Herpetological Conservation and Biology 19(2):161–172.
Submitted: 21 December 2023; Accepted: 4 April 2024; Published: 31 August 2024.

Foothill Yellow-legged Frog (*Rana boylii*) Distribution and Oviposition Sites on Managed Timberlands in Coastal Northwestern California, USA

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***Abstract.*—We conducted surveys for Foothill Yellow-legged Frog (*Rana boylii*) egg masses annually from 2009 through 2023 (mean survey date = 31 May ± 13.5 (standard deviation) d; range, 11 May–25 June) on a reach (mean reach length = 2.37 km ± 0.24 km; range of values 1.93–3.03 km) of the Mad River, Humboldt County, California, USA. We expanded our egg mass surveys in 2018 to better understand the distribution and abundance of *R. boylii* in northwestern California, and we conducted a property-wide effort across Green Diamond Resource Company timberlands in northwestern California (about 162,000 ha), surveying more than 100 km of streams in eight watersheds. Between 2009 and 2023 we detected more than 8,300 egg masses along the annual Mad River survey reach, and in 2017 we documented the highest known density of *R. boylii* egg masses (625.1 egg masses/km). During the 2018 property-wide survey, we counted more than 5,600 egg masses, furthering information about the distribution and abundance of these frogs in northwestern California.**

Key Words.—amphibians; Del Norte County; egg mass; Humboldt County; north coast; ranid frog

Introduction

Foothill Yellow-legged Frogs (*Rana boylii*) are small- to medium-sized frogs (37–82 mm snout-urostyle length) ranging from northwestern Baja California to west-central Oregon (Hayes et al. 2016). These frogs are generally associated with low-gradient sections of streams, consisting of variable substrates dominated by exposed cobble, in open to partially open canopy with sunlight reaching most of the stream (Hayes and Jennings 1988). Because adult female *R. boylii* lay one egg mass during the breeding season (Thomson et al. 2016), egg mass counts are a reliable way to enumerate actively breeding females in a particular area (Wheeler and Welsh 2008), which can be used to determine effective population size and track population viability (Pearson 2013; Rose et al. 2023). *Rana boylii* oviposit their eggs from late spring through early summer, generally attaching their egg masses to the downstream side of rocky substrates at stream margins in shallow, relatively slow-moving water (Fuller and Lind 1992; Ashton et al. 1998; Stebbins 2003), with tadpoles developing in the same habitat as oviposition sites (Hayes et al. 2016). Although once common throughout its range, *R. boylii* has experienced dramatic declines in recent decades and has been extirpated in parts of its range (Davidson 2004; Fellers 2005; Adams 2017).

Since 1994, *R. boylii* has been a Species of Special Concern in California (Jennings and Hayes 1994). In July 2012, *R. boylii* was petitioned for listing under the U.S. Endangered Species Act (ESA; Adkins Giese et al. 2012), and in December 2016, *R. boylii* was petitioned to be listed as Threatened under the California Endangered Species Act (CESA; Center for Biological Diversity. 2016 Petition to list the Foothill Yellow-legged Frog as threatened under the California Endangered Species Act. Available from https://www.biologicaldiversity.org/species/amphibians/foothill_yellow-legged_frog/pdfs/FYLF_state_petition_12-14-16.pdf [Accessed 5 July 2017]). In July 2015, it was determined that *R. boylii* may warrant listing under the ESA, and in June 2017, the California Fish and Game Commission (CFGC) accepted *R. boylii* as a candidate species under the CESA (California Fish and Game Commission. 2020. California Fish and Game Commission Notice of Findings for Foothill Yellow-legged Frog (*Rana boylii*). Available from https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=177905&inline [Accessed 17 March 2022]).

Two landscape genomic studies determined distinct breaks across the range of *R. boylii*, resulting in multiple divergent, geographically cohesive, distinct clades (McCartney-Melstad et al. 2018; Peek 2018). Based on the results of these studies, on 11 December 2019, the CFGC listed five of six *R. boylii* clades as threatened or endangered under the CESA (California Fish and Game Commission. 2020. *op cit.)*. The U.S. Fish and Wildlife Service (USFWS) published a proposed rule to list four of six *R. boylii* clades as Threatened or Endangered under the ESA with 28 September 2023 as the effective date for the final rule (U.S. Fish and Wildlife Service 2023). In both the state and federal listing determinations, *R. boylii* on the north coast of California (Northwest/North Coast clade) did not currently warrant listing; however, they are still considered a State Species of Special Concern (California Fish and Game Commission 2020. *op. cit.*; U.S. Fish and Wildlife Service 2023).

We conducted annual *R. boylii* egg-mass surveys along a reach of the Mad River, Humboldt County, California, USA, from 2009 through 2023. Additionally, as part of a salmonid habitat typing project (Green Diamond Resource Company [GDRCo] 2006), we conducted 316 km of stream surveys from 2015 through 2018. Survey crews observed larval, juvenile, and adult *R. boylii* in tributaries to larger watercourses, many of which had no previous documentation of *R. boylii* breeding populations. The 2012 and 2016 petitions to list *R. boylii* under the ESA and the CESA revealed the lack of published information regarding the distribution and abundance of *R. boylii* in northwestern California, with few recent accounts. To better understand *R. boylii* breeding distribution and abundance across GDRCo timberlands in northwestern California, we expanded *R. boylii* egg-mass surveys to eight watersheds during the spring of 2018. Here, we report our findings to describe the breeding distribution and annual dynamics of reproductive output for the species in coastal northwestern California.

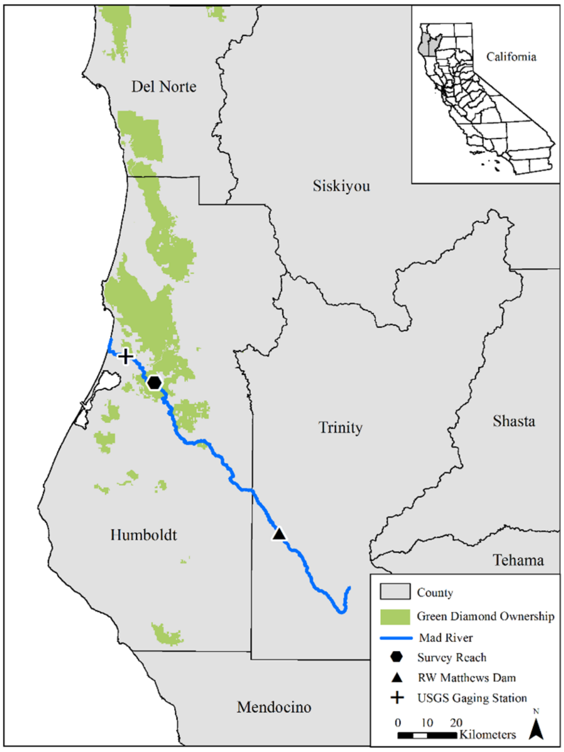

Figure 1. Location of the annual Foothill Yellow-legged Frog (*Rana boylii*) egg-mass survey reach and the U.S. Geological Survey gaging station referenced for flow data on the Mad River, Humboldt County, California, USA, relative to the location of R.W. Matthews Dam in Trinity County, California, USA. Inset map shows California, USA, with Humboldt and Trinity counties highlighted in gray.

Materials and Methods

Study site: Mad River annual egg-mass survey.—Green Diamond Resource Company owns and manages about 162,000 ha of timberlands in northwestern California. The annual Mad River survey reach is in Humboldt County, California, USA, about 67 km (straight-line distance) downstream of R.W. Matthews Dam (Fig. 1). The dam impounds runoff from the upper quarter of the Mad River basin forming Ruth Lake; tributaries downstream of the dam contribute significantly to the overall discharge of the river. The primary function of the dam is to provide domestic water supply. Power production from a hydroelectric plant is secondary, and potential effects of the dam on the natural flow regime are limited because water released from the dam is not modified for power needs, mimicking low flow summer conditions (Humboldt Bay Municipal Water District. 2004. Habitat conservation plan for its Mad River operations. Available from https://www.hbmwd.com/files/d0c19c09a/HBMWD-HCP+2004.pdf [Accessed 2 April 2019]).

Survey methods: Mad River annual egg-mass survey.—From 2009 through 2023, we planned surveys each spring in conjunction with the receding limb of the hydrograph. During reconnaissance surveys, we determined the onset of oviposition and tracked egg development to identify the peak and decline in oviposition frequency to time the annual egg-mass survey at the end of the breeding season.

We used a single-pass Visual Encounter Survey (VES; Crump and Scott 1994) and searched for egg masses near the edge of the water as we walked along gravel/cobble bars. We recorded global positioning system (GPS) coordinates of each oviposition site and the number of egg masses at each oviposition site. We also recorded egg development stage (Gosner 1960) or condition of each egg mass using a simplified version of the Gosner staging system and two additional condition categories: round (stages 1–14), bean (15–18), tail (19–21), partially hatched (> 21, egg mass partially hatched with hatchlings on and around egg mass), fully hatched (> 21, egg mass fully hatched, hatchlings on and around egg mass), stranded (egg mass viable during survey but out of water), and desiccated (egg mass out of water, dried out, and eggs no longer viable).

During three of the survey years (2010, 2019, 2020), large spring storms after the first documentation of oviposition increased flows and scoured away early egg masses. This resulted in incomplete surveys for these years, and we did not include these years when calculating the overall average density for this reach. To examine average daily spring flows relative to the first documented occurrence of oviposition and annual survey date, we acquired flow data from the U.S. Geological Survey Mad River gaging station near Arcata, California, USA (Fig. 1), which is about 19.1 km downstream from the start of the annual survey reach (https://waterdata.usgs.gov/monitoring-location/11481000/#parameterCode=00065&period=P7D).

Study area and reach selection: property-wide egg-mass survey.—In 2018, we expanded the *R. boylii* egg-mass survey efforts across the timberlands owned by GDRCo in California. To identify potentially suitable breeding habitat for *R. boylii*, we used ArcMap Geographic Information Systems (GIS) software version 10.7.1 (Esri, Redlands, California, USA) to overlay 2014 satellite imagery from the National Agriculture Imagery Program (https://datagateway.nrcs.usda.gov/GDGHome_DirectDownLoad.aspx) with locations of incidental observations of *R. boylii* from previous surveys. We used a 1:3,000 scale to assess mainstem streams and tributaries for potentially suitable breeding habitat (e.g., canopy openings and gravel/cobble bars). The streams and tributaries identified during this process ranged from orders five to eight (Strahler 1957). We categorized potentially suitable breeding habitat into one of three habitat strata based on likelihood to provide *R. boylii* breeding habitat: (1) high likelihood - areas previously surveyed for egg masses with documented occurrences of breeding (e.g., egg masses or tadpoles present) or areas that had favorable breeding habitat (determined via aerial imagery) close to known breeding areas (e.g., ≤ 500 m); (2) moderate likelihood - unsurveyed areas with open canopy and gravel/cobble bars (i.e.., potentially suitable breeding habitat); and (3) low likelihood - unsurveyed areas for *R. boylii* egg masses with marginal breeding habitat (e.g., limited open canopy, few gravel/cobble bars) and isolated from known breeding areas (i.e., no documented breeding within the watershed). We initially identified 10 watersheds with potential breeding habitat (Fig. 2); however, reaches identified in two watersheds (Wilson Creek and Hunter Creek) are known to go dry during the breeding season of *R. boylii* and were eliminated from the survey.

We then applied a Balanced Acceptance Sampling (BAS) survey design (Brown et al. 2015) to each habitat stratum. Balance Acceptance Sampling is a spatially balanced survey design that can be applied to large-scale surveys where it is not feasible to visit every site. The survey design selects sampling units spread evenly across the survey area to ensure spatial coverage of the entire survey area and allow inferences to be made for unsurveyed areas (Brown et al. 2015). Using ArcMap GIS software, we applied BAS to create 500-m survey reaches. We chose this reach length because we thought this length would capture a variety of habitats (e.g., pools, riffles, runs) and their associated gravel/cobble bars. Although 500 m was the target reach length, in some cases, we combined disjunct segments that were < 500 m in length with other nearby short segments to meet a 250-m minimum reach length (e.g., 75-m reach + 175-m reach = 250 m) or added to adjacent 500-m segments to reach a 750-m maximum reach length.

Survey methods: property-wide egg-mass survey.—We initiated VES soon after the onset of oviposition at the Mad River study reach (about 10 May 2018). The property-wide effort took place from 18 May through 13 June 2018. Using two-person survey teams, we followed the same survey protocol established for the Mad River annual survey. Additionally, we noted and tallied post-metamorphic *R. boylii* (juveniles and adults) observed during the property-wide survey. We prioritized high-likelihood reaches and surveyed these reaches first, and when moderate- and low-likelihood reaches were located

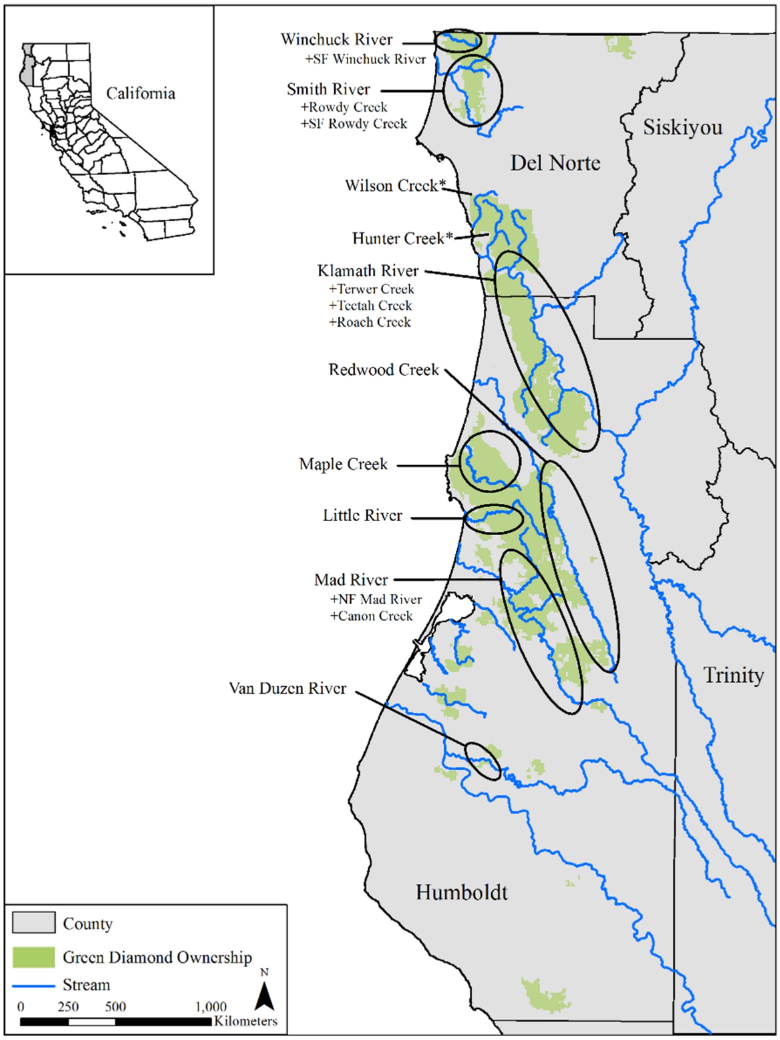

Figure 2. Mainstem streams (+ tributaries) on Green Diamond Resource Company ownership in northern California, USA, that were included as having potential breeding habitat for the 2018 property-wide Foothill Yellow-legged Frog (*Rana boylii*) egg-mass survey. Ellipses indicate approximate areas that were surveyed. Streams with asterisks included as having potential *R. boylii* breeding habitat but were not surveyed because the reaches with potential breeding habitat are known to go dry during the summer. Inset map shows California, USA, with Del Norte and Humboldt counties highlighted in gray.

close to high-likelihood reaches, we opportunistically surveyed them. We did not derive estimates for the moderate- and low-likelihood strata because we did not follow the formal sample selection process.

Results

Mad River annual egg-mass survey.—From 2009 through 2023, we detected 8,358 *R. boylii* egg masses within the survey reach (Table 1). Our survey dates ranged from 11 May to 25 June (mean = 31 May ± 13.5 (standard deviation) d; n = 15), and water temperatures at the survey start ranged from 14.5°–18.6° C (mean = 16.5° ± 1.06° C; n = 15). The mean daily flow in cubic meters per second (m3/s) at the first documented occurrence of oviposition ranged from 5.5–30.0 (mean = 14.4 ± 8.2 m3/s; n = 15), and the mean daily flow on the annual survey date ranged from 3.4–26.3 m3/s (mean = 8.9 ± 5.2 m3/s; n = 15; Fig. 3). The average egg-mass density for years without large scouring events (increased flows that sweep away egg masses) ranged from 71.5–625.1 egg masses/km with a mean of 269.6 ± 148.0 egg masses/km (n = 12; Table 1). Most notable, during the 2017 survey, we observed 1,469 egg masses over 2.35 km surveyed (625.1 egg masses/km; Table 1). From 2009 through 2023, survey reach egg-mass mortality (i.e., stranded and desiccated egg masses) ranged from 0–18.1% (mean = 3.5 ± 4.75%; n = 15), with the highest percentage of stranding and desiccation

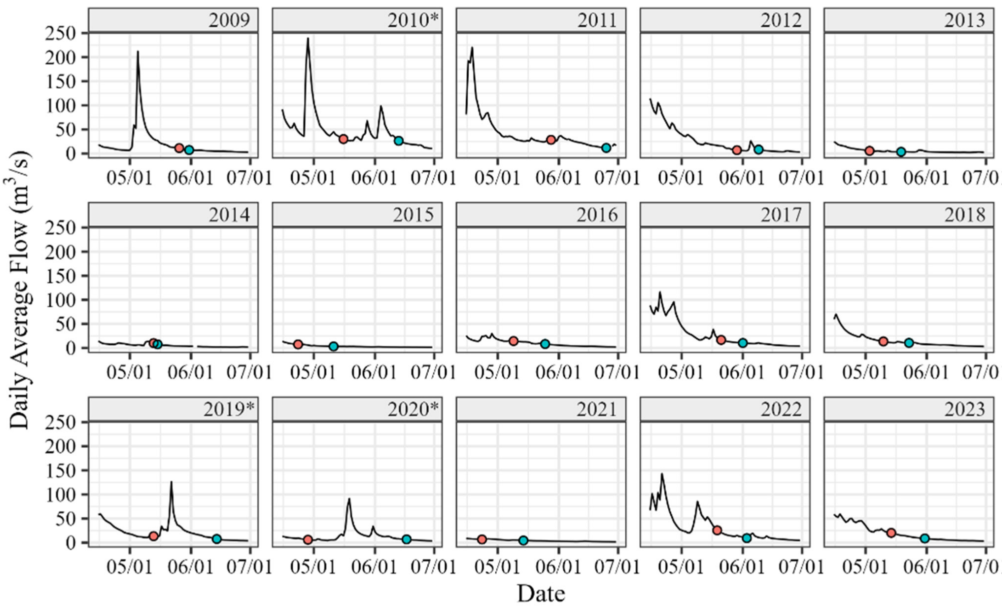

Figure 3. Average daily spring flows (2009–2023) on the Mad River, Humboldt County, California, USA, in cubic meters per second (m3/s) on the date of first documented occurrence of oviposition (orange dot) and on the date (Table 1) of the annual Foothill Yellow-legged Frog (*Rana boylii*) egg-mass survey (blue dot). Years that scour events occurred after the onset of oviposition are denoted with an asterisk.

Table 1. Summary of Foothill Yellow-legged Frog (*Rana boylii*) egg-mass surveys (2009–2023) at the Mad River annual survey reach, Humboldt County, California, USA. A single asterisk (*) denotes years that large storm events increased flow after the first documentation of oviposition, resulting in scouring away early egg masses and not allowing for an accurate survey of the reach (these years were not included in overall average egg masses/km). Double asterisks (**) denote that distance surveyed and egg-mass density data from 2009–2020 was contributed to Rose et al. (2023) for use in multiple population viability analysis models. Abbreviations are DS = distance surveyed and TNEM = total number of egg masses.

			Development Stage/Condition (number of egg masses)								
Year	Survey date	DS (km)**	Round	Bean	Tail	Partially hatched	Fully hatched	Stranded	Desiccated	TNEM	Egg masses/ km**
2009	31 May	2.25	58	166	107	0	355	41	0	727	323.1
2010*	13 June	3.03	85	62	19	1	52	14	1	234	77.2
2011	25 June	1.93	0	4	5	1	128	0	0	138	71.5
2012	9 June	2.45	8	10	150	156	184	27	0	535	218.4
2013	19 May	2.35	69	81	92	41	194	0	0	477	203.0
2014	15 May	2.17	94	18	25	109	29	0	0	275	126.7
2015	11 May	2.36	137	75	148	145	222	1	6	734	311.0
2016	25 May	2.34	84	133	94	162	406	8	22	909	388.5
2017	1 June	2.35	77	183	241	408	466	2	92	1,469	625.1
2018	23 May	2.50	104	140	131	383	142	1	0	901	360.4
2019*	14 June	2.36	11	21	44	79	161	21	49	386	163.6
2020*	17 June	2.17	0	5	19	15	37	0	0	76	35.0
2021	14 May	2.39	63	45	88	77	88	0	1	362	151.5
2022	3 June	2.38	86	66	87	138	53	7	7	444	186.6
2023	31 May	2.57	108	149	120	117	178	1	18	691	268.9
Total	15	–	984	1,158	1,370	1,832	2,695	123	196	8,358	–
Average	31 May	2.37	65.6	72.2	91.3	122.1	179.7	8.2	13.1	557.2	269.6

occurring during two survey years that experienced scour events (2010 and 2019; Table 1; Fig. 3).

***Property-wide egg-mass survey*.**—Due to the ephemeral nature of amphibian egg masses (e.g., about three to five weeks to hatching for *R. boylii* in northwestern California; Hayes et al. 2016), we were limited to how many reaches we could survey during the 2018 property-wide survey before egg masses hatched and larvae had begun to disperse. We were able to survey 101.6 km of the 143.7 km (70.7%) of potentially suitable breeding habitat for *R. boylii* in eight watersheds (Table 2; Fig. 2). This survey yielded 5,662 *R. boylii* egg masses and 1,074 incidental post-metamorphic (juvenile and adult) *R. boylii* observations (Table 2). We detected most egg masses (90.4 %) in the Redwood Creek and Mad River watersheds (Table 2). These two watersheds represented most of the distance that we surveyed relative to the other watersheds we surveyed (56.0%; Table 2), as these two watersheds contained the highest percentage of high-likelihood reaches for *R. boylii* breeding habitat within GDRCo ownership (60.8% combined; Table 2). The Klamath River watershed had a relatively high percentage of potentially suitable breeding habitat (30.3%); however, this watershed only yielded 5% of the observed egg masses (Table 2). The estimated number of egg masses from the BAS procedure in high-likelihood reaches for *R. boylii* breeding habitat across GDRCo timberlands in California was 5,369 egg masses (95% confidence interval = 5,277–5,461 egg masses), which is close to the actual number that we counted (5,308 egg masses) for this stratum, indicating that we surveyed most of the area with high likelihood to provide potential breeding habitat.

During the property-wide survey, we observed high densities of egg masses associated with tributary confluences in some watersheds. In particular, we observed the highest egg-mass densities during this survey within an area surrounding the confluences of Cañon Creek and Vincent Creek with the Mad River. The confluences of these two creeks are separated by about 420 m (Fig. 4), and we observed 805 egg masses from about 500 m above the Cañon Creek confluence to about 500 m below the Vincent Creek confluence (Fig. 4). Furthermore, during the property-wide survey, we also observed aggregations of egg masses on the Mad River near the confluences (about 500 m above and below) of Blue Slide Creek (254 egg masses), an unnamed tributary (186 egg masses), Dry Creek (224 egg masses), and Black Dog Creek (160 egg masses; Fig. 4). On Redwood Creek, within about 500 m above and below the confluence with Lacks Creek, we observed 271 egg masses, and similarly near the confluence of Garrett Creek, we observed 231 egg masses (Fig. 5). In addition to these observations, we saw small breeding populations on

Table 2. Summary of the 2018 property-wide Foothill Yellow-legged Frog (*Rana boylii*) egg-mass survey in northwestern California, USA, by watershed, showing potential breeding habitat and actual habitat surveyed (in parentheses) for each likelihood stratum identified via aerial imagery (see Materials and Methods). Total egg masses observed per stratum: high likelihood = 5,308; moderate likelihood = 352; low likelihood = 2. A single asterisk (*) indicates that the column represents the total number of incidental post-metamorphic *R. boylii* observed per watershed during the survey. A double asterisk (**) indicates watersheds included in the total potential survey distance but were not surveyed because the reaches with potential breeding habitat in these watersheds are known to go dry during the summer. Abbreviations are TPBH = total potential breeding habitat, TNEM = total number of egg masses, and EM = egg masses.

	Likelihood strata						
Watershed	High (km)	Moderate (km)	Low (km)	TPBH (km)	TNEM /watershed	EM/km surveyed	Number of frogs*
Winchuck River	–	–	2.4 (1.9)	2.4 (1.9)	0	0.0	5
Smith River	–	4.1 (4.1)	0.8 (0.0)	4.9 (4.1)	29	7.1	47
Wilson Creek**	–	–	3.8 (0.0)	3.8 (0.0)	–	–	–
Hunter Creek**	–	–	6.8 (0.0)	6.8 (0.0)	–	–	–
Klamath River	31.8 (30.8)	1.5 (0.0)	10.3 (0.0)	43.6 (30.8)	286	9.3	264
Redwood Creek	26.6 (26.6)	–	–	26.6 (26.6)	1,853	69.7	270
Maple Creek	–	–	7.7 (1.5)	7.7 (1.5)	0	0.0	3
Little River	–	–	3.7 (3.7)	3.7 (3.7)	0	0.0	0
Mad River	27.0 (27.0)	4.3 (2.3)	9.9 (1.0)	41.2 (30.3)	3,268	107.9	459
Van Duzen River	2.7 (2.7)	–	0.3 (0.0)	3.0 (2.7)	226	83.7	26
Totals	88.1 (87.1)	9.9 (6.4)	45.7 (8.1)	143.7 (101.6)	5,662	–	1,074

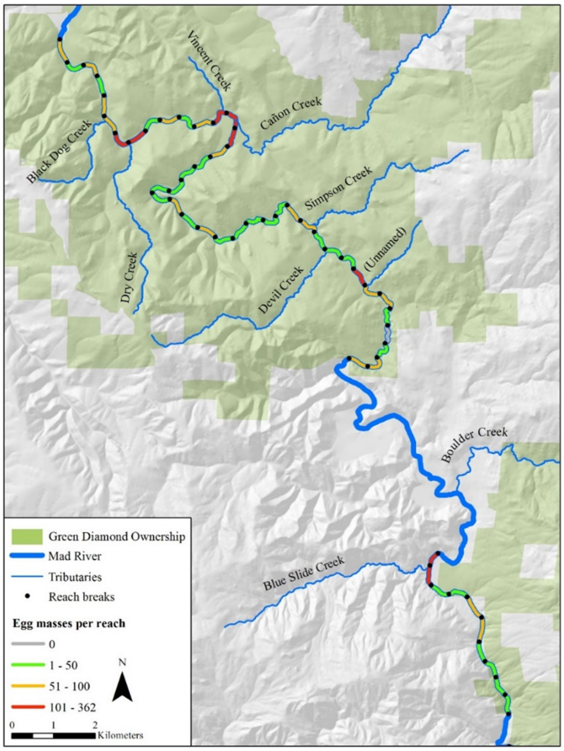

Figure 4. Foothill Yellow-legged Frog (*Rana boylii*) egg-mass counts per reach from the 2018 property-wide survey on the Mad River, Humboldt County, California, USA. The river flows north.

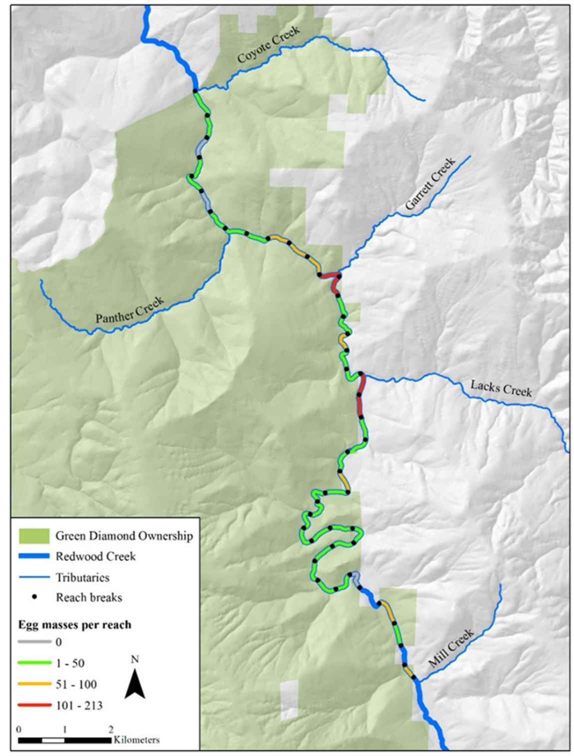

Figure 5. Foothill Yellow-legged Frog (*Rana boylii*) egg-mass counts per reach from the 2018 property-wide survey on Redwood Creek, Humboldt County, California, USA. The creek flows north.

tributaries where oviposition had not previously been documented. We observed egg masses on tributaries up to 4.6 km upstream from the Klamath River (Terwer Creek: n = 36; Roach Creek: n = 57; Tectah Creek: n = 6) as well as on a tributary 3.4 km upstream from the Mad River (North Fork Mad River: n = 23).

Discussion

Our results indicate that *R. boylii* populations in coastal northwestern California may be more robust than previously thought. Fellers (2005) noted that healthy *R. boylii* populations occur throughout the northwestern California region; however, there is a lack of information regarding the distribution of *R. boylii* and their breeding areas in this region. Many *R. boylii* observations for northwestern California that were used in the petitions to list the species were spatially scant, with much of the area lacking recent surveys or observations (Center for Biological Diversity. 2016. *op. cit.*).

Since the late 1800s, timber harvest has occurred at least once along the stream reaches that we surveyed during the property-wide survey in 2018 (Diller and Wallace 1996). With the implementation of the California Forest Practices Act in 1973, riparian protections for streams have improved (Burkholder and Diller 2007), and management measures that minimize sediment inputs to streams may limit the impacts from current timber harvest activities and thus provide protections for stream-associated species, such as *R. boylii*. Additionally, the reaches we surveyed were remote with little to no public access and exhibit minimal human development along them, resulting in much less anthropogenic disturbance compared to other parts of the range of *R. boylii*. Most of the reaches were on unregulated stream flow systems and one semi-regulated stream flow system (Mad River) with natural flow and thermal regimes, which appear to be key components of *R. boylii* conservation (Rose et al. 2023). The exception to this was the Klamath River, which is the only navigable river accessible to motorized watercraft that we surveyed and is also currently subject to dam control influences upriver from the survey reaches. These factors likely played a role in the low numbers of egg masses that we detected in the Klamath River reaches, as regulated streams tend to have lower egg-mass densities compared to unregulated streams (Rose et al. 2023). It should be noted, however, that after decades of altered flows due to six dams on the Klamath River, removal of four of the dams and restoration of riverine habitat has begun. As of May 2024, one dam has been completely removed and the removal of three others are in progress. This project is estimated to be completed by the end of 2024 and will return much of the Klamath River watershed to a more natural flow regime (American Rivers. 2024. Four things to know about the impacts of dam removal on the Klamath River. Available from: https://www.americanrivers.org/2024/05/four-things-to-know-about-the-impacts-of-dam-removal-on-the-klamath. [Accessed 2 July 2024]), which will likely benefit the *R. boylii* populations in this watershed.

Within GDRCo ownership in northwestern California, as well as throughout the entire range of *R. boylii*, the Mad River has the highest documented number of egg masses/km of stream surveyed (Bourque and Bettaso 2011; Hayes et al. 2016; Rose et al. 2023). To our knowledge, the density observed during the 2017 Mad River annual egg-mass survey is the highest documented to date, exceeding the highest published density of egg masses/km by 93.2% (from the 2009 survey on the Mad River annual survey reach; Bourque and Bettaso 2011), as well as the second highest density within the Mad River annual egg-mass survey reach observed in 2016 by 60.9%. These high densities are likely due to a combination of the factors mentioned above and how the Mad River is managed. The operational procedures of R.W. Matthews Dam do not significantly affect the natural flow regime of the river and likely benefit the Mad River *R. boylii* populations, avoiding summer pulse flows and maintaining a stable, minimum baseflow similar to a natural flow regime, providing aquatic habitat during breeding and rearing periods of *R. boylii* (Humboldt Bay Municipal Water District. 2004. *op. cit.*). We recognize that any system with perennial flow has the potential to harbor introduced species such as American Bullfrogs (*Lithobates catesbeianus*) and *R. boylii* require flow throughout summer into early fall to achieve metamorphosis, so there is the potential for *L. catesbeianus* to gain a foothold in streams inhabited by *R. boylii*. Although *L. catesbeianus* is present in the Mad River watershed, they appear to be in low numbers, primarily inhabiting lentic habitats, but we have not detected them within the annual survey reach or in the river where it flows through GDRCo ownership.

Abrupt changes in flow that occur after the onset of *R. boylii* oviposition can have detrimental effects on egg mass and larval success (Kupferberg 1996; Kupferberg et al. 2012), and we observed this on the Mad River annual egg-mass survey reach. In the Mad River, scouring during spring storms negatively affected egg-mass survival (e.g., 2010, 2019, and 2020), and rapid decreases in river stage has resulted in egg-mass stranding and desiccation. Sudden fluctuations in flow after the onset of oviposition in 2019 resulted in the highest percentage of stranded and desiccated egg masses at 18.1%. Climate change has contributed to increased rainfall intensity, duration, and frequency (Tebaldi et al. 2006; Jentsch et al. 2007; Martel et al. 2021), which could further increase negative effects on *R. boylii* egg-mass survival if these events occur during the breeding season.

Studies have documented temporary suspension of breeding activity when storm events increase stream flows (Wheeler and Welsh 2008; Gonsolin 2010), and we observed this as well. In 2019, about one-week post-storm, we performed reconnaissance surveys in areas where high flows had scoured egg masses; *R. boylii* resumed breeding in those areas once flows decreased. We performed the 2019 annual egg-mass survey about three weeks after high flows had receded and observed 163.6 egg masses/km, which was less than the mean density of egg masses/km, but still high relative to other areas within the range of *R. boylii* (Bourque and Bettaso 2011; Kupferberg et al. 2012; Lind et al. 2016; Van Hattem et al. 2021; Rose et al. 2023). Additionally, in 2020, we observed partially hatched egg masses before a late-spring storm event. During a reconnaissance survey, about two and a half weeks post-storm, we observed tadpoles, which indicates that some of the early hatchlings persisted after the storm. These tadpoles likely avoided scouring and/or stranding because flows increased and decreased at a gradual rate. The 2020 survey took place about four weeks after high flows receded. This was the second latest survey and yielded the lowest egg-mass density to date (35.0 egg masses/km). Late-spring storm events did not occur after the onset of oviposition in 2021, 2022, and 2023, and we saw an increase in egg-mass densities during each of these three years.

Tributaries serve an important habitat role for *R. boylii* (Bourque 2008; Kupferberg 1996; Peek 2010; Yarnell 2005), acting as travel corridors for migrating frogs that often use them for overwintering habitat (Bourque 2008). As part of a separate project while *R. boylii* was a CESA candidate species, we performed surveys to gather information on winter tributary use by these frogs in the Mad River watershed (January

2018) and found adult *R. boylii* in a tributary to Cañon Creek, approximately 3.5 km upstream from the confluence of Cañon Creek with the Mad River. We also observed adult *R. boylii* in Sullivan Gulch, approximately 4 km upstream from the confluence with the North Fork Mad River, which is about 3.9 km upstream of the confluence of North Fork Mad River and the mainstem of the Mad River, and juvenile *R. boylii* in a tributary to Simpson Creek, 1.8 km upstream from the confluence with Mad River.

Using aerial imagery, we identified potential breeding habitat on tributaries to mainstem streams, and we observed small breeding populations on some of these tributaries. During the 2018 property-wide survey, we found *R. boylii* egg masses on Tectah Creek, Terwer Creek, and Roach Creek, 1 km, 3.8 km, and 4.6 km, respectively, upstream from their confluences with the Klamath River. Furthermore, on 18 July 2019 while performing an unrelated survey, we incidentally observed remnant *R. boylii* egg masses and tadpoles on Boulder Creek, 13.4 km upstream from the confluence with the Mad River. In addition to providing overwintering refugia, travel corridors, and in some instances breeding habitat, these tributaries contribute coarse substrates that aggregate at confluence areas (Benda et al. 2003), increasing habitat diversity and creating breeding habitat (Kupferberg 1996; Yarnell 2005) as we observed during the property-wide survey. We saw this at the confluences of Blue Slide Creek, Cañon Creek, and Dry Creek with the Mad River, and at the confluences of Lacks Creek and Garrett Creek with Redwood Creek where we observed large aggregations of *R. boylii* egg masses.

The expanded *R. boylii* egg-mass survey effort in 2018 contributes to information on the distribution and abundance of these frogs and their breeding habitat in northwestern California. Based on the understanding that adult female *R. boylii* lay one clutch per year (Thomson et al. 2016), we can approximate that by observing 5,662 egg masses during the 2018 survey, there were at least that many breeding females across GDRCo timberlands in California. We detected most of these egg masses within high and moderate-likelihood survey reaches, and although we were not able to survey as many of the low-likelihood reaches as planned, we believe the low-likelihood reaches we did survey represented the habitat within this stratum across GDRCo ownership. Many of the low-likelihood reaches were isolated, with minimal canopy openings, and some of the reaches, even though they had open canopy and gravel/cobble bars, dried up during integral periods of *R. boylii* larval development and were therefore not viable breeding or rearing habitat for these frogs (e.g., Wilson Creek and Hunter Creek).

Because we had over 140 km of potential breeding habitat to cover during our property-wide survey, we started the surveys earlier (about 8 d after the onset of oviposition on the Mad River) than we normally start our annual survey, so in some cases we may have missed the peak of breeding on some of our reaches. Despite this, this survey indicates that *R. boylii* are relatively abundant in these coastal watersheds in northwestern California; however, the 2018 survey is a snapshot of one breeding season in a subset of watersheds in coastal northwestern California. There are still many unknowns regarding the ecology and natural history of *R. boylii*. Longer-term monitoring programs throughout their range may be useful in gaining a better understanding of population trends. Monitoring can provide insight into how climate change influences hydrology and thermal regimes, and how anthropogenic disturbances (e.g., mining, construction and development, cannabis cultivation, timber harvest, and road building), and introduced nonnative predators (e.g., *L. catesbeianus*, crayfish, and centrarchid fish) affect *R. boylii* populations, and can aid in furthering conservation efforts for this species.

Acknowledgments.—We dedicate this manuscript in memory of Lowell V. Diller, who developed the Conservation Planning Department at the Green Diamond Resource Company, and we also want to acknowledge all the work he did for species conservation on the north coast of California. Additionally, we would like to thank the following for their help with data collection: Paul Amato, Jamie Bettaso, Nicole Bogle, Taylor Cain, Antoine Chery, David Dimitrie, Bianca Hayashi, David Lamphear, Elizabeth Meisman, Jason Labrie, Angela Moran, Jessica Mejia, Matt Nannizzi, Jonathan O'Connell, Jon Pini, Sean Studer, Aimee Taylor, Mike Van Hattem, and Mike Zontos. Finally, we would like to thank Melissa Reneski for assisting with figure development, and David Lamphear for lending his ArcMap knowledge and expertise to our property-wide survey efforts. Work was conducted under California Department of Fish and Wildlife Scientific Collecting Permit # S-191440001–20048–001.

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