

Color Polymorphism and Individual Variation in Disparate Populations California Red-legged Frogs (*Rana draytonii*)

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The Linnaean system of taxonomy considered speciation in wildlife as delimited by morphometric characterization, geographic range (individuals of a species typically live together), and overall morphology and patterning in coloration. The concept followed the plan that if two animals looked alike, they must be related (Larson 1968). More recently, the biological species concept suggested that appearance of two related individuals meant very little and two very similar looking species may remain separate species irrespective of their similarities. This can be found in cryptic species (i.e., Northwestern and Southwestern Pond Turtles [*Actinemys marmorata* and *A. pallida*]; Burroughs et al. 2024) as well as in Batesian mimicry (Myers and Daly 1983). Conversely, individual variation in a single species does not require speciation. For example, *Ensatina eschscholtzii eschscholtzii* and *E. e. croceator*, common in California, are the same species (although different subspecies) and are markedly different in appearance and can be syntopic (Stebbins 1957, Wake et al. 1986). Individual variation in coloration is reported in many species of garter snakes, and numerous species of amphibians, such as California Tiger Salamander (*Ambystoma californiense*), Black Salamander (*Aniades flavipunctatus*), and *Ensatina* salamanders (Stebbins 2003, Alvarez and Foster 2016). This appears equally true in some

anurans, where the Pacific Treefrog (*Pseudacris regilla*) and the Sierra Nevada Yellow-legged Frog (*Rana sierrae*) showed marked variation in coloration (Stebbins 2003, Jones et al. 2005).

Throughout its range, from Mendocino County, south to Baja California (Stebbins 1951) the California Red-legged Frog (*Rana draytonii*) exhibits a variable coloration. The original description by Baird and Girard (1852) was brief: “The ground color is olivaceous green and maculated with black on the upper region of the body and limbs.” Storer (1925) gave greater detail in his description, summarized here: referring to the dorsal coloration as buffy brown to olive brown, becoming darker posteriorly; back and sides of the body covered in black blotches, each with a light-colored central papilla, with these becoming larger posteriorly (Fig. 1). He describes the ventral surface as white with the undersides of the body, thighs, legs, and feet covered in dragon’s blood red. Those researchers that summarized the coloration following Storer (1925) were predominantly similar (Slevin 1928, Stebbins 1966, 1985, 2003, Dodd 2013, Stebbins and McGinnis 2018). Stebbins (1951) reported dark “dusky” blotches on the dorsum with a fuzzy outline, a character that carries through to adults from larval color patterning and one that became a useful comparative diagnostic tool when invasive American

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Fig. 1. Typical coloration of California Red-legged Frog (*Rana draytonii*) in both the adult life stage and the post-metamorphic life stage, Napa County, CA. Photo by Jeff A. Alvarez.

Bullfrogs (*Lithobates catesbeianus*) became established.

Most anurans are capable of rapid color change due to background matching to achieve crypticism in escaping predators, possibly in thermoregulation, and to enhance breeding colors (reviewed in Rojas et al. 2023). We note an example of this where an adult California Red-legged Frog that was captured from a pond bottom in conditions where the air temperature was 5° C and the surface water temperature was 6° C. The frog, probably due to mobilization of melanophores from deep in its dermal layers, presented with an atypical color; nearly black. After approximately 3 minutes of exposure to the sun, the ground color transmogrified from dark purple to a more typical coloration (i.e., Fig. 2). This drastic color change is representative of short-term color change due to physiological triggers, not a permanent color polymorphism.

Atypical coloration (color polymorphism) has been reported by Jansen and Alvarez (2022), and Solis-Sotelo et al. (2022), reporting amelanistic and leucistic California Red-legged Frogs respectively. These reports described individual frogs that were from geographically disjunct locations (San Francisco Bay Area and northern Baja California, respectively). The majority of frogs we have encountered ($n \geq 150,000$ individuals, unpubl. data) would fall under the original description by Storer (1925; Fig. 1). We report here on populations in which we found multiple individuals with distinctive color polymorphisms.

The population with the widest range of color polymorphisms is the Big Gun Conservation Bank, Michigan Bluff, Placer County, California—a site owned and managed by Westervelt Ecological Services—where over the past 16 years we have captured all life stages of California Red-legged Frogs. Approximately half of the captured frogs represented the typical adult coloration (Fig. 1). A small percentage of frogs (approximately 10%) were colored in an extraordinary pattern not representing the typical coloration of California Red-legged Frogs in any way (Fig. 3). These individuals have an overall ground color of black with a pattern of yellow, cream, gold, or pink spotting (irregular shapes) over much of the dorsal



Fig. 2. Atypical coloration of a California Red-legged Frog (*Rana draytonii*) seined from a cold pond bottom in winter, eastern Contra Costa County, California. Note: this is not a color polymorphism, but is likely mobilized melanophores, which can return to a typical coloration in 0.5 to 3 minutes. Photo by Jeff A. Alvarez.

surface. These atypically colored California Red-legged Frogs appear more similar, visually, to some color morphs of Sierra Nevada Yellow-legged Frogs (*R. sierrae*) than they do California Red-legged Frogs (Stebbins 2003, McGinnis and Stebbins 2018). Moreover, approximately 40% of frogs from Big Gun are colored in yet another color polymorphism, with a suffuse pattern of yellow or cream spots covering the dorsum (Fig. 4). These two distinct color polymorphisms appear to be isolated to this site, yet common to the Big Gun site, which has at least three distinct variations (i.e., black with light flecks, dominant gold color with dark braids of color, and typical

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Fig. 3. Two adult frogs with one typical coloration (right) and one (left) from the polymorphic forms at the Big Gun Site, Placer County, California, referenced by Jeffery T. Wilcox as the galactic form of California Red-legged Frog (*Rana draytonii*). Photo by Tara Collins.



Fig. 4. Adult California Red-legged Frog (*Rana draytonii*) from one of three polymorphic forms at the Big Gun Site, Placer County, California. Photo by Jeffery T. Wilcox.

coloration), as well as individuals that appear to have one or more of these color polymorphisms mixed together.

Two additional sites that do not exhibit the range of color polymorphisms of Big Gun but are worth noting because they represent geographically disparate populations in dramatically different habitat types. The first site includes eastern Contra Costa County, CA (Kellogg Creek and Brushy Creek watersheds), which are comprised of open annual grasslands, on the eastern side of the Coast Range, in northern California (see Alvarez et al. 2004). Small proportion of the population includes individuals that have a dorsum that is completely red (Fig. 5). An additional site showing a color polymorphism falls in the southern extreme of the range of the species, and is situated in a fen meadow at 6,400 feet elevation in the Sierra San Pedro Mártir in Baja California, Mexico. California Red-legged Frogs found here are frequently noted to have a field color of forest green, with cream and gold highlights (Fig. 6).



Fig. 5. Adult California Red-legged Frog (*Rana draytonii*) eastern Contra Costa County, CA illustrating an additional polymorphic form. Photo by Jeff A. Alvarez.

Storer (1925) described a California Red-legged Frog that changed color from nearly black to more typical coloration, and back to nearly black in a matter of seconds. This is similar to the frog we described as collected from a cold-water source that modified its color within a couple of minutes. This clearly shows that individuals can alter the color of the skin in the context or temperature (our frog) or stress (Storer 1925). We have further observed individuals captured and placed in buckets, lighten their skin color while housed out of the sun, again showing an ability to contract and expand melanophores at a relatively fast rate. We report this to note that variation in coloration can be exemplified in an individual frog due to extrinsic and intrinsic factors, as well as being a color polymorphism—variation among individuals and populations.

It is not unusual to see high levels of variation in the coloration of amphibians (Stewart 1974). Some species have been misclassified, misidentified, or mismanaged due simply to misunderstandings in the frequency and occurrence of color variations (Paterson et al. 2016). We acknowledge that early zoologists/naturalists like Storer (1925) had a paucity of tools compared to modern times. Early investigators took notes from live specimens, when possible, but often had to work from preserved specimens in museum collections (D. Wake, pers. comm). In addition, for expediency, they picked a few specimens from representative locations from which to draw the species description. Modern researchers have the luxury of capturing and distributing highly accurate color images, allowing for highly varied descriptions of species range wide.

The high level of variability in this species at Big Gun may be phenotypic variation but further research is required to make that determination. Whatever the mechanism for this level of variation in a species, it shows a persistently stable coloration pattern. At sites such as Big Gun, which are over 1,000 m elevation, the California Red-legged Frog could be misidentified as a Sierra Nevada Yellow-legged Frog (*Rana muscosa*) or an exotic species

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Fig. 6. Adult California red-legged frog (*Rana draytonii*) from a polymorphic form at Sierra San Pedro Mártir in Baja California, Mexico. Photo by Jeffery T. Wilcox.

that may then be targeted for control or removal. Biologists working in these areas should be aware of the wide range in color morphotypes that have the potential to be expressed in California Red-legged Frogs, such as we have reported here.

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