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Observations of atypical habitat use by Foothill Yellow-legged Frogs (*Rana boylii*) in the Coast Range of California

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Abstract.—Foothill Yellow-legged Frogs (*Rana boylii*) have experienced extreme range-wide declines in recent decades. This stream-dwelling species is thought to be in decline primarily due to the alteration of streams through anthropogenic water development, the effects of which may be exacerbated by climate change. Although *R. boylii* has long been considered an obligate inhabitant of perennial streams, recent observations indicate that this species exhibits greater behavioral plasticity in habitat use, particularly for reproduction. Herein, we report on several observations of *R. boylii* using atypical habitat for both refuge and reproduction. We found several *R. boylii* individuals reproducing within lentic habitat over a several year period. We also found up to 27 egg masses of *R. boylii* in a primarily mud-substrate intermittent stream, where the species bred and recruited individuals in 5 of 10 years. Behavioral plasticity in the use of habitat types described herein indicates a possible search bias in traditional *Rana boylii* surveys. Our observations may have implications for future assessment of *R. boylii* habitats and for species recovery.

Resumen.—En las últimas décadas, la rana pata amarilla (*Rana boylii*) ha sufrido una disminución extrema en toda su distribución. Se piensa que, el principal motivo del declive de esta especie de rana que habita en arroyos es la alteración de su hábitat a causa del desarrollo antropogénico, situación que puede verse agravada por el cambio climático. Durante mucho tiempo, la rana pata amarilla se consideró un habitante obligado de los arroyos perennes. Sin embargo, observaciones recientes indican que *R. boylii* exhibe una mayor plasticidad de comportamiento en el uso del hábitat, particularmente durante la temporada reproductiva. En este documento, reportamos varios registros de *R. boylii* utilizando un hábitat atípico como refugio y sitio de reproducción. En varios años, registramos individuos de *R. boylii* reproduciéndose dentro del hábitat léntico. Además, encontramos hasta 27 agrupaciones de huevos de *R. boylii* en una corriente primaria intermitente, compuesta principalmente de sustrato de lodo, donde adicionalmente, registramos crianza y reclutamiento de individuos, en cinco de diez años de estudio. La plasticidad del comportamiento en el uso de los tipos de hábitat descritos en este documento indica un posible sesgo en el muestreo tradicional de *R. boylii*. Nuestras observaciones pueden tener implicaciones para la evaluación futura de los hábitats de *R. boylii* y para la recuperación de especies.

Population declines of the Foothill Yellow-legged Frog (*Rana boylii*) have led to its listing as a Species of Special Concern by the state of California (Jennings and Hayes 1994, Thompson et al. 2016) and have recently prompted the United States Fish and Wildlife Service to consider listing *R. boylii* under the Endangered Species Act (Adkins Giese et al. 2012). Hayes et al. (2016) recently published a comprehensive work describing various causes for the near extirpation of the once-common *R. boylii* over two-thirds of its historic range, which once spanned from Marion County in Oregon to the Sierra San Pedro Mártir in Baja California, Mexico (Storer 1925, Stebbins 1951, Loomis 1965). In California, *R. boylii* can be found today in low-elevation streams throughout the Pacific slope of the Coast Ranges and along the Sierra Nevada foothills (Stebbins and McGinnis 2012, Hayes et al. 2016).

Rana boylii is considered a stream obligate (Storer 1925, Stebbins, 1951, Hayes et al. 2016). Zweifel (1955) stated, "These frogs are so closely restricted to streams that it is unusual to find one at a greater distance from the water than it could cover in one to two leaps." Generally, researchers have described *R. boylii* habitat as gently flowing, low-gradient perennial streams, with substrates predominated by unconsolidated cobble and boulder

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(Kupferberg 1996, Van Wagner 1996, Wheeler and Welsh 2008, Bondi et al. 2013). However, Moyle (1973) was the first to mention that the species utilized intermittent pools, a finding which was later supported by work from Hayes and Jennings (1988). More recently, this species has again been reported utilizing pools in intermittent creeks and streams (Bourque 2008, Leidy et al. 2009, 2019, Bogan et al. 2019). Reports of breeding microhabitat for this species have been restricted to low-flow sections of creeks where cobble, boulder, and gravel are available for attachment (Storer 1925, Kupferberg 1996, Wheeler and Welsh 2008). Researchers report that breeding frogs oviposited egg masses in runs or in the tails and outlets of pools, where egg masses were typically attached to cobble or boulders located near river margins in shallow, relatively slow water (i.e., <5 cm/s moving water; Van Wagner 1996, JAA personal observation). Fitch (1938) reported finding *R. boylii* in slow-moving rivers with mud substrates in Oregon, but no published reports exist of oviposition in this microhabitat.

We concur that *R. boylii* is strongly associated with stream habitats, but recent observations indicate that this species may exhibit more behavioral plasticity than previously reported. Here we report 2 observations of reservoir use by *R. boylii* and also describe atypical breeding habitat in a mud-bottomed intermittent stream. Our observations occurred at 3 locations in 2 widely disparate sites within the drainage of the Russian River in Sonoma County, California.

At 2 locations in Sonoma County, California, we observed *R. boylii* using reservoir habitats. One such use involved a relatively short period, while the other has occurred over several years and also involved successful reproduction during consecutive years. Our first observation of pond use occurred at Turtle Pond on the Mitsui Ranch, a cattle ranch at the top of Sonoma Mountain, approximately 8 km west of the city of Petaluma (536661.9 m E, 4242809.5 m N, Zone 10S). Turtle Pond is a small (0.004 ha), deep (2 m), mud-bottomed freshwater stock pond (i.e., constructed reservoir) that is heavily shaded and covered in duckweed (*Lemna* spp.) most of the year. It supports a breeding population of Rough-skinned Newt (*Taricha granulosa*) as well as adult California Red-legged Frogs (*Rana draytonii*). This small perennial reservoir is maintained by a slow perennial seep from a hillside spring 20 m upslope. Although Turtle Pond overflows in wet months from an outfall pipe, no surface water flow connects Turtle Pond to any other water body (the nearest of which is Copeland Creek, 375 m north).

On the night of 26 June 2017, while conducting a movement ecology project with *R. draytonii* in Turtle Pond, we hand-captured a single *R. boylii* (67-mm snout-to-urostyle length [SUL] and 36 g), which we determined from SUL to be a breeding-age female (Zweifel 1955, Van Wagner 1996, Wheeler and Welsh 2008). We inserted an 8-mm subdural PIT tag (Biomark, Inc.) into the frog and released it at the point of capture. The same frog was encountered 10 nights later in the same pond. Despite more than 80 subsequent focused searches, this frog was not observed thereafter at this site.

Our second reservoir site in eastern Sonoma County was on the western slope of Mount St. Helena (529550.1 m E, 4277540.0 m N; Zone 10S). Stewart Pond is a reservoir constructed for the irrigation of vineyards and for human recreation. At full capacity, the reservoir surface area is approximately 0.8 ha and fills to a depth of 8 m. Stewart Pond is fed by 3 intermittent tributaries to Kellogg Creek, which is a perennial stream that drains the northern and western slopes of Mount St. Helena. Emergent aquatic vegetation (*Typha* sp.) grew in shallow areas on the east side, and mannagrass (*Glyceria leptostachya*) and dallisgrass (*Paspalum dilatatum*) were dominant along the edges of the south end of the pond. Stewart Pond also supported breeding Western Toads (*Anaxyrus boreas*), Pacific Tree Frogs (*Hyliola regilla*), American Bullfrogs (*Lithobates catesbeianus*), Northwestern (= Western) Pond Turtles (*Actinemys marmorata*), and Mosquitofish (*Gambusia affinis*).

An American Bullfrog (hereafter "bullfrog") eradication program compelled us to visit Stewart Pond one day and night each month to remove bullfrogs using air rifles (Alvarez et al. in review). The baseline density of bullfrogs at the start of the project in October 2013 was approximately 3 frogs/m along the shoreline. By the end of 2014, after 7 visits, the density had decreased to 0.01 frogs/m, with approximately 1850 bullfrogs removed. During our last seasonal visit in 2014 (October), we had 2 independent observations of 6 post-metamorphic and 2 subadult *R. boylii* along the shoreline of Stewart Pond during the evening survey. We initially assumed these frogs had moved upstream from Kellogg Creek, perhaps in anticipation of seasonal increases in flow rates within adjacent lotic habitat (Van Wagner 1996, Hayes et al. 2016). When we returned for control efforts the following spring on the evening of 5 May 2015, we noted 3 adult *R. boylii* basking/foraging along the shoreline on the north side of Stewart Pond. We immediately used headlamps and handheld flashlights (approximately 400–600 lumens each) to search for additional *R. boylii*. This detailed search revealed 2 egg masses at the base of a stone-and-mortar wall. Each egg mass was surrounded by *R. boylii* larvae in various stages of development (Fig. 1). The egg masses were attached to the surfaces of rocks in water that ranged from 0.4 m to 1 m deep. Subsequently, throughout our control efforts of 2016 and 2017, as the bullfrog population decreased at Stewart Pond (i.e., fewer than 5 bullfrogs in the pond), *R. boylii* numbers increased, and we observed newly transformed *R. boylii* at the pond each spring. In April 2018 we found a new cohort of larval *R. boylii*, indicating that breeding had occurred for 3 consecutive years in Stewart Pond. Although we did not visit Stewart Pond in 2019, a follow-up visit in April 2020 revealed 6 *R. boylii* egg masses in the same lekking site—2 freshly oviposited on the date of our visit (9 April 2020)—with 5 adult frogs observed. During a subsequent June visit we observed approximately 200 *R. boylii* larvae in the littoral zone of Stewart Pond.

Our third site, Copeland Creek, also on the Mitsui Ranch in Sonoma County, is a low-gradient stream for approximately 1.2 km from its source, a series of isolated springs. This intermittent creek flows approximately 0.4 km through open grasslands before becoming shaded by a dense canopy of California baylaurel (*Umbellularia californica*), valley oak (*Quercus lobata*), coast live oak (*Quercus agrifolia*), and willow (*Salix* sp.), just prior to intersecting Rose Creek and becoming a second-order stream (Vannote et al. 1980). This reach of Copeland Creek has its greatest topographic fall through a riparian forest, but flattens out on a run through a long, low meadow shortly after the Rose Creek confluence. The channel width through this meadow stretch of creek is never greater than 1.5 m. Shallow runs through this flat habitat are typically covered by Himalayan blackberry (*Rubus armeniacus*). Only one unvegetated stretch exists in this riparian area: a long, deep run followed by a 105° curve against a steep clay cutbank (Fig. 2). The substrate of the cutbank consists of lithified volcanic ash mixed with small pebbles and cobbles. In April 2016, 2018, and 2019, we observed egg masses of *R. boylii* attached to the pebbles and cobbles within the ash matrix (Fig. 3). In each of the past 10 years, between 1 and 27 *R. boylii* have oviposited within the unvegetated section of the creek. In 6 of those 10 years the hydroperiod was insufficient and the stream dried before larvae transformed, but in the remaining 4 years metamorphosis was observed. At the main lek site, female *R. boylii* oviposited in water with a mean depth of 9.1 cm (range 2.5–20.5 cm) and a mean distance from shore of 28.8 cm (range 4–49 cm). The wet-channel width ranged from 0.74 to 1.72 m wide, and the maximum depth was 23 cm. The range of flow rates was measured at 1.5–5.4 cm/s.

Our observations of reservoir use by *R. boylii* contrast with one another: we have a brief single-specimen observation of *R. boylii* at Turtle Pond and multiseason observations of a small population at Stewart Pond. Unlike Stewart Pond, Turtle Pond cannot be considered an in-stream impoundment. It is fed by a streamlet that emerges from a spring 20 m above the reservoir, and the reservoir overflows only for a brief period during bouts of intense rain, making Turtle Pond an isolated water body. We surmised that the breeding-age female *R. boylii* that we observed used Turtle Pond as a stopover during seasonal dispersal (i.e., emigration, transfer, or immigration; Andreassen et al. 2002) or during a dispersal event associated with foraging (Semlitsch 2008). The nearest known breeding habitat is approximately 400 m north and downslope, across a seasonally wet open meadow at the Copeland Creek site (described above). At the time of our observations, the meadow was mostly dry. Bourque (2008) recorded a maximum downstream travel distance of 1386 m in one day for a female *R. boylii*. The distance our female would have been required to travel to reach Turtle Pond is well within the known range of daily travel reported by Bourque

Fig. 1. Multiple larval cohorts of *Rana boylii* around an egg mass of the same species, oviposited on rock rubble at the base of a submerged rock wall, Kellogg Pond, Sonoma County, California.

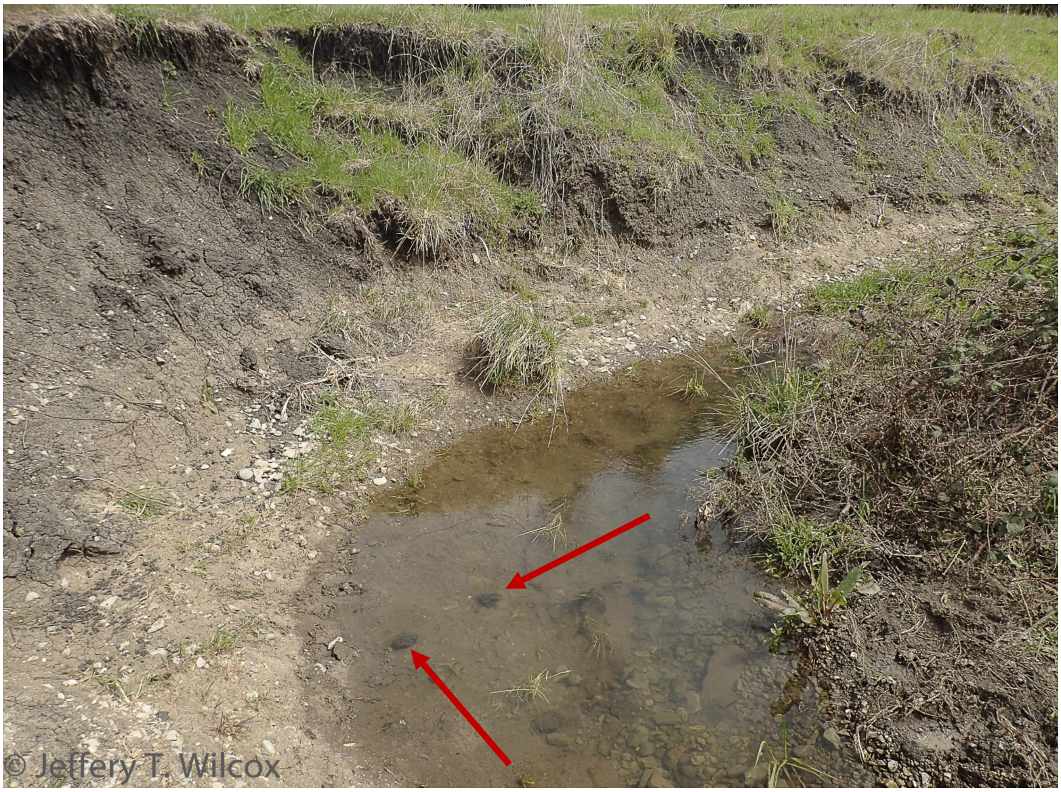

Fig. 2. Two *Rana boylii* egg masses oviposited on volcanic ash substrate in an oxbow bend in Copeland Creek, Sonoma County, California.

(2008), but we must assume this frog crossed open dry grasslands to reach Turtle Pond, a movement not previously reported for *R. boylii*. Conversely, the use of Stewart Pond by *R. boylii* would not likely have required overland movement, since Stewart Pond is an in-line impoundment. Its use also contrasts in that it was utilized for breeding over successive years.

Our observations of successful breeding of *R. boylii* in Copeland Creek indicate that the species can and will successfully breed in intermittent second-order creeks. Although the extended lekking area is made up of cobbles, the most frequently used lekking area is concentrated within an area where substrates are primarily unconsolidated muds, with only widely dispersed pebbles and cobbles. We find this distinctly important because there is a dearth of data showing that the species exhibits this level of flexibility in oviposition site location.

Rana boylii has been observed in a wide range of habitat types, including permanent streams, third-order intermittent streams, and isolated pools in streams (Hayes and Jennings 1988, Leidy et al. 2009, Gonsolin 2010, Bogan et al. 2019). Vincent (1947) reported collecting a single *R. boylii* in "the pond of a small spring" associated with Red Blanket Creek in Oregon, but no details were provided for the habitat (i.e., size, depth, connectivity, etc.). It remains unclear whether the "pond" was a natural pond, a puddle, a plunge pool, a reservoir, or another type of water body. We feel that our observations at Stewart Pond are the first report of *R. boylii* inhabiting and breeding in lentic water over multiple years. It is possible that gravid *R. boylii* females oviposit in Stewart Pond much as they would in a large in-stream pool, because the egg masses we observed were typically attached to large cobble at the edge of the pond and in a location that receives direct solar radiation. Still their use of a reservoir for reproductive microhabitat is unique. During one year, our observations included multiple *R. boylii* larval

Fig. 3. *Rana boylii* egg mass attached to a cobble in the matrix of lithified volcanic ash in Copeland Creek, Sonoma County, California.

size-cohorts (see Fig. 1), establishing that our observations were not an isolated event. Further, over 4 breeding seasons we observed 10 egg masses in Stewart Pond, along with larvae and postmetamorphic individuals.

Summary

We describe 3 examples of atypical use of habitat and/or microhabitat not previously published for *R. boylii* at 2 disparate locations in Sonoma County, California. We believe these observations suggest that *R. boylii* may exhibit more behavioral plasticity and may be a more vagile species than previously known. Historical assignations of *R. boylii* as a stream obligate may have inadvertently introduced a suitability bias to biologists who survey and assess *R. boylii* habitats. Interestingly, unnatural stream flow regimes caused by impounded waters have resulted in the decline of this species (Lind et al. 2005, Kupferberg et al. 2012), yet impoundments on minor streams or on offstream sites may be viable surrogate habitat. We recommend that field surveys consider ponded or impounded waters within travel distance (1386 m) of streams that are currently or historically occupied by *R. boylii* (Bourque 2008), particularly in-stream impoundments.

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