

that chytrid fungus infections may be a recent pathogen to affect the mountain yellow-legged frog, although visual detections of chytrid-like abnormalities may be neither longlasting nor attributable to this fungus (Fellers *et al.* 2001; V. Vredenburg, *in litt.* 2002). Since at least 1976, chytrid fungus has affected adult Yosemite toads (Green and Kagarise Sherman 2001). The Yosemite toad is sympatric with the mountain yellow-legged frog (their ranges overlap). Therefore, it is possible that this pathogen has affected both of these amphibian species since at least the mid-1970s. Chytrid fungus is only a recently detected pathogen in amphibian populations; this may be an emerging infectious disease. How it has been transmitted to the mountain yellow-legged frog is unclear (Briggs *et al.* 2002).

Saprolegnia is a globally distributed fungus that commonly attacks all life stages of fishes (especially hatchery reared fishes), and has recently been documented to attack and kill egg masses of western toads (*Bufo boreas*) (Blaustein *et al.* 1994b). This pathogen may be introduced through fish stocking or it may already be established in the aquatic ecosystem. Fishes and/or migrating or dispersing amphibians may be a vector for this fungus (Blaustein *et al.* 1994b; Kiesecker *et al.* 2001). *Saprolegnia* has not been reported in the mountain yellow-legged frog; however, if hatchery fishes are vectors of this disease, it may have been introduced via fish stocking into historically occupied mountain yellow-legged frog habitat.

No viruses were detected in the specimens of mountain yellow-legged frogs that Fellers *et al.* (2001) analyzed for chytrid fungus. In Kings Canyon National Park, Knapp (pers. comm. 2002) found mountain yellow-legged frogs showing symptoms preliminarily attributed to a ranavirus. Mechanisms for disease transmission, including viruses, to the mountain yellow-legged frog remain unknown. However, Mao *et al.* (1999) isolated identical iridoviruses from wild co-occurring populations of the threespine stickleback (*Gasterosteus aculeatus*) and the red-legged frog (*Rana aurora*), indicating that infection by a given virus is not limited to a single species, and that iridoviruses can infect animals belonging to different taxonomic classes. This suggests that if virus-hosting trout are introduced into mountain yellow-legged frog habitat, they may be a vector of amphibian viruses.

Whether amphibian pathogens in the high Sierra Nevada have always coexisted with amphibian populations

or if their presence is a recent phenomenon is uncertain (Fellers *et al.* 2001). The susceptibility of amphibians to pathogens may have recently increased in response to anthropogenic (human-caused) environmental disruption (Carey 1993; Blaustein *et al.* 1994b; Carey *et al.* 1999). This hypothesis suggests that environmental changes may be indirectly responsible for certain amphibian dieoffs by immune system suppression of larval or postmetamorphic amphibians to the extent that they are not resistant to diseases (Carey 1993; Blaustein *et al.* 1994b; Carey *et al.* 1999). Pathogens such as red-leg disease, which are present in fresh water and in healthy organisms, may erupt, potentially causing localized amphibian population dieoffs when the immune system of individuals within the host population are suppressed (Carey 1993; Carey and Bryant 1995). Wind-borne pesticides from upwind agriculture potentially contribute to contaminant concentrations that may be high enough to compromise amphibian immune systems (Carey 1993; Carey *et al.* 1999; Daszak *et al.* 1999). Recreationists may contribute to the spread of pathogens between water bodies and populations via clothing and fishing equipment. Given the uncertainty surrounding the potential for researchers to contribute to the spread of pathogens, they have begun to implement equipment sterilization procedures between survey sites (H. Eddinger, *in litt.* 2002; R. Knapp, *in litt.* 2002; V. Vredenburg, *in litt.* 2002).

A compounding effect of disease-caused extinctions of mountain yellow-legged frogs is that recolonization may never occur, because streams connecting extirpated sites to extant populations now contain introduced fishes, which act as barriers to frog movement within metapopulations. This isolates the remaining populations of mountain yellow-legged frogs from each other (Bradford 1991; Bradford *et al.* 1993).

In summary, mountain yellow-legged frogs are vulnerable to multiple pathogens, whose effects range from population persistence, with low levels of infection within populations, to extinction of entire populations. Little is understood about these pathogens, making disease difficult to manage without a better understanding of their life histories and modes of transmission. Red-leg disease and chytrid fungus have been identified as having potentially catastrophic effects (localized extinction) on mountain yellow-legged frog populations. Though chytrid fungus was only recently discovered to affect amphibians (including the mountain

yellow-legged frog), chytrid currently appears to have the highest rate of infection relative to other pathogens in mountain yellow-legged frog populations. The negative consequences of chytrid infection to mountain yellow-legged frog populations may be exacerbated by the fragmentation and isolation of remaining mountain yellow-legged frog metapopulations and populations due to non-native fish introductions. This is because there may not be an adjacent mountain yellow-legged frog population with habitat connectivity that is able to recolonize an area following a pathogen-caused extinction event.

D. *The inadequacy of existing regulatory mechanisms.* Existing regulatory mechanisms that could provide some protection for the mountain yellow-legged frog in the Sierra Nevada include: (1) Federal laws and regulations; (2) State laws and regulations; and (3) local land use processes and ordinances. However, these regulatory mechanisms have not prevented non-native fish introductions, pathogen outbreaks, and habitat modifications, all of which result in population declines of mountain yellow-legged frogs in the Sierra Nevada.

Federal

In response to the overgrazing by livestock of the available rangelands from the 1800s to the 1930s and the subsequent years of the Dust Bowl, Congress passed the Taylor Grazing Act in 1934. This was an effort to stop the damage to the remaining public lands from overgrazing and soil depletion, to provide for an order to grazing on public lands, and to attempt to stabilize the livestock industry using these lands (Meehan and Platts 1978; *Public Lands Council et al. v. Babbitt Secretary of the Interior et al.* (167 F. 3d 1287)). Although passage of the Taylor Grazing Act resulted in reduced grazing in some areas, it did not reduce grazing severity, as use remained high, and it did not allow regeneration of many meadow areas (Beesley 1996; Menke *et al.* 1996; *Public Lands Council et al. v. Babbitt Secretary of the Interior et al.* (167 F. 3d 1287)). The Taylor Grazing Act of 1934, as amended, did initiate some grazing reform, possibly lessening impacts of livestock grazing on many species and populations of wild plants and animals, including the mountain yellow-legged frog and its habitat. However, it does not have any provisions specific to the protection of either the mountain yellow-legged frog or its habitat.

The Multiple-Use Sustained-Yield Act of 1960 (MUSY), as amended, provided