Long-Term Observations of Boreal Toads at an ARMI Apex Site

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Abstract

The U.S. Geological Survey's Amphibian Research and Monitoring Initiative (ARMI) is a national project with goals to monitor the status and trends of amphibians, conduct research on causes of declines, and provide information and support to management agencies for conservation of amphibian populations. ARMI activities are organized around extensive inventories and place-based monitoring (such as collaboration with the Greater Yellowstone Inventory and Monitoring Network), and intensive population studies and research at selected locations (apex sites). One such site is an oxbow pond on the Buffalo Fork near the Black Rock Ranger Station east of Grand Teton National Park. We have been conducting mark-recapture of boreal toads (*Anaxyrus boreas*) at Black Rock since 2002. In concert with studies of other toad populations in the Rocky Mountains, we have documented a high rate of incidence of the chytrid fungus *Batrachochytrium dendrobatidis* (Bd) and a negative rate of growth of the toad population, but not the population crash or extinction observed in other populations with high prevalence of Bd. Long-term observations at other ARMI apex sites have proven invaluable for studying effects of climate change on amphibian behavior, and the Black Rock site has been upgraded with onsite recording of weather data and auditory monitoring of other amphibian species. Continued research at Black Rock will be critical for understanding the interrelated effects of climate and disease on amphibians in the Greater Yellowstone Ecosystem.

The ARMI Effort

The Amphibian Research and Monitoring Initiative (ARMI) of the U.S. Geological Survey (USGS) is a national effort to document status and trends of amphibian populations on federal (mainly Department of Interior) lands, conduct research into causes of amphibian declines and malformations, encourage partnerships to expand the scope of monitoring efforts, and provide information that will assist land managers in protecting amphibian populations (Corn et al. 2005a). Monitoring and research is conducted by ARMI in a hierarchical manner, conceptualized as a pyramid, with relatively less effort at relatively more sites (for example, inventory work) forming the base, greater effort at a restricted number of sites in the middle (for example, monitoring occupancy in a defined area of inference such as a national park), and intensive effort at a few sites at the apex of the pyramid (Corn et al. 2005a).

ARMI in the Rocky Mountain Region. Nationally, ARMI is divided into seven regions, and USGS research zoologists Steve Corn and Erin Muths are the principal investigators in the Rocky Mountain Region (Montana, Wyoming, Colorado, and New Mexico). At the middle level of the ARMI pyramid, amphibian populations are monitored in the national parks on the Continental Divide: Glacier, Yellowstone, Grand Teton, and Rocky Mountain National Parks (Corn et al. 2005b). ARMI partners with the National Park Service Greater Yellowstone Inventory and Monitoring Network (GRYN) to conduct monitoring in Yellowstone and Grand Teton National Parks, where amphibians are considered one of GRYN's vital signs. Analysis of trends in amphibian populations is accomplished by examining the change in occupancy by each species in small drainages (catchments). Each catchment encompasses several individual wetlands that are searched for evidence that breeding has occurred. Multiple visits are conducted so that detection probabilities can be estimated to account for the possibility that a species could have bred at a site but been missed by the surveys (MacKenzie et al. 2006).

Middle-level occupancy monitoring targets all the amphibian species that occur in the study area, but monitoring at apex sites is usually focused on a single species and

Figure 1. West arm of the Black Rock apex monitoring site. Photo by Steve Corn, U.S. Geological Survey.

often employs intensive capture-recapture methods to estimate demographic parameters, including population size and survival. Research often addresses the environmental influences that affect populations. The ARMI Rocky Mountain Region conducts apex studies at several locations in Montana, Wyoming, and Colorado. For example, populations of boreal chorus frogs (*Pseudacris maculata*) near Cameron Pass in northern Colorado have been studied since 1986, making this one of the longest continuous amphibian studies in the world. Data from this site have contributed to our understanding of how exposure of amphibian embryos to ultraviolet radiation varies from year to year, driven by the dependence of breeding phenology on mountain snowpack (Corn and Muths 2002). At another apex site, ARMI has supported studies by two University of Montana graduate students on a population of Columbia spotted frogs (*Rana luteiventris*) occupying a high-elevation fishless basin in the Bitterroot Mountains. Frogs have been marked since 2000, and annual survival of post-metamorphic life stages is higher in years with smaller snowpacks (McCaffery and Maxell 2010). Such results are important in predicting responses of amphibian populations to climate change.

The Black Rock ARMI Apex Site. In the Greater Yellowstone Ecosystem, ARMI maintains an apex site east of Grand Teton National Park at an old oxbow of the Buffalo Fork near Bridger-Teton National Forest's Black Rock Ranger Station (Figure 1). This site, which we name Black Rock, supports breeding populations of four of the five amphibian species known to have occurred in the Jackson Hole area (Figure 2). Only the northern leopard frog (*Lithobates pipiens*), which has likely been extirpated from the area, is missing (and we have no evidence that this species ever occurred at Black Rock). The boreal toad is the primary species monitored at Black Rock. Studies began in 2003 after two of the authors (EM and DSP) received a grant from ARMI to examine the distribution of the amphibian chytrid fungus (*Batrachochytrium dendrobatidis* [Bd]) in the Rocky Mountains and its effects on the population dynamics of boreal toads. Adult toads are sampled on several occasions during the breeding season in May or June each year, and individuals are identified by their passive integrated transponder (PIT) tag that is inserted under the dorsal skin upon first capture. Some toads are sampled for Bd by running a cotton swab over the ventral skin. Swabs are submitted to a laboratory for detection of Bd DNA using polymerase chain reaction (PCR) analysis.

Amphibians are in decline worldwide and Bd is considered a leading cause (Collins and Crump 2009). Bd is suspected as the primary cause of the collapse of boreal toad populations in the southern Rocky Mountains, including the crash to near extinction of toads in Rocky Mountain National Park in the mid-1990s (Muths et al. 2003). The first component of the ARMI study documented that Bd is common throughout the Rocky Mountains, including at Black Rock. Muths et al. (2008) detected Bd at 64 percent of 97 study sites (clusters of wetlands within 3 km of one another) and in 23 percent of 1,151 boreal toads sampled. Despite the high prevalence of Bd, toad populations in the northern Rocky Mountains did not seem to be undergoing the sudden and steep declines seen in Colorado.

In the second component of the ARMI study, Pilliod et al. (2010) addressed the population-level effects of Bd infection by comparing demographic parameters at two sites with Bd present (Black Rock and Lost Trail National Wildlife Refuge, Montana) to a site free of Bd (Denny Creek, in the Sawatch Range, San Isabel National Forest, central Colorado). This study found high annual survival

(0.73–0.77) of adult toads that were not infected with Bd at all three locations, but at Black Rock and Lost Trail, toads that tested positive for presence of Bd had lower survival (0.42 and 0.53, respectively). As a consequence, the population at Denny Creek was stable, but numbers of adult toads at Black Rock and Lost Trail were declining 5–7 percent per year.

Black Rock has served as a site for related studies. One of the authors (PSC), with Sophie St.-Hilaire and Peter Murphy from Idaho State University, obtained research grants in 2006 and 2008 through the USGS Park Oriented Biological Support (POBS) program to document Bd in and around Grand Teton National Park and study the apparent differences in the consequences of Bd infection between toads in the northern and southern Rocky Mountains. Murphy et al. (2009) found Bd present at all 10 boreal toad breeding sites sampled, with a mean prevalence of 64.5 percent. In the laboratory, Bd isolated from toads collected at Black Rock killed toads as effectively as Bd isolated from Colorado, but recently metamorphosed toads from Black Rock survived longer than toadlets from Colorado. Papers describing the results of the second POBS study, involving field and laboratory data on behavioral characteristics of toads from Black Rock and Colorado that might affect the outcome of Bd infection, are currently in preparation. This study included radio telemetry of adult toads at Black Rock in 2008.

We intend to continue data collection at Black Rock for the foreseeable future, with several enhancements. We began using an automated recording system in 2009 to document breeding activity by boreal chorus frogs and Columbia spotted frogs. Because temperature is impli-

Figure 2. Amphibians that breed at Black Rock. Clockwise from upper left: boreal toad (*Anaxyrus boreas*), barred tiger salamander (*Ambystoma mavortium*), Columbia spotted frog (*Rana luteiventris*), and the boreal chorus frog (*Pseudacris maculata*). Photos by Steve Corn, U.S. Geological Survey.

cated in the presence and expression of Bd (Muths et al. 2008; Pilliod et al. 2010), we installed a weather station in 2009 to provide more precise climatic data. In 2010, we began marking both boreal toads and boreal chorus frogs at a newly constructed pond 400 m west of the oxbow. Finally, we have begun using quantitative PCR analysis of the Bd samples, which provides an estimate of zoospore density, rather than qualitative analysis, which provides a categorical assessment of the degree of infection. These additional data may prove useful, because population-level effects of Bd infection may be related to the severity of infection of individual animals (Briggs et al. 2010). The data collected at Black Rock already have proven extremely valuable to the study of amphibian populations in the Rocky Mountains. Because lengthy time series of amphibian population data are relatively rare, the longer we collect these data, the greater the contribution is likely to be.

We would like to thank the Buffalo Fork Ranger District of the Bridger-Teton National Forest for permissions and logistical support, Rick Scherer for population analyses, and Deb Patla, Blake Hossack, Sophie St.-Hilaire, Peter Murphy, and Chuck Peterson for observations, data on Bd, and assistance with fieldwork. Research has been conducted under Wyoming Game and Fish Department Chapter 33 Permit and Research Permits from Yellowstone and Grand Teton National Parks. This is contribution 368 of the U.S. Geological Survey Amphibian Research and Monitoring Initiative.

Suggested Citation

Corn, P. S., E. Muths, and D. S. Pilliod. 2011. Long-Term Observations of Boreal Toads at an ARMI Apex Site. In *Questioning Greater Yellowstone's Future: Climate, Land Use, and Invasive Species. Proceedings of the 10th Biennial Scientific Conference on the Greater Yellowstone Ecosystem.* October 11–13, 2010, Mammoth Hot Springs Hotel, Yellowstone National Park. C. Andersen ed., 101–104. Yellowstone National Park, WY, and Laramie, WY: Yellowstone Center for Resources and University of Wyoming William D. Ruckelshaus Institute of Environment and Natural Resources.

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