Tamalpais Natural Resources 2016 (Ch. 14, p. 174)
- Seltenrich, C.P. and A.C. Pool. 2002. A Standardized Approach for Habitat Assessments and Visual Encounter Surveys for the Foothill Yellow-Legged Frog (*Rana boylei*). May 2002. Pacific Gas and Electric Company, Technical and Ecological Services, unpublished report.
- Wiseman, K. D., K.R. Marlow, R.E. Jackman, and J.E. Drennan. 2005. *Rana boylei* (foothill yellow-legged frog) predation. *Herpetological Review* 36(2): 162-163.
- Zweifel, R. G. 1955. Ecology, distribution, and systematics of frogs of the *Rana boylei* group. University of California Publications in Zoology. 54:207-292.

Appendix A

Representative Photographs
2018-2019



Photo 1. Amplexing FYLF in Big Carson Creek, 4-1-19.



Photo 2. Amplexing FYLF in Pool 2 of Little Carson Creek, 4-8-19.



Photo 3. Recently laid egg masses A, B, C and D in Tributary 2 of Big Carson Creek, 4-3-18.



Photo 4. Recently laid egg mass E, located in Tributary 2 at Big Carson Creek, 4-3-18.



Photo 5. Recently laid egg mass A, in Pool 2 at Little Carson Creek, 3-19-19.



Photo 6. Egg mass A (compare to Photo 5), found nearly completely scoured from Pool 2 at Little Carson Creek, following over 4" of rainfall between March 19 and April 2, 2019.



Photo 7. Young tadpoles in Big Carson Creek, 5-10-18.



Photo 8. Two distinct cohorts of FYLF tadpoles: young, dark tadpoles and older, mottled tadpoles in Big Carson Creek, 5-28-19.



Photo 9. Young-of-the-year (YOY) frog near the confluence of Tributary 1 in Big Carson Creek, 11-5-19.



Photo 10. Four adult male FyLF observed basking along Big Carson Creek mainstem, downstream of the confluence with Tributary 1, 4-29-19.