JAMES REARDON

Archey's Frog (*Leiopelma archeyi*) has the dubious distinction of being ranked the the world's most evolutionarily distinct and globally endangered (EDGE) amphibian.

CONSERVATION ALERT

The Plight of the World's Most Archaic Frogs

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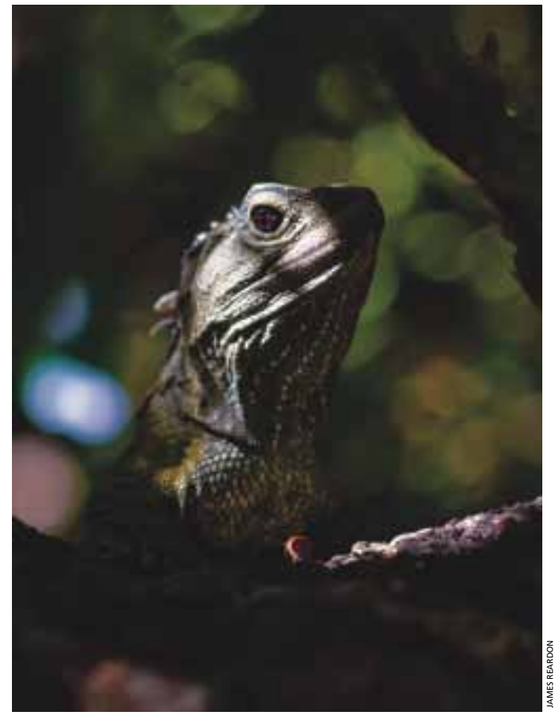
Mention New Zealand to most people and many will have heard of it, although most may not know exactly where it is. This tiny nation in the South Pacific, with ten times as many sheep as people, has become famous for a number of things, from the scenery behind the *Lord of the Rings* movies to mountaineers such as Sir Edmund Hillary and amazing wildlife found nowhere else in the world. The last of these, the country's unique fauna, draws visitors and scientists from around the globe. Due to its unique geological history and lack of native mammalian predators (the only native terrestrial mammals are two species of bats), New Zealand is home to some truly exceptional animals: Species such as the flightless Kiwi and the Tuatara (large lizard-like creatures that are the sole survivors of the order Sphenodontia) are found nowhere else in the world. While tourists flock to take photos of penguins and millions of dollars of conservation money are devoted to saving numerous species of native flightless birds, another group of animals goes largely unnoticed by both New Zealanders and the rest of the world. These amazing little creatures are the country's endemic leiopelmatid frogs.



JOHN BINNS

New Zealand is an island nation in the southern Pacific Ocean.

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New Zealand is home to species like the Tuatara (*Sphenodon punctatus*) that are found nowhere else in the world.

New Zealand's native frogs are the world's most archaic frogs and, although they may look like any other frog at first glance, they are quite extraordinary. A recent ranking by the Zoological Society of London of over 6,000 species of amphibians has placed all four of New Zealand's native species in the top 60 of the world's most evolutionarily distinct and globally endangered (EDGE) amphibians, with Archey's Frog (*Leiopelma archeyi*) having the dubious honor of being ranked the #1 EDGE amphibian (www.edgeofexistence.org/amphibians/default.php).

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While tourists flock to take photos of penguins and millions of dollars of conservation money are devoted to saving species of native flightless birds, New Zealand's endemic leiopelmatid frogs go largely unnoticed. This is a dark green morph of Archey's Frog (*Leiopelma archeyi*).

Leiopelmatid frogs possess a number of primitive traits that set them apart from other frogs. These include presacral ribs, an extra tail-wagging muscle, amphicoelous vertebrae, and the lack of a tympanic membrane and middle ear structures (Stephenson and Stephenson 1957, Bell 1994). The last of these features, the lack of an external eardrum, is responsible for another distinctive characteristic of these frogs — they are silent, a trait that makes the distinction of native New Zealand frogs from introduced and common Australian imports easy for even the most amateur herpetologist. Unlike most frog species, in which the males' calls echo through rainy nights in their efforts to find mates, leiopelmatid frogs communicate chemically, a characteristic that makes these species more similar to salamanders than other anurans. In addition to these primitive features, the native New Zealand frogs are long-lived. Dr. Ben Bell of Victoria University has been leading some of the world's longest running population studies on frogs and has shown that native frogs can survive for over 30 years in the wild, with the oldest known frog being over 37 years old! These frogs produce small clutches of fewer than 20 eggs at a time. The males of the terrestrial species show parental care, guarding egg clutches that hatch directly into free-living froglets without a tadpole phase. These froglets then crawl onto the backs of males and are carried until they can survive on their own. Of the four extant species, three are terrestrial (*Leiopelma hamiltoni, L. pakeka, L. archeyi*) and only one (*L. hochstetteri*) inhabits rocky stream environments.

The world is facing a global amphibian extinction crisis, with over a third of all known amphibians currently threatened with extinction, and as many as 122 species going extinct since the 1980s (Stuart et al. 2004). Unfortunately, New Zealand's remote location has not spared its endemic frog fauna. Three frog species have gone extinct since the arrival of humans, who introduced mammalian predators such as rats, mice, and stoats to this land of naïve wildlife. The frogs' natural instinct when approached is to freeze, relying on their cryptic coloration to hide them from avian predators. Although this tactic may have worked for the native predator suite with which the frogs evolved, like most of New Zealand's reptilian and avian species, these frogs have become easy prey for nocturnal mammalian predators with a keen sense of smell.

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Searching for Hochstetter's Frogs in rocky streambeds.

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Archey's Frog (*Leiopelma archeyi*) and Hochstetter's Frog (*L. hochstetteri*) have persisted on New Zealand's North Island despite the presence of introduced mammals, but fossils indicate that they were formerly much more widely distributed. Here, researchers search for frogs in the Whareorino Forest.

According to the World Conservation Union (IUCN 2008), all four of the remaining native frogs are threatened with extinction. Two closely related forms distinguishable only with genetic testing, the Maud Island Frog (*L. pakeka*) and Hamilton's Frog (*L. hamiltoni*), are restricted to small offshore, predator-free islands. Even

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Unlike most frogs, New Zealand's native species are silent, communicating instead by using chemical signals. This is the Maud Island Frog (*Leiopelma pakeka*), one of two extant species found only on predator-free offshore islands.

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New Zealand's frogs, such as this Archey's Frog (*Leiopelma archeyi*) freeze when approached, relying on cryptic coloration to hide them from the avian predators with which they evolved. Unfortunately, they become easy prey for introduced mammalian predators with a keen sense of smell.


JEN GERMANO


PHIL BISHOP

Maud Island Frogs (*Leiopelma pakeka*) and Hamilton's Frogs (*L. hamiltoni*) are restricted to small offshore, predator-free islands.

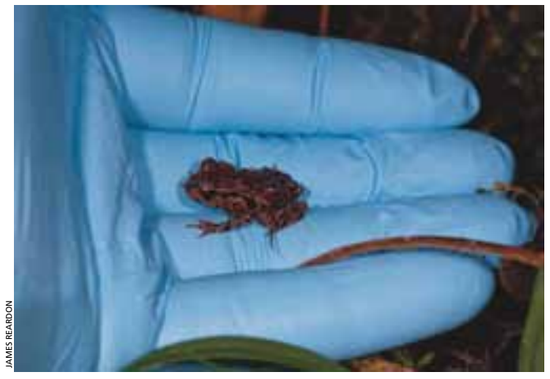
so, the total population of Hamilton's Frogs is less than 400 individuals. The remaining two species, Archey's Frog (*L. archeyi*) and Hochstetter's Frog (*L. hochstetteri*), have persisted on New Zealand's North Island despite the presence of introduced mammals, but fossil remains indicate that they were formerly much more widely distributed (Worthy 1987).

The persistence of remnant populations does not necessarily indicate that these species are safe from the risk of extinction. In the past decade, populations of Archey's Frog have declined by nearly 90% (Bell et al. 2004). This decline has been attributed to the introduction of the amphibian chytrid fungus, a deadly infection that has killed frogs throughout the world and is known to be present in all Archey's Frog populations. Hochstetter's Frogs are the most abundant and widespread of the native frog species and, so far, do not seem to have contracted this life-threatening infection. They are, however, under threat from habitat degradation and loss throughout their range. In addition, many of the Hochstetter's Frog populations are geographically isolated, and recent genetic work suggests that each population should be managed as an independent unit (Gemmell et al. 2003).

Researchers from universities, zoos, and the New Zealand Department of Conservation (DOC) have been working hard to try to bring the leiopelmatid frogs back from the brink of extinction. The establishment of captive populations, research into rodent predation and disease susceptibility, and the translocation of frogs to create populations in new areas are just some of the conservation techniques being used. The transfer of frogs (into either a captive situation or new location in the wild) allows the establishment of "security" populations, while research into threats such as predation and disease helps develop the long-term management strategies for these species.

Since introduced mammalian predators pose one of the greatest threats to native frogs, the DOC is conducting research into the effects of rodent control on the survival and recruitment of established Archey's Frog populations. This research was prompted by the discovery of dead frogs displaying bite marks characteristic of rat predation. Mark-recapture monitoring in rat-trapped and untrapped habitat has been carried out over the past four years using the distinctive patterns and markings of Archey's Frogs for individual identification. Initial results suggest that predator control is helping the frogs, but findings to date are inconclusive.

While monitoring on the mainland is an important part of native frog recovery in New Zealand, one of the best conservation options available to wildlife managers is translocation to offshore islands. With introduced mammals posing the greatest threat to native fauna and with the availability of numerous small offshore islands, New Zealand conservationists have been developing techniques to rid islands of introduced species for decades, and their successes and ingenuity have made them world leaders in this work. Today, over 19,000 ha of pest-free habitat have been re-created with rats removed from 37% of the rodent-infested offshore islands over 5 ha in size (Towns and Broome 2003). This has opened up a huge amount of habitat to which native fauna can be reintroduced.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Populations of Archey's Frog have declined by nearly 90%, largely attributable to the introduction of the deadly chytrid fungus, which has been identified in all populations. Consequently, extreme caution is necessary when handling frogs to prevent transmission of the fungus.


LISA DAGLISH

Research into the effects of rodent control on survival and recruitment in established Archey's Frog populations was prompted by the discovery of dead frogs displaying bite marks characteristic of rat predation.


KAYA KLOP-TOKER

Hochstetter's Frogs (*Leiopelma hochstetteri*) are the most abundant and widespread of the native frog species.

Over the past three decades, eight translocations of New Zealand frogs have taken place, with most to mammal-free islands and mainland sanctuaries. Although some have failed, we have learned from them, and guidelines have been established for the transfer of amphibians to island habitats. Long-term success has been seen in two translocations of Maud Island Frogs, and a more recent translocation of Hamilton's Frog is showing initial positive signs of survival and reproduction. The lessons learned from these island translocations are now being applied to frog transfers on the mainland, with the first Archey's Frog translocation taking place in late 2006. While the threat of introduced mammals cannot be completely eliminated on the mainland, this transfer is providing information on whether a translocation can succeed if pest numbers are kept low through targeted rodent control. Preliminary monitoring has detected breeding in both seasons since the release, and shown survival of young to sub-adult size. This indicates that predator-controlled mainland sites may be appropriate for use in transfers of endangered amphibians in the absence of predator-free sites.

In addition to the creation of new frog populations through wild-to-wild transfers, two New Zealand zoos are working with the DOC in an attempt to establish healthy captive populations of Archey's and Hochstetter's frogs. In addition, the Orana Wildlife


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The distinctive patterns and markings of Archey's Frogs are used for individual identification and documented by photographing each frog on a photo stage.


JAMES MUIR

Collecting urine from frogs is a minimally invasive method for identifying sex in individuals and monitoring their reproductive condition. Here, the senior author is taking a urine sample from a Maud Island Frog (*Leiopelma pakeka*).

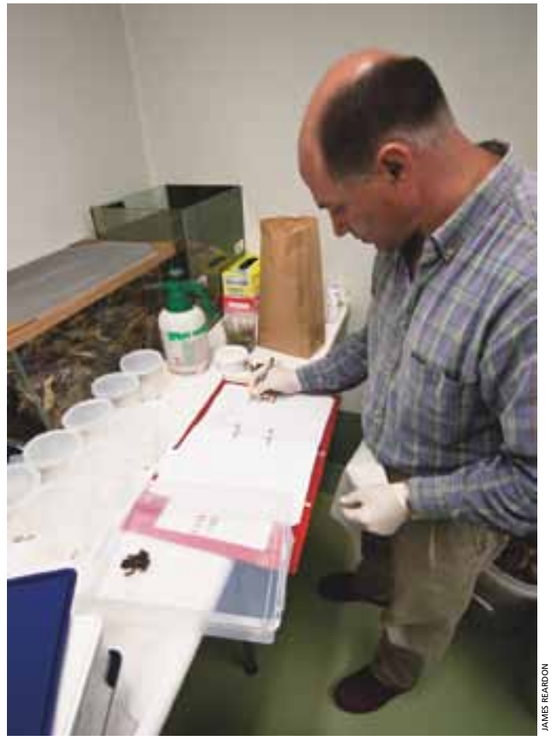
Trust is on its way to setting up a third facility, focusing on Maud Island Frogs. While many wild translocations have been successful, captive populations are recognized as an important part of native frog recovery, as they can provide insurance in the case of catastrophic declines in the wild and should be able to produce greater numbers of frogs than possible in the wild. However, maintaining amphibians in captivity is a challenging task.

Since these frogs are unique and so much about their biology remains unknown, attempts at keeping them in captivity have highlighted many of the important areas in which further research is needed. The zoo populations were started at Auckland Zoo in 2005 and Hamilton Zoo in 2006. Although a handful of egg clusters have been produced at both zoos, no healthy froglets have survived in either of the captive populations.

One problem faced by both zoo staff and by field researchers is the fact that these frogs are monomorphic (lacking obvious outward physical differences capable of distinguishing males from females). Additionally, since these frogs are silent, we also lack the behavioral sex difference of males calling to attract mates that occurs in most species of frogs. This is a huge problem when trying to match potential mates in captive situations and for selecting individuals to translocate. The senior author at the University of Otago (in collaboration with Frank Molinia from Landcare Research and supervisors Phil Bishop and Alison Cree) has found a new non-invasive technique that may help with this problem. She has been measuring hormone concentrations in the frogs' urine and has found that the sex of the frogs can be determined from their hormone metabolite

LISA DAGLISH

The first Archey's Frog translocation took place in late 2006.



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Drs. Russell Poulter and Phil Bishop (in his lab at the University of Otago) have discovered that the antibiotic chloramphenicol is an effective cure for the chytrid fungus in two species of introduced frogs.

levels. This non-invasive technique will not only help with future management of the frogs, but will also aid in revealing more information about the timing of breeding in these cryptic frogs.

In addition to studies concerning captive breeding programs, New Zealand researchers also have been busy investigating the effects of amphibian chytrid on native frogs and searching for a cure for this fatal disease. These studies are considered particularly important for Archey's Frog, given that amphibian chytrid is present in all populations and a large decline in one population has been attributed to the presence of the fungus (Bell et al. 2004).

Recognizing the huge threat that amphibian chytrid poses, Drs. Russell Poulter and Phil Bishop have begun to search for a substance that would eliminate the fungus without adversely affecting the frogs. Having discovered that the antibiotic chloramphenicol (found in eye ointment and used in human and veterinary medicine) could destroy the disease *in vitro*, they proceeded to test its effectiveness on live amphibians using two species of introduced frogs, and discovered it was an effective cure for these introduced species. They continued with the research, applying the treatment to wild-caught Archey's Frogs that had been naturally infected with the fungus. Eleven of the 12 frogs cleared their infections naturally and the remaining frog cleared the infection after treatment, without apparent ill effects (Bishop et al. 2009). This is excellent news and, although further testing is recommended to confirm that the

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Biosecurity measures are employed when venturing into frog habitat. Here, boots worn into the field are sanitized before they are used again.

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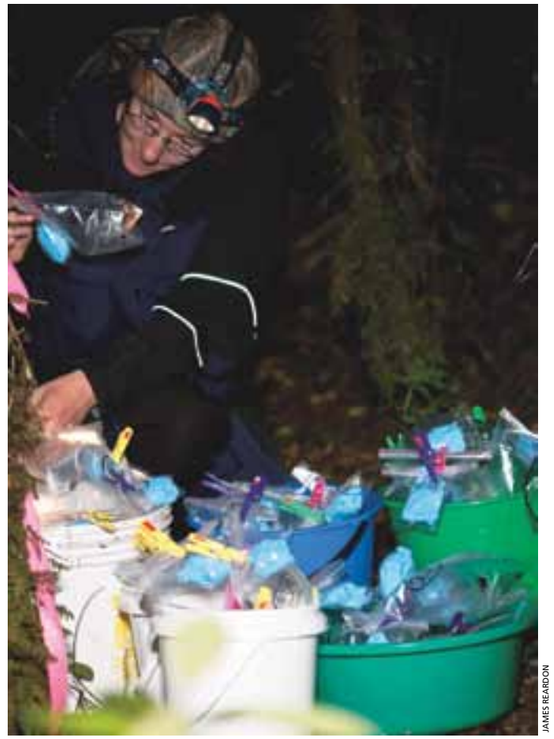
Having to work by flashlight at night makes catching and handling these tiny frogs a difficult proposition.

technique is safe, it is a potential tool for treatment of sick captive or wild-caught individuals.

The strong commitment to research and management of native frogs shown by researchers and organizations in New Zealand has led to substantive advances in our knowledge and understanding of these unique amphibians. While the threats have not lessened, the suite of tools available to protect and conserve these species is constantly increasing. Active conservation and management of these species should help the world's most archaic frogs survive long into the future.



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Department of Conservation ranger Lisa Daglish with buckets full of *Leiopelma archeyi* in biosecure bags for rapid processing before re-release at precise points of capture.

To learn more about New Zealand frogs or to help support their conservation and research in New Zealand, please visit the NZFRoG website at www.NZfrogs.org. NZFRoG is the New Zealand Frog Research Group, comprised of researchers and conservationists across the country, for the purpose of encouraging interactions among people working with frogs and to promote public awareness of native frogs and their declines.

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