Brief Encounters with Archey's Frog

By Bruce Waldman

New Zealand frogs (Leiopelmatidae) are "living fossils" that have changed little over perhaps 200 million years. Their world, until the arrival of humans, was dominated by birds rather than mammals. Now they exist only in limited tracts of native bush in the North Island and Marlborough Sounds. So with great anticipation, in 1992 I first ventured to the Coromandel Peninsula in search of Archey's frogs (*Leiopelma archeyi*), one of four described extant native species (but see Holyoake et al. 2001 for further discussion).

Archey's frogs move slowly, seemingly deliberately, generally are silent, and their round eyes do not reflect light, so at first I couldn't find any. Then I saw one perched on short vegetation, then another, and another, and having developed a search image I suddenly realized that they had been all around me the entire time (Figure 1). Indeed, the frogs were so abundant that I couldn't count them all. Later we would find that *Leiopelma* frogs communicate among one another with scents rather than sounds (Lee and Waldman 2002, Waldman and Bishop 2004).

Figure 1. Archey's frog foraging at night in the Coromandel Peninsula. Photo: Bruce Waldman.

I was surprised to find Archey's frogs not only on mountain tops but also in regenerating bush near sea level. However, in subsequent years, the frogs became progressively more difficult to find, first disappearing totally from lowland habitat. Beginning in 1995, finding frogs required exhaustive searching, not just in the vegetation at night, but also under rocks in which the same individuals had been repeatedly seen for up to 23 years (Bell et al. 2004).

Initial discovery of chytrid fungus in New Zealand

In 1999, about 1000 km south in Canterbury, on the South Island, I witnessed the first frogs showing clinical signs of chytridiomycosis in New Zealand. Southern bell frogs (*Litoria raniformis*) swam erratically in a pond at Godley Head. Many struggled to leave the pond, showing seizures and partial paralysis (Figure 2). With Richard Norman, we identified *Batrachochytrium dendrobatidis* (*Bd*) zoosporangia in the skin of sick frogs and carcasses (Waldman et al. 2001). The epizootic appeared short-lived among adults, but metamorphosing froglets died in large numbers.

I knew this pond to be a major source of frogs for the pet trade, so I attempted, unsuccessfully, to seek legal action to cordon off the pond and to halt trade in frogs. During the following months, we documented that *Bd* had spread throughout and possibly beyond Canterbury. Few frogs returned to the pond over the next few years. But by 2006 the population started to recover and in 2011 I observed no mortality among metamorphs.

Figure 2. Left: Southern bell frog, infected by chytrid fungus, struggling to leave a pond in November1999. Right: Sign warning people not to collect frogs from this pond. Photos: Bruce Waldman.

While *Litoria raniformis* and its close relative *L. aurea* are threatened or endangered in their native Australia, many consider them pests in New Zealand where the species remain unprotected and populations persist. I feared that *Litoria* frogs sold as pets would be released into areas of the North Island inhabited by *Leiopelma* frogs and spread *Bd* to them.

Witnessing Archey's frogs dying in the field

At the University of Canterbury (UC), with the assistance of Richard Norman, I set up a histology laboratory to diagnose *Bd* and soon thereafter, my student Ermin Šadic and I devised a sensitive PCR test for *Bd*. Until 2005, this facility served as the primary New Zealand center for *Bd* diagnoses. We found the incidence of *Bd* infection to range between 30 and 37% in the three introduced *Litoria* species, but barely above 0% in Archey's frogs (Šadic and Waldman 2004). Archey's frog are fully terrestrial, breeding on land, so infection would require exposure to high concentrations of *Bd* zoospores in soil.

Yet, Archey's frogs continued to disappear from Coromandel populations. In 2001 and 2002, I felt fortunate to find even a single frog during my nighttime searches. Even then, the frogs that I found appeared unhealthy, bearing skin ulcerations or blisters that I had never seen before (Figure 3). Not infrequently, I found carcasses. Frustrated by the Department of Conservation's (DOC) slow response, I engaged the media to warn of the frogs' imminent demise. *New Scientist* called for urgent action to save Archey's frog: "New Zealand has a fine record of conserving endangered species such as the kakapo, the flightless parrot that is intensively monitored. It's time to lavish similar attention on the nation's amphibians. They may not be as cute as the kakapo, but they are no less important" (Editorial 2002).

Sick frogs recover and successful breeding

My efforts were successful and I obtained support and funding to maintain an *ex situ* population of Archey's frogs. Forty-nine Archey's frogs were delivered to a new purpose-built facility at UC, accompanied by Māori tribal elders. For months, my students and I monitored the frogs carefully for any signs of disease. Once confident that they were safe, we released the frogs into tanks simulating their natural environment, where they began to breed within weeks (Figure 4).

Meanwhile, in my laboratory, we recorded the disease progression of sick Archey's frogs that I found in the field, as agreed by DOC. None of the sick frogs showed clinical signs of chytridiomycosis and all tested negative for *Bd* infection. Although some individuals subsequently succumbed to disease, many others recovered. Skin ulcerations healed and many blisters disappeared without pharmacological intervention.

Tests were needed urgently to determine the susceptibility of Archey's frogs to *Bd*. I contracted with DOC to conduct these tests, first perfecting our techniques on introduced bell frogs (Carver et al. 2010). However, in the intervening few months, Archey's frog populations continued to dramatically decline and I no longer could find frogs in the field. I feared that the frogs that I had collected earlier for the infection experiment might be the last surviving Coromandel Archey's frogs. I was not willing to put these animals at risk by infecting them with *Bd*.

Figure 3. Left: Denuded ventral skin, heavily infiltrated by bacteria. Right: Blisters under lower jaw. Photos: Matt Walters.

Figure 4. Left: Archey's tadpole, reared in our laboratory on moist filter paper. Photo: Matt Walters. Right: After metamorphosis, the same froglet on its parent's back, held in the author's hand. Photo: Martin Hunter.

So why are Archey's frogs dying?

Our necropsies suggested that dying frogs suffered from a variety of diseases. I suspected that something in the environment, possibly pesticides or poisons such as those used to kill introduced mammals, was causing sublethal stress on the frogs that compromised their immune systems. This, in turn, might make them vulnerable to pathogens, possibly including chytrid fungus but also bacteria, viruses and other fungi that normally would pose no risk to them. I feared that the species was in danger of imminent extinction, so when approached by a reporter, I discussed my concerns (Ross 2005). Soon thereafter, DOC halted research at my UC laboratory and the Archey's frog colony was transferred to Auckland Zoo.

Four years later, over half of the colony had died, including offspring bred at UC, and the frogs have not successfully bred again in captivity (Gibson 2009). We had been making good progress on several lines of investigation into why the frogs were dying, but neither my collaborators nor I were able to complete these studies. Other researchers continued some aspects of the work that we started. Why the frogs are dying in the wild remains a mystery.

Conclusion

Saving a species requires detailed knowledge and appreciation of the organism's biology, solid scientific research, and meaningful collaboration among researchers, governmental departments, zoos, and the public. Further studies are needed to determine whether frogs remaining in the field suffer from immunosuppression, and if so, to identify the factors that are making them susceptible to disease. We share a responsibility to save Archey's frog, ranked the most evolutionarily distinct amphibian in the world, from extinction.

Acknowledgements

I thank Deuknam An, Arnaud Bataille, Jonathan Fong, Emily Fountain and Jungbae Park for reading the manuscript. The New Zealand Department of Conservation issued permits and funding for my work. The captive frog facility was funded by the New Zealand Lottery Grants Board and the University of Canterbury.

Author details: Bruce Waldman, Department of Ecology, P.O. Box 84, Lincoln University, Canterbury 7647, New Zealand; and Laboratory of Behavioral and Population Ecology, School of Biological Sciences, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-747, South Korea (waldman@snu.ac.kr).

Literature Cited

Bell, B.D., S. Carver, N.J. Mitchell, and S. Pledger. 2004. The recent decline of a New Zealand endemic: how and why did populations of Archey's frog *Leiopelma archeyi* crash over 1996–2001? Biological Conservation 120: 189-199.

Carver, S., B.D. Bell, and B. Waldman 2010. Does chytridiomycosis disrupt amphibian skin function? Copeia 2010: 487-495.

Editorial. 2002. Forlorn farewell to frogs. New Scientist 173(2337): 5. 6 April.

Gibson, E. 2009. Half of zoo frog colony dies. New Zealand Herald, 28 March. http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10563995. Retrieved 13 October 2011.

Holyoake, A., B. Waldman, and N.J. Gemmell. 2001. Determining the species status of one of the world's rarest frogs: a conservation dilemma. Animal Conservation 4: 29-35.

Lee, J.S.F., and B. Waldman. 2002. Communication by fecal chemosignals in an archaic frog, *Leiopelma hamiltoni*. Copeia 2002: 679-686.

Ross, T. 2005. Pesticides blamed for killing our rarest frogs. Sunday Star-Times, 1 May, p. A8. http://frogs.orcon.net.nz/sundaystartimes. Retrieved 13 October 2011.

Šadic, E. and B. Waldman. 2004. Rapid detection of amphibian chytrid fungus by PCR assay. Captivity, Reintroduction and Disease Control Technologies for Amphibians Conference, 11–14 December 2004, Amphibian Research Centre, Werribbee, Victoria, Australia. http://frogs.org.au/ppt/ErminSadic-RapidDetection/. Retrieved 13 October 2011.

Waldman, B., and P.J. Bishop. 2004. Chemical communication in an archaic anuran amphibian. Behavioral Ecology 15: 88-93.

Waldman, B., K.E. van de Wolfshaar, J.D. Klena, V. Andjic, P.J. Bishop, and R. J. de B. Norman. 2001. Chytridiomycosis in New Zealand frogs. Surveillance 28(3): 9-11.