

ESSAY 8.2. AMPHIBIAN DECLINES IN CALIFORNIA

California, along with Central America and Australia, has been a focal area for the study of amphibian population declines, because of the severe declines of many of its species. The region is recognized as one of the world's biodiversity hotspots (the "California Floristic Province") and contains a heterogeneous landscape that sustains a wide variety of ecosystems, such as Sonoran deserts, marshes and wetlands, oak woodlands, high-elevation alpine systems, temperate rain forests, and many others. The amphibian fauna is diverse and, at the time of writing, includes 64 recognized native species (Figure 1a), including 40 species of salamanders from five families and nine genera, and 24 species of frogs and toads from five families and six genera (plus two introduced species; AmphibiaWeb 2006). Amphibians in California can be found in nearly all habitat types ranging from near Mount Whitney (at 3,657 m, the highest peak in the contiguous United States) to Death Valley (85 m below sea level). Despite the fact that California contains some of the largest contiguous protected habitats in the continental United States, nearly one-quarter of amphibians in California are threatened (Figure 1b).

Many potential causes for the widespread declines of amphibians have been proposed. In general these can be grouped into two major categories: 1) factors general to the overall biodiversity crisis, including habitat destruction, alteration and fragmentation, introduced species and over-exploitation, and 2) factors associated with amphibians that might account for declines in relatively undisturbed habitats. The first category includes relatively well understood direct ecological phenomena, whereas the second includes complex and elusive mechanisms, such as climate change, increased ultraviolet (UV-B) radiation, chemical contaminants, infectious diseases, and the causes of deformities (or malformations). The underlying mechanisms behind these factors are complex and may be working synergistically with more evident factors, such as habitat destruction and introduced species, to exacerbate declines. Many biologists believe that there are some dominant causes, such as new infectious diseases, whereas others are not convinced that there is a single overarching cause for global declines, but that many factors are threatening amphibian populations to a greater or lesser extent.

In California, amphibian declines are associated with many of the various hypotheses. Habitat destruction, alteration, and fragmentation have affected a large number of species including the Foothill Yellow-legged Frog *R. boylei* (NT), the Arroyo Toad *Bufo californicus* (EN), and the California Tiger Salamander *Ambystoma californiense* (VU), to name a few (Lannoo 2005). Some amphibians suffered declines long ago. In the 19th century, the California Gold Rush brought waves of new settlers who quickly over-exploited some frog species for food. They also altered the environment in ways that have had much more substantial effects on amphibians. Cities were built, rivers dammed and diverted, forests were cleared, and the waterways of Great Central Valley were completely altered for agriculture and to provide water for cities and industrial growth. The effect on California's ecosystems has been profound. As elsewhere, habitat conservation has become a central theme in efforts to preserve the region's biodiversity. However, recent amphibian declines in California have occurred in remote habitats well protected from development.

Beginning in the 1980s, scientists began to document alarming amphibian disappearances in protected habitats in California, Central America, and Australia. Some of the best documented examples of declines can be found in the Sierra Nevada, which not only contains large sections of roadless, undisturbed habitat, but also has a rich history of biological surveys going back to the turn of the 20th century (Grinnell and Storer 1924). These data are useful for comparisons with present day distributions of amphibians. For example, historical surveys noted abundant amphibians throughout the Sierra Nevada, and at higher elevations (>1500 m) the Mountain Yellow-legged Frog *Rana muscosa* (CR) (Figure 2) was termed the most abundant of all vertebrates! But, in the last three decades, nearly the entire amphibian fauna of the Sierra Nevada has collapsed. Air pollution, increases in harmful ultraviolet radiation (UV-B), introduced predators, and emerging diseases have

all been proposed as key factors that may explain the enigmatic declines in this protected landscape.

The first reports of amphibian collapse in the Sierra Nevada came from Yosemite Toads *Bufo canorus* (EN) (Stebbins and Cohen 1995). Hundreds of animals were found dead and dying, and many populations simply disappeared. A similar pattern was found with Mountain Yellow-legged Frogs (Stebbins and Cohen 1995), while Western Toads *Bufo boreas* (NT), Foothill Yellow-legged Frogs, and even Long-toed Salamanders *Ambystoma macrodactylum* (LC) also suddenly declined throughout their ranges. On the other hand, Pacific Chorus Frogs *Pseudacris regilla* (LC) remained abundant (Stebbins and Cohen 1995).

The Sierra Nevada became a testing ground for hypotheses that could account for disappearances in remote, seemingly pristine, habitats. One example is the UV-B hypothesis, which states that human-induced climate modification results in increased levels of harmful UV-B that can kill amphibian eggs exposed to direct sunlight. A correlational analysis showed that there was no negative pattern between expected high UV-B dose and disappearance of frogs, but did reveal that frog populations occurring closer to pesticide and fertilizer sources were more likely to have gone extinct than populations in more remote areas (Davidson *et al.* 2001). Disease, in particular chytridiomycosis, is also a factor and responsible for the collapse of amphibian populations in Central and South America (Berger *et al.* 1998; Lips *et al.* 2006), and Australia (Berger *et al.* 1998). This disease was found in collapsing populations of Mountain Yellow-legged Frogs in the Sierra Nevada (Rachowicz *et al.* 2006), although it also appears to be endemic in other amphibian species that have stable populations.

Amphibian declines may be the window into the future of what we can expect as humans continue to alter their environment on a global scale. As we learn more about the mechanisms responsible for declines, we may be able to reverse some of them, though there remain few examples. In the Sierra Nevada, one study has shown that, in the absence of disease, population recovery of threatened frogs is possible (Vredenburg 2004). Trout have been extensively introduced throughout the Sierra Nevada for sport fishing, and more than 90% of the naturally fishless lakes now contain non-native trout. The Mountain Yellow-legged Frog, which is adapted to living in environments without any fish, has declined dramatically (more than 93% of historical populations are now extinct; Vredenburg *et al.* 2007), and while there are several potential causes, removal of introduced trout from entire lakes leads to recovery of local frog populations.

Vance T. Vredenburg, Michelle S. Koo, and David B. Wake

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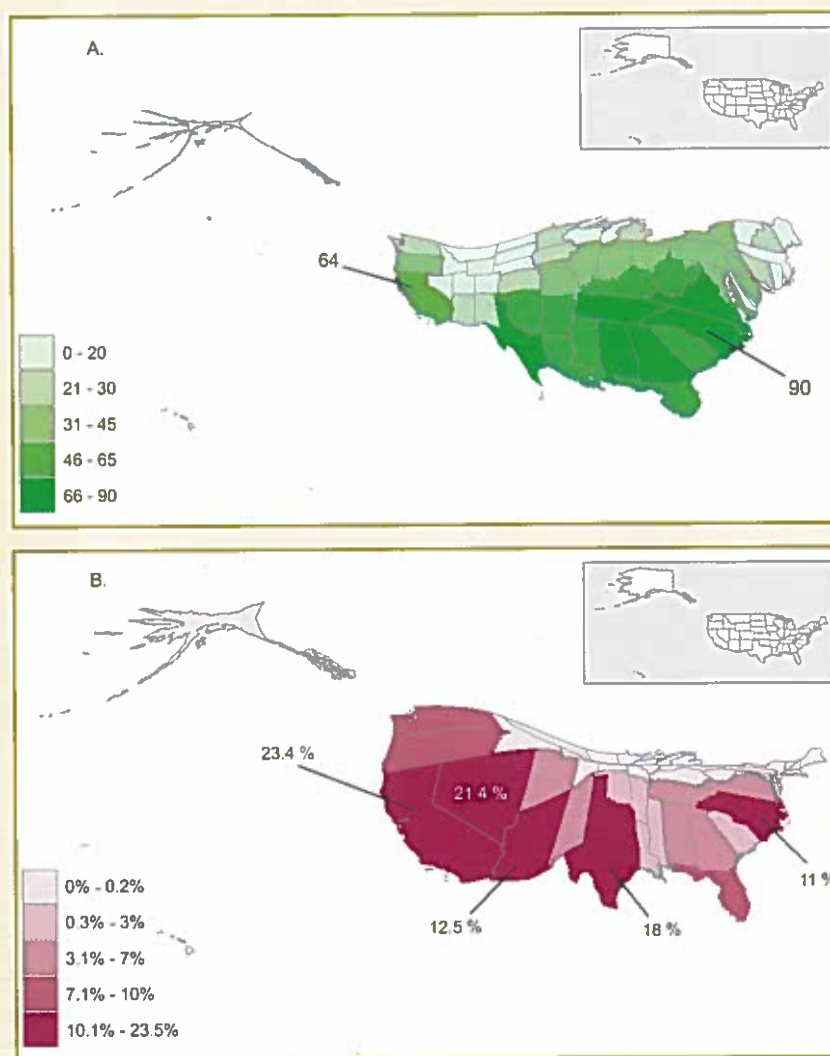


Figure 1. Amphibian species diversity by U.S. state (A), and percent of threatened amphibian species by state (B) visualized using density equalizing cartograms (technique after Gastner and Newman 2004). State size and shape are purposefully distorted in proportion to (in A) the total number of amphibian species, and (B) the percentage of threatened species by state (data sources: A: AmphibiaWeb 2006; B: Stuart *et al.* 2004).

The Mountain Yellow-legged Frog *Rana muscosa* (Critically Endangered) from California and Nevada, USA, has declined by the loss of over 93% of historic populations. This frog is extinct in the state of Nevada, but scattered populations remain in the Sierra Nevada along eastern California and in three mountain tops surrounding Los Angeles (fewer than 200 individuals survive in only eight populations in the southern mountains). Major threats to remaining populations include air pollution, disease and introduced predators (trout).

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