Herpetology Notes, volume 15: 395-397 (2022) (published online on 13 June 2022)

Small size of *Rana boylii* (Anura: Ranidae) at metamorphosis in a seasonal stream may confound survey methods

Jeff A. Alvarez[1,*], Lisa L. Surber[2,3], Ellen A. Gallanty[2], and Jeffery T. Wilcox[4]

Metamorphosis is a critical time in the development of biphasic amphibians, as they use the stored energy acquired by larvae in aquatic environments to completely reconfigure their bodies for a terrestrial adulthood (Wilbur and Collins, 1973; Semlitsch et al., 1988; Denver et al., 1998). There are many factors that can influence growth rate, developmental rate, and other allometric characteristics. Tejedo et al. (2010) investigated the influence of water temperature, predation risk, resource availability, and habitat desiccation on the progress of development and growth in anurans and noted that these factors can slow, speed, or limit rates of development and growth. They further reported that increasing one factor, such as temperature, could increase developmental rate while not having a similar influence on growth rate, implying that larvae can fully develop at a small size under warmer water temperatures. Denver et al. (1998) suggested that larvae that metamorphose at a smaller size may incur additional costs related to physiological performance and size at first reproduction. Although sizes of individual amphibians range widely at the time of metamorphosis (Storer, 1925; Jones et al., 2005; Denver et al., 1998), size at metamorphosis can be associated with increased predation potential. Lawlor et al. (1999) found that smaller metamorphosed ranid frogs may be subject to more predation during work she conducted with a related congener. Alvarez (2013) noted that smaller post-metamorphic California red-legged frogs (*Rana draytonii* Baird & Girard, 1852) were subject to cannibalism by slightly larger conspecifics. It appears that size at metamorphosis may have important consequences on fitness and survival for many amphibian species. Herein we report on the smallest reported size for a foothill yellow-legged frog (*Rana boylii* Baird, 1852) at metamorphosis, along with potential conservation implications.

While conducting visual encounter surveys for amphibians along Copeland Creek, Sonoma County, California, USA (38.3356° N, 122.5820° W), we regularly observed *R. boylii* (see Alvarez and Wilcox, 2021). Copeland Creek is a second order ephemeral stream along its reach atop Sonoma Mountain, and in most years has no surface flow by July. The winter of 2018-2019 brought above-average rainfall, and under these wet conditions, *R. boylii* produced > 5 times the mean number (n = 5) of egg masses observed in the prior 10 years. Surface flows persisted until the first week of July, and on 24 July 2019 we initially observed metamorphosed *R. boylii* along the wetted edge of some small pools in Copeland Creek. At our initial observation, the size of these recently metamorphosed frogs appeared unusually small. We hand-captured individuals and recorded weight and size measurements. We used a Pesola (Lightline 10020) scale to weigh the individuals to the nearest 0.2 g, and a standard ruler to measure snout-to-urostyle length (SUL) and gape (across the head, between jaw hinges). We returned to the site on 01 August 2019 and collected 18 additional *R. boylii* froglets; this time using Mitutoyo digital callipers (part No. 5000-196-30) to measure SUL. No weight data was recorded during the second visit.

The SUL of post-metamorphic *R. boylii* on 24 July ranged from 14.0–18.0 mm (mean = 15.9 mm); gape ranged from 6.0–9.0 mm (mean = 7.1 mm); and weights ranged from 0.2–0.8 g (mean = 0.36 g). On 1 August, SUL ranged from 13.67–20.08 mm (mean = 16.59 mm; Fig. 1). A literature review produced 6 reports that summarised the lengths of post-metamorphic *R. boylii*. Storer (1925) collected "fully metamorphosed"

[1] The Wildlife Project, PO Box 188888, Sacramento, 95818 California, USA.
[2] Biology Department, Sonoma State University, 1801 East Cotati Ave., Rohnert Park, 94928 California, USA.
[3] Department of Evolution, Ecology, and Behavior, University of Illinois at Urbana-Champaign, 61820 Illinois, USA.
[4] Sonoma Mountain Ranch Preservation Foundation, 3124 Sonoma Mountain Road, Petaluma, 94954 California, USA.
[*] Corresponding author. E-mail: Jeff@thewildlifeproject.com

individuals on 7 August 1922 from San Pablo Creek, Contra Costa County, California, that were 23.2–30.0 mm SUL. Zweifel (1955) measured specimens at metamorphosis as 22–27 mm SUL, which was also reported in Nussbaum et al. (1983) in the summary of the *R. boylii* account. Jones et al. (2005) included a minimum size that ranged from 18–28 mm for recently metamorphosed *R. boylii.* Lannoo (2005) reported that recently metamorphosed *R. boylii* ranged in size from 14–17 mm; however, no reference for those data was provided. Thus, Dodd (2013) may have excluded the report by Lannoo (2005) when he summarised all previous research on *R. boylii,* listing a range size for this age class of 18–30 mm, without regard to time of year.

Our observations suggest that post-metamorphic *R. boylii* can be as small as 13.67 mm, slightly (3%) smaller than previously reported accounts that have been reported as 14–30 mm. We noted that the range in sizes at metamorphosis reported for *R. boylii* overlaps the range of sizes for the sympatric Pacific treefrog (*Hyliola regilla*) (Baird & Girard, 1852) which was reported by Storer (1925) to be 11.2–22.5 mm. Both species occupied the same habitat during their post-metamorphic phase along Copeland Creek making this an important observation because at this size range (< 20 mm) the two species are similar enough to be confused if not examined in-hand, resulting in the presence of *R. boylii* being potentially overlooked in surveys. We used the presence of a dark eye-stripe and presence of toe pads to positively identify *H. regilla*, while we used the absence of those features in addition to the presence of an intermittent dorsal-lateral fold to positively identify *R. boylii* (Fig. 2; Storer, 1925). We noted that these features were not readily identifiable when these two post-metamorphic cohorts were free-roaming.

The range of size in recently metamorphosed frogs we observed may have been attributed to a truncated hydroperiod that occurred as the metamorphic process began (Crump, 1989; Denver et al., 1998; Tejedo et al., 2010). Morey and Resnick (2001) reported that crowded larval conditions can influence size at metamorphosis, however, in our study area larval density was never measured and its influence cannot be determined. We also note that *H. regilla* was sympatric within the larval habitat at this site. Tejado and Reques (1994) reported that competitive stresses within the habitat of larvae can function to reduce size at metamorphosis. We would also suggest that there may be more variation in size at metamorphosis for this species that previous

Figure 1. Smallest measured post-metamorphic *Rana boylii* (13.7 mm), resting on a US one cent piece; collected along Copeland Creek, Sonoma County, CA. Photo by Jeff Alvarez.

understood. Most research on *R. boylii* has occurred in perennial streams so our observations may be within a normal size range for seasonal streams, or we may have observed a geographic extreme in *R. boylii* life history traits (Storer, 1925; Berven and Gill, 1983). We believe, based on additional captures one week later, that the mean size of this age class at Copeland Creek increased, which suggests the minimum size at metamorphosis may be smaller still. In any case, despite rapidly decreasing surface flow, *R. boylii* successfully metamorphosed just

Figure 2. Newly transformed Pacific tree frog (*Hyliola regilla*) and foothill yellow-legged frog (*Rana boylii*) captured on Copeland Creek on 01 August 2019. Photo by Jeffery T. Wilcox.

prior to Copeland Creek drying, albeit, they were at a very small size. The small size of individual *R. boylii* may compromise their survival in that many potential predators could easily prey on animals of this size (Werner, 1986; Berven, 1990).

Rana boylii is a declining species in California (Thomson et al., 2016). Factors influencing the detectability or contributing to the potential impacts on populations of this species are crucial to understand. In a stream setting, researchers should consider the potential for very small (< 14 mm) *R. boylii*, and consider brief hand-capture to facilitate positive identification when conducting surveys. This activity may require both federal and State permits. Moreover, anecdotally, we found that recently metamorphosed *R. boylii* were more numerous and more easily detected at night than during the day. Therefore, we suggest conducting night surveys, in addition to day surveys, for this species when conducting presence/absence survey efforts.

Acknowledgements. We are grateful to the Sonoma Mountain Ranch Preservation Foundation for access to the Mitsui Ranch, and to Z. Cava, D. Davis, A. Engstrom, K. Garten, J. Jones, and H. Sardiñas for assistance in the field. An anonymous reviewer offered extremely constructive comments that greatly improved this manuscript. We also thank D. Cook and R. Sullivan for a pre-peer review of this manuscript.

References

Alvarez, J.A. (2013): *Rana draytonii* (California red-legged frog). Cannibalism. Herpetological Review **44**: 126–127.

Alvarez, J.A., Wilcox, J.T. (2021): Observations of atypical habitat use by foothill yellow-legged frogs (*Rana boylii*) in the Coast Range of California. Western North American Naturalist **81**: 293–299.

Berven, K.A. (1990): Factors affecting population fluctuations in larval and adult stages of the wood frog (*Rana sylvatica*). Ecology **71**: 1599–1608.

Berven, K.A., Gill, D.E. (1983): Interpreting geographic variation in life-history traits. American Zoologist **23**: 85–97.

Crump, M.L. (1989): Effect of habitat drying on developmental time and size at metamorphosis in *Hyla pseudopuma*. Copeia **1989**: 794–797.

Denver, R.J., Mirhadi, N., Phillips, M. (1998): Adaptive plasticity in amphibian metamorphosis: response of *Scaphiopus hammondii* tadpoles to habitat desiccation. Ecology **79**: 1859–1872.

Dodd, C.K., Jr. (2013): Frogs of the United States and Canada. The Johns Hopkins University Press, Baltimore.

Duellman, W.E., Trueb, L. (1994): Biology of Amphibians. Johns Hopkins University Press. Baltimore.

Jones, L.L.C., Leonard, W.P., Olson D.H. (2005): Amphibians of the Pacific Northwest. Seattle Audubon Society, Seattle.

Lannoo, M. (2005): Amphibian Declines: The Conservation Status of the United States Species. University of California Press, Berkeley.

Lawler, S.P., Dritz, D., Strange T., Holyoak M. (1999): Effects of introduced mosquitofish and bullfrogs on the threatened California red-legged frog. Conservation Biology **13**: 613–622.

Morey, S., Reznick, D. (2001): Effects of larval density on postmetamorphic spadefoot toads *(Spea hammondi)*. Ecology **82**: 510–522.

Nussbaum, R.A., Brodie, E.D., Jr., Storm, R.E. (1983): Amphibians and Reptiles of the Pacific Northwest. News-Review Publishing Company, Moscow.

Semlitsch, R.D., Scott, D.E., Pechmann, J.H. (1988): Time and size at metamorphosis related to adult fitness in *Ambystoma talpoideum*. Ecology **69**: 184–192.

Storer, T.I. (1925): A synopsis of the amphibia of California. University of California Publications in Zoology **27**: 1–342.

Tejedo, M., Marangoni, F., Pertoldi, C., Richter-Boix, A., Laurila, A., Orizaola, G., et al. (2010): Contrasting effects of environmental factors during larval stage on morphological plasticity in post-metamorphic frogs. Climate Research **43**: 31–39.

Tejedo, M., Reques, R. (1994): Plasticity in metamorphic traits of natterjack tadpoles: the interactive effects of density and pond duration. Oikos **71**: 295–304.

Thomson, R.C., Wright, A.N., Shaffer, H.B. (2016): California Amphibian and Reptile Species of Special Concern. University of California Press, Berkeley.

Werner, E.E. (1986): Amphibian metamorphosis: growth rate, predation risk, and the optimal size at transformation. American Naturalist **128**: 319–341.

Wilbur, H.M., Collins, J.P. (1973): Ecological aspects of amphibian metamorphosis. Science **182**: 1305–1314.

Zweifel, R.G. (1955): Ecology, distribution, and systematics of frogs of the *Rana boylei* group. University of California Publications in Zoology **54**: 207–292.

Accepted by Omar Rojas-Padilla