

Return of the Tarahumara Frog to Arizona

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Abstract—The last wild Tarahumara frog (*Rana tarahumarae*) in Arizona was found dead in Big Casa Blanca Canyon, Santa Rita Mountains, in May 1983. However, the species is still well represented in the majority of its range in the northern Sierra Madre Occidental and adjacent Sky Islands of Sonora and Chihuahua. Plans to re-establish *R. tarahumarae* in Arizona were initiated in 1992 and have been coordinated by the Tarahumara Frog Conservation Team. Initial experimental releases of Tarahumara frogs to Big Casa Blanca Canyon, Santa Cruz County, Arizona, are tentatively scheduled for June 2004. If successful there, releases of *R. tarahumarae* would also be considered at Sycamore Canyon and other historical Arizona localities.

Introduction

The Tarahumara frog (*Rana tarahumarae*) is a medium-sized, drab green-brown frog with small brown to black spots on the body and dark crossbars on the legs (figure 1). The species is known from 63 localities in montane canyons in extreme southern Arizona south to northern Sinaloa and southwestern Chihuahua, Mexico (Rorabaugh and Hale, in press; see figure 1 in Hale et al., this proceedings). Its habitat is located within oak and pine-oak woodland and the Pacific coast tropical area (foothills thornscrub and tropical deciduous forest; Hale et al. 1995, McCranie and Wilson 1987), where it breeds in permanent springs and “plunge pools” in bedrock or among boulders, often with deep underwater and streamside retreats. Similar to the plight of leopard frogs in the Southwestern United States, *R. tarahumarae* has declined or disappeared from portions of its range, including all localities in Arizona. Herein we detail the decline of the *R. tarahumarae* and initial efforts to re-establish the species in Arizona.

Discovery, Decline, and Disappearance From Arizona

In 1931, G. W. Harvey showed Berry Campbell “Mexican frogs” or *R. tarahumarae* in a series of pot holes and a “tumbled-in mine that had filled with water” in Alamo Canyon in the Pajarito Mountains, Santa Cruz County, Arizona. That same year Campbell published this first United States record of *R. tarahumarae* in Copeia (Campbell 1931; Wright and Wright 1949). The frog was subsequently discovered at two more locations in the Pajarito Mountains, including Peña Blanca

Springs in 1933 (Campbell 1934) and Sycamore Canyon in 1938. Williams (1960) reported 1948 collections from Tinaja Canyon in the Tumacacori Mountains, and then in 1972 the range of the species in Arizona was extended to the Santa Rita Mountains where it was found in Big Casa Blanca, Gardner, Adobe, and Walker canyons (Hale et al. 1977).

Fifty-two years after their discovery in Alamo Canyon, a wild *R. tarahumarae* was observed for the last time in Arizona when a large female frog was found dead in Big Casa Blanca Canyon by Stephen Hale and Jim Jarchow on May 28, 1983. Hale and his colleagues investigated the status and ecology of all *R. tarahumarae* localities in Arizona from 1966-1992, the results of which were detailed in Hale et al. (1977, 1995) and unpublished reports to the Arizona Game and Fish Department (AGFD) or U.S. Fish and Wildlife Service (FWS) in 1983, 1988, and 1992. The first indication of decline was on April 7, 1974, when Clay May and Darrell Frost observed 19 dead *R. tarahumarae* in Sycamore Canyon below Yanks Spring. Several live but lethargic *R. tarahumarae* were also observed, and the skin on top of the head of some individuals was dry. Two live leopard frogs (*Rana yavapaiensis* or *R. chiricahuensis*) showed no escape movements. However, when Stephen Hale visited the canyon in August, frogs were abundant and appeared healthy. Although leopard frogs have persisted in Sycamore Canyon, that was the last time *R. tarahumarae* were observed there (Hale et al. 1995).

A similar pattern of decline and then extirpation occurred in the Santa Rita Mountains from 1977-1983. In October 1977 a very strong tropical storm drenched the area, dropping 194 mm of rainfall on Patagonia from October 6-9. Big Casa Blanca and adjacent canyons were scoured and littered with debris. When Big Casa Blanca Canyon was surveyed in the spring of



Figure 1—Tarahumara frog at the Kofa National Wildlife Refuge semi-captive holding and propagation facility.

1978, no juvenile frogs from the 1977 cohort were found, and it was thought that many frogs had been flushed downstream or drowned. However, many tadpoles survived the flood and metamorphosed frogs were observed in 1978 and 1979. Yet in July 1980 no tadpoles or metamorphosed frogs were found. From that time until the last frog was observed in May 1983, only one or two frogs and no tadpoles were observed during visits to the canyon. No *R. tarahumarae* were observed in the limited habitat of Adobe Canyon after August 1974, nor in Gardner Canyon after 1977. Leopard frogs declined and disappeared from these same areas during 1977-1978, although they persist to this day at lower elevations in Gardner and adjacent canyons to the north. A visit to Tinaja Canyon in 1980 revealed limited habitat and no Tarahumara frogs, and from 1980 to the present we have not found *R. tarahumarae* at Peña Blanca Springs or Alamo Canyon.

Evidence From Sonora

From 1981-2000, Hale and his colleagues investigated the distribution and status of *R. tarahumarae* populations in Sonora. Visits were made to numerous historical localities and apparently suitable habitats through 2000 to search for frogs. *Rana tarahumarae* were found at 23 sites from the Sierra San Luis and Sierra de la Madera in northern Sonora to the Sierra el Rincón and Sierra Milpillas east of Alamos in southern Sonora. *R. tarahumarae* were not found at 8 sites where they had been recorded or collected in the past. From 1981-1986, Hale and his colleagues observed population declines in progress in the lower reach of Arroyo La Carabina (La Bota) in the Sierra el Tigre (Hale et al. 1995; also see Hale et al., this proceedings). No frogs were found in this lower reach in 1998.

Causes of Decline

Likely causes of decline include chytridiomycosis, a fungal disease; airborne pollutants from copper smelters; predation by non-native organisms; flooding; habitat alteration; drought; and winter cold (Hale et al. 1995; Hale et al., this proceedings;

Rorabaugh and Hale, in press). Habitat degradation at Arroyo El Cobre, Sierra el Rincón, in southern Sonora following clearing and planting of buffelgrass (*Pennisetum ciliare*) on the slopes above the canyon and subsequent erosion and sedimentation in the canyon bottom appear to have favored the pustulose frog (*R. pustulosa*). No frogs identified as *R. tarahumarae* have been found there since 1993. Predation by *R. catesbeiana* at Peña Blanca Springs and by chubs (*Gila* sp.) at one site in southern Sonora likely contributed to disappearance of *R. tarahumarae* from those sites. Flooding in 1977 at Big Casa Blanca Canyon probably contributed to the extirpation of *R. tarahumarae* from that canyon, and recent drought was probably a factor in some declines in Sonora. However, frogs in natural habitats should be able to survive periodic flooding or drought, suggesting additional causal factors may have been important.

Stephen Hale, Jim Jarchow, and others (1995) provided evidence that die-offs at Sycamore Canyon and Arroyo La Carabina may have been caused by cadmium toxicity resulting from airborne pollutants from copper smelters in northern Sonora and Arizona. However, in retrospect, symptoms during these die-offs were consistent with what is now known to be chytridiomycosis, a disease that is affecting frog and toad populations around the globe (Carey et al. 2003). *Rana tarahumarae* collected during a die-off in Sycamore Canyon in 1974 were infected with chytridiomycosis (T. R. Jones and P. J. Fernandez, personal communication), and histology of Chiricahua leopard frogs collected in Sycamore Canyon as recently as 2003 confirm frogs are still infected with chytrids. Chytridiomycosis has not been documented in Big Casa Blanca Canyon; however, *R. tarahumarae* captured in 1977 showed symptoms similar to those exhibited by frogs in Sycamore Canyon in 1974. As a result, although flooding was an apparently important cause of decline, we cannot rule out the possibility that chytridiomycosis contributed to the extirpation of *R. tarahumarae* from Big Casa Blanca and adjacent canyons in the Santa Rita Mountains. Chytridiomycosis was confirmed from *R. tarahumarae* collected at several sites in Sonora from 1982-1999, including Arroyo La Carabina, but frogs have persisted with the disease at most of these sites (see Hale et al., this proceedings). Although chytridiomycosis has been present at some sites of decline or extirpation, airborne pollutants from copper smelters could still have contributed to declines of *R. tarahumarae*, as hypothesized by Hale et al. (1995). Stress associated with cadmium toxicity could compromise immune function and make frogs more susceptible to chytridiomycosis (Carey et al. 1999; Rollins-Smith et al. 2002). *Rana tarahumarae* may be particularly affected by disease or toxicants during winter at colder sites (see Hale et al., this proceedings). If copper smelters contributed to declines in the past, they are probably no longer a factor, as they have either closed (Douglas and Cananea) or are now equipped with pollution control scrubbers (Nacozari).

Tarahumara Frog Conservation Team 1992-1998

A group of biologists and land managers first met in June 1992 to develop a plan to re-establish *R. tarahumarae* into

Arizona. That group, which became the Tarahumara Frog Conservation Team (TFCT), began to outline a re-establishment and monitoring program under the AGFD's 12 step "Procedures for Nongame Wildlife and Endangered Species Re-establishment Projects," a required process to re-establish the frog in Arizona. A proposal abstract, step 3 of the procedures, was drafted in 1993, and a "Conservation Plan for the Tarahumara Frog" was produced in 1995 by the TFCT as a more detailed re-establishment plan that could potentially meet the requirements for a proposal to AGFD as step 8 of the procedures.

The TFCT suffered from a lack of dedicated funding until 1998 when Stephen Hale received a small grant from the Arizona Zoological Society to evaluate the status of the frog and potential source populations for re-establishment at five sites in northern Sonora. Arroyo el Tigre, Sierra el Tigre, was identified as the best source population for a re-establishment program. Also in 1998, FWS obtained a Department of the Interior Border XXI grant to re-establish the *R. tarahumarae* into Arizona. These funds were distributed to Stephen Hale and the Instituto del Medio Ambiente y El Desarrollo Sustentable de Estado de Sonora (IMADES—Eduardo López Saavedra and Andrés Villareal) for additional status surveys in Sonora and collection and transport of *R. tarahumarae* to Arizona for captive propagation. AGFD was also funded out of the grant to complete the 12-step procedures and to begin re-establishment and monitoring of frogs. Additional FWS funds were transferred to the Arizona-Sonora Desert Museum (ASDM) to cost-share development of rearing and captive propagation facilities.

Collection, Rearing, and Propagation of Tarahumara Frogs for Re-establishment, 1999-2004

Four *R. tarahumarae* frogs and 30 small tadpoles were collected from Arroyo el Tigre during October 25-27, 1999, for rearing and captive propagation at the ASDM. One of the frogs died on 27 October, and the other three succumbed soon thereafter. Frogs from this canyon were later confirmed to be positive for chytridiomycosis, and stress associated with their capture and transport may have pre-disposed them to chytridiomycosis. The tadpoles did well initially, but growth slowed and eventually stopped after 8 weeks in captivity. At that point, mortalities began and continued for 4 weeks until the last tadpole died.

In 2000, a new population was found at Arroyo el Chorro, Sierra de la Madera, southeast of Imuris. This is the nearest-known population of *R. tarahumarae* to Arizona (approximately 72 km south of the border). On May 1, 2000, about one-third of an egg mass was collected and transported to the FWS office in Phoenix for initial rearing. The partial egg mass contained an estimated 850-900 eggs, which hatched in 8 days (Rorabaugh and Humphrey 2002). The tadpoles grew rapidly and were eventually transferred to captive facilities at the ASDM and San Bernardino National Wildlife Refuge

(NWR), and semi-captive, contained facilities at Coronado National Memorial, Arizona State University, a backyard pond in Tucson, and at Kofa and Buenos Aires NWRs (figure 1). Metamorphosis occurred in as little as 86 days, but most tadpoles did not metamorphose until the spring or summer of 2001. In 2001-2002, 25 *R. tarahumarae* were reared by the Detroit Zoo's National Amphibian Conservation Center. Ivanyi and Poulin (appendix 2 of Sredl et al. 2003) prepared a *R. tarahumarae* husbandry protocol that details outdoor and indoor rearing and propagation facilities, recommended animal densities, and tadpole and frog diets.

The frogs matured and bred under a variety of conditions at the San Bernardino and Kofa NWRs and the ASDM in 2001-2004. By May 2004, approximately 70-90 mostly adult frogs and many hundreds of late stage tadpoles were available for release in Arizona.

Completion of the 12 Step Procedures and Other Environmental Compliance and Coordination

AGFD revised the 1995 TFCT re-establishment proposal (Sredl et al. 2004), which became steps 8-11 in the 12-step Procedures for Nongame Wildlife and Endangered Species Re-establishment Projects. The proposal outlines a 10-year program that includes releases of frogs to Big Casa Blanca Canyon, followed by monitoring of the release site and adjacent canyons. If frogs become established at Big Casa Blanca Canyon, then releases to Sycamore Canyon and potentially other historical localities could be considered. Big Casa Blanca and Sycamore canyons were the stronghold of the species in Arizona historically. Of the two, Big Casa Blanca Canyon is considered optimal due to apparently intact habitat, absence of non-native predators, and no confirmation of chytridiomycosis. If *R. tarahumarae* thrive in Big Casa Blanca Canyon, they would likely disperse to Gardner, Adobe, and Walker Canyons where the species occurred historically. Chytrids are present in Sycamore Canyon, and *R. catesbeiana* have been found recently in the canyon near Ruby Road. As a result, re-establishment may be more difficult in that canyon. Protocols are described in the proposal to ensure that diseased frogs are not released, and frogs would be marked with an individual or cohort mark for identification. The 12-step process was completed in May 2004.

Endangered Species Act compliance, in the form of a formal intra-service FWS section 7 consultation to evaluate the effects of the proposed re-establishment on threatened and endangered species and critical habitat in the release areas, was completed in November 2003. A FWS Environmental Assessment (EA) and Finding and No Significant Impact were finalized and signed in March 2004. Both the draft re-establishment proposal and draft EA were made available for public comment; the final documents were revised in response to those comments. A coordination meeting was held among AGFD, FWS, Nogales Ranger District of the Coronado National Forest, and

livestock grazing permittees in the vicinity of Big Casa Blanca and Sycamore Canyons in April 2003 to brief ranchers on the proposal and seek their input.

Initial Releases and Monitoring

Initial releases to Big Casa Blanca Canyon are tentatively scheduled for June 2004. We are hopeful that our efforts to re-establish *R. tarahumarae* into Arizona will be successful. However, the causes of decline and extirpation of *R. tarahumarae* in Arizona are not fully understood. We do not know if those causes are still operating to a degree that will preclude successful re-establishment. As a result, re-establishment has been designed to be experimental. Careful monitoring of frogs and environmental conditions will be necessary to fully evaluate the re-establishment effort. If our initial attempts to re-establish *R. tarahumarae* fail in Big Casa Blanca Canyon, we will use those monitoring data to better understand the causes of failure. We would then adapt this new information by revising our approach to hopefully be more successful in future efforts.

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