# ENDANGERED TOADS IN THE ROCKIES

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The western toad species complex, endemic to western North America, includes two montane species that have undergone extensive declines. These are the Yosemite toad, *Bufo canorus*, in the Sierra Nevada, and the southern Rocky Mountain populations of the boreal toad, *B. boreas*. Most declines in the Rockies appear to have occurred before 1980, but a recent episode in Rocky Mountain National Park illustrates the rapidity and severity with which populations of toads can succumb, and that the phenomenon is still occurring. Causes of these declines, with experimental or observational support, include increasing ultraviolet radiation; disease; and interactions among several factors. However, significant questions about the generality of each of these hypotheses remain to be answered. Regardless of the cause of past and current declines, climate change in the coming decades may create conditions that will challenge the persistence of these species, and others not currently threatened.

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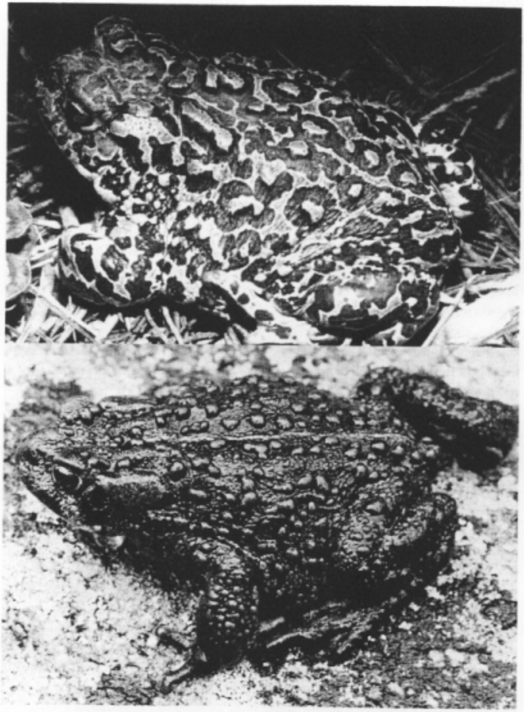
The common species of toads that inhabit the mountains of western North America belong to the western toad species complex, which includes the boreal toad, *Bufo boreas*, and the Yosemite toad, *B. canorus*. Populations of both these species are in serious decline (Corn 2003b; Fellers and Davidson 2003). Boreal toads are listed as endangered by the State of Colorado, and populations in the southern Rocky Mountains (Colorado, New Mexico, southeastern Wyoming) are considered candidates for listing as threatened or endangered by the U.S. Fish and Wildlife Service. In this paper, I will describe these species and their status and discuss causes of declines, and prospects for the future.

The Yosemite toad is endemic to the central Sierra Nevada in California and mainly occurs at wetland sites above 2500 metres in elevation. Although genetically closely related to western toads (Shaffer et al. 2000; Goebel 2003), Yosemite toads are distinct morphologically and behaviourally (Figure 1). Yosemite toads display striking sexual dimorphism in colour pattern (females are more strongly patterned), and males make a distinct advertisement call during breeding (Karlstrom 1962; Fellers and Davidson 2003).

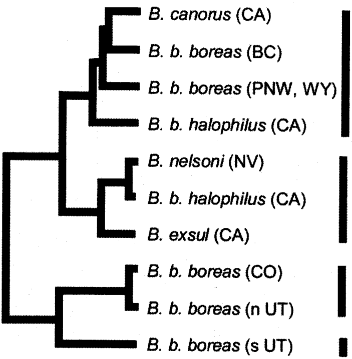
The boreal toad occupies a greater range of elevations within a much larger geographic range than does the Yosemite toad. Boreal toads occur historically from northern New Mexico in the south to the Yukon and Alaska in the north, and from the Pacific coast in the west to the front ranges of the Rocky Mountains in the east. They breed in a variety of habitats, from small, ephemeral wetlands to large lakes. Adults, particularly females, may wander over distances of several kilometres in the surrounding forest. These toads likely comprise a complex of two or more species (Figure 2). Boreal toads in the southern Rocky Mountains — in New Mexico, Colorado, Utah, southeastern Wyoming and southeastern Idaho — are genetically distinct and geographically isolated from boreal toads that occur to the north and northwest (Goebel 2003). Like the Yosemite toad, the southern boreal toads are restricted to mountain habitats, occurring mainly above elevations of 2500 metres (Hammerson 1999). Male toads in the southern Rocky Mountains do not have an advertisement call, and there is little variation in colour or pattern between sexes. Toads north and west of Colorado and Utah also usually lack a breeding call.

Figure 1. Top: female Yosemite toad from Alpine County, California (photo by Joyce Gross). Bottom: female boreal toad from Rocky Mountain National Park, Colorado (photo by Stephen Corn).



However, populations occur both in the mountains and in the valleys between mountain ranges, and there is considerably more colour variation than is expressed in the southern Rocky Mountains. Female toads, particularly from high elevations in Glacier National Park, Montana, may have dorsal patterns similar to those of Yosemite toads, and male toads display a dorsal colour polymorphism that includes a green ground colour in addition to the usual brown or brownish-black morph.

**Figure 2. Phylogeny of the *Bufo boreas* complex, based on mitochondrial DNA variation (Goebel 1996)** Solid bars on the right identify major clades. States or provinces from which samples were drawn are in parentheses (PNW includes samples from northwestern Wyoming, Idaho, Montana, Oregon, Washington and British Columbia).




## Status of Mountain Toads

Many species of amphibians throughout the world are in decline, and the phenomenon is now accepted by most biologists as a serious problem and not as a function of normal population dynamics (Alford and Richards 1999; Corn 2000). The problem is acute in the western United States and continues to deteriorate. More than half (7 of 13) of the amphibian species listed by the U.S. Fish and Wildlife Service as threatened or endangered have been listed since 1990 (Corn 2003b). Frogs of the genus *Rana* are in especially bad shape. Bradford (in press) summarized information from species accounts in Lannoo (in press) and concluded that *all* ranid frogs in the West were either "adversely affected" or in "major decline". Several species of western *Bufo* have also suffered significant declines, including the Yosemite and boreal toads.

Davidson et al. (2002) failed to find Yosemite toads at 29 (52%) of 55 known locations, and abundance appears to be low where toads do persist. Bradford and Gordon (1992) found this species present at only seven per cent of sites within 30 randomly selected study areas. Yosemite toads studied by Kagarise Sherman and Morton (1993) declined in abundance at seven sites in the central Sierra Nevada, including a ninefold decline in numbers of males from 1971 to 1982 and then to extreme rarity by 1991 at their main study area at Tioga Pass Meadow. Surveys between 1992 and 1998 found toads present at 122 sites, but 88 of these observations were of one or two adult toads, and adult populations were estimated to be larger than 25 individuals at only four sites (Fellers and Davidson, in press).

Declines of boreal toads are especially severe in the southern Rocky Mountain population. Examples include absence from more than 80 per cent of known localities in northern Colorado and southern Wyoming, extinction of 11 populations in central Colorado, extinction in New Mexico, and declines in Utah (Corn et al. 1989; Carey 1993; Stuart and Painter 1994; Ross et al. 1995). As with Yosemite toads, most of the remaining populations are small. The few remaining large populations are in trouble as well. Two relatively large populations made up the bulk of a metapopulation of boreal toads along the North Fork of the Big Thompson River in Rocky Mountain National Park, Colorado. However, the metapopulation crashed from an estimated 500 to 800 adult males in 1994 and 1995 to near-extinction in 2001 (Muths et al. 2003).

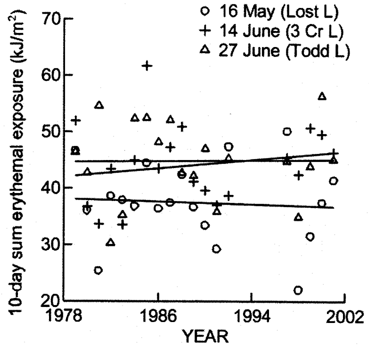
In the northwest clade of boreal toads, recent surveys in Montana and northwestern Wyoming find evidence of breeding at less than five per cent of all wetland sites (unpublished data). Boreal toads are apparently rare at lower elevations, particularly in the Puget Sound lowlands of Washington (Richter and Azous 1995; Adams et al. 1998, 1999). Olson (1992) described declines in abundance of adult toads, and Blaustein et al. (1994b) described mortality of several million eggs at sites in the central Cascades in Oregon. However, Olson (2001) reported that, by 2000, numbers of toads in these populations had recovered to abundances observed in the early 1980s. Boreal toads also apparently recovered rapidly from the 1980 eruption of Mount St. Helens, in southern Washington, where they are now abundant within the blast zone (Crisafulli and Hawkins 1998).

## Causes of Declines

Declines of Yosemite and boreal toads have occurred in relatively undisturbed landscapes such as national parks and wilderness areas, and there are few anthropogenic influences that can be reasonably suspected of causing the declines. Davidson et al. (in press) compared the occurrence of California amphibians to potential stressors, and there were significant associations between absence of several species, particularly ranid frogs, and agricultural and urban influences. Absence of Yosemite toads showed the same trend with respect to amount of agriculture upwind, but there were no significant associations with any potential stressor. Acid precipitation was considered and rejected as a cause of amphibian declines in both the Rocky Mountains (Corn and Vertucci 1992; Vertucci and Corn 1996) and the Sierra Nevada (Bradford et al. 1994). Predation on breeding adult toads, especially by common ravens (*Corvus corax*), can potentially have serious effects on local populations, but this is unlikely to have caused the widespread declines that have been observed.

Increasing ultraviolet-b radiation (UV-B) resulting from stratospheric ozone depletion has received considerable attention as a possible cause of declines of boreal toads since Blaustein et al. (1994a) showed that ambient UV-B caused mortality of boreal toad embryos in Oregon. Corn (1998) did not observe mortality related to UV-B in experiments with boreal toads conducted in Rocky Mountain National Park, but differences between the Oregon and Colorado studies might reflect differences in experimental design or genetic differences between the different clades of toads. However, a more fundamental question needs to be answered. Even if ambient UV-B increases mortality of toad embryos, this may be an ordinary occurrence. Exposure to UV-B must have increased if UV-B has caused recent declines. However, on the average dates of toad breeding at three sites in Oregon (Blaustein et al. 2001), satellite-based estimates of UV-B at the earth's surface (Middleton et al. 2001; Corn and Muths 2002) show no increase from 1979 to 2001 (Figure 3).

**Figure 3. Estimated UV-B exposure (see Corn and Muths 2002) during the average date of the beginning of breeding by boreal toads at three lakes in the Cascades of central Oregon (data from Blaustein et al. 2001; see Corn 2003a)** None of the regressions of UV-B on year are significant.




A pathogenic chytrid fungus (*Batrachochytrium dendrobatidis*) associated with amphibian declines (Berger et al. 1998; Daszak et al. 1999; Longcore et al. 1999) has also been detected in Yosemite and boreal toads. Green and Kagarise Sherman (2001) describe chytrid infection in preserved

Yosemite toads that died at Tioga Pass Meadow from 1976 to 1979, just before the population crashed in the early 1980s. Muths et al. (2003) also detected chytrids in boreal toads that died from 1998 to 2000 during the collapse of the North Fork metapopulation in Rocky Mountain National Park. Chytrid infection is also now thought to be the primary cause of the decline and near extinction of the endangered Wyoming toad (*B. baxteri*), a species endemic to the Laramie Basin in southeastern Wyoming (Corn 2003b; Muths et al. 2003). These observations do not constitute proof that chytrids have caused the declines of Yosemite and boreal toads. A cause-and-effect relationship between the fungus and the decline has not been demonstrated in any of the cases. However, the observations are suggestive and allow the hypothesis that chytrid infections may be at least the proximate cause of these declines.

Declines of toads may not be due to single factors. Kiesecker et al. (2001) reported that boreal toad embryos develop in shallower water and suffer greater mortality in years with low winter precipitation, compared to in wetter years, when embryos develop in deeper water. Dry winters in the Pacific Northwest are associated with strong El Niño Southern Oscillation (ENSO). Embryo mortality, caused by the pathogenic fungus *Saprolegnia ferax*, occurs only in the presence of UV-B (Kiesecker and Blaustein 1995), but this relationship is dependent on depth, with no significant mortality due to UV-B below 10 centimetres (Kiesecker et al. 2001). These observations suggest the hypothesis that, in ENSO years, boreal toad embryos develop in shallower water, are exposed to higher doses of UV-B and consequently suffer catastrophic mortality from *Saprolegnia* infection, which if a frequent occurrence might cause a decline in abundance of adult toads (Kiesecker et al. 2001; Blaustein and Kiesecker 2002). However, UV-B dose in aquatic environments is not simply a function of water depth. The concentration of dissolved organic carbon (DOC) strongly controls the depth to which UV-B can penetrate, and the majority of amphibian breeding sites have DOC concentrations that prevent the UV-B dose observed by Kiesecker et al. (2001) to cause mortality of boreal toad embryos (Diamond et al. 2002; Palen et al. 2002). UV-B dose is also temporally variable. For mountain amphibians, dry winters are related to earlier breeding, because the timing of snowmelt is the main influence on breeding phenology. However, earlier breeding results in lower exposure to UV-B (Corn and Muths 2002), counteracting at least some of the increased UV-B dose attributed to shallower water.

## Prospects for Mountain Toads

Is it possible to draw conclusions about the cause of the declines of Yosemite and boreal toads? Blaustein and Kiesecker (2002) proposed that amphibian declines result from complex synergistic interactions among numerous biotic and abiotic factors, and cited as an example the scenario proposed by Kiesecker et al. (2001). Yet the preceding paragraph suggests reasons to question the generality of this scenario, and even if it applies, the boreal toad populations in the central Cascades apparently are not declining (Olson 2001).

If disease is the cause of declines of Yosemite and boreal toads, the question of whether the chytrid fungus represents a novel pathogen (Daszak et al. 1999) or interacts with cofactors (Blaustein and Kiesecker 2002) or is both novel and a cofactor, is important to predicting the persistence of toad populations and devising management plans to recover species. Carey (1993) hypothesized that an environmental stress suppressed immune system function in boreal toads, allowing disease to kill toads, and ultimately causing the population declines in the 1970s in central Colorado. If this is the case, then similar stresses should be acting on boreal toads, Yosemite toads and also Wyoming toads, which declined during the same period as the other two species (Corn 2003b). However, not only does this stress need to affect a large geographic area, with the inclusion of Wyoming toads, it also needs to have similar effects on species with different behaviour, habitat, and life history. The alternative hypothesis, that the chytrid fungus is a novel pathogen that infected populations of all three species at about the same time, is challenged by geography. No realistic mechanism has been proposed for how a novel pathogen could infect toads more or less simultaneously in the Rocky Mountains and the Sierra Nevada.

Regardless of the cause of the declines of Yosemite and boreal toads, the future is uncertain for both species. Climate change is predicted to have severe effects on the toads' environments, including reduced extent and duration of mountain snowpack (MacCracken et al. 2001) and increasing frequency of ENSO events (Timmerman 1999). In the Pacific Northwest, Cayan et al. (2001) have documented changes in plant phenology and stream flow during the past 30 years consistent with warmer spring temperatures and reduced winter precipitation. Boreal toads in the Cascades in Oregon may be breeding earlier in some populations in response to these conditions (Corn 2003a). Breeding earlier may result in more frequent exposure to lethal temperatures or may increase the likelihood that the scenario described by Kiesecker et al. (2001) may apply. Few of the effects of climate change are likely to be beneficial to toads.

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