The Armoured Mistfrog (*Litoria lorica*)

Narrowly Avoided Extinction but Remains on the Edge

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In the late 1990s, I started researching frogs in the Wet Tropics of north Queensland. Chytridiomycosis, a disease caused by the introduced fungus, *Batrachochytrium dendrobatidis*, swept through the Wet Tropics in the late 1980s and early 1990s with devastating effects. The fungal disease was novel to Australia and had already decimated some stream-dwelling species in south-east Queensland and the Eungella region, including causing the extinction of two gastric-brooding frog species (*Rheobatrachus silus and R. vitellinus*). By the mid-1990s, when I was first in the Wet Tropics region, four upland rainforest, stream-dwelling species had vanished. Wind forward thirty years, and three of those species are deemed extinct, but one of the species had a lucky escape. This story is the story of that species.

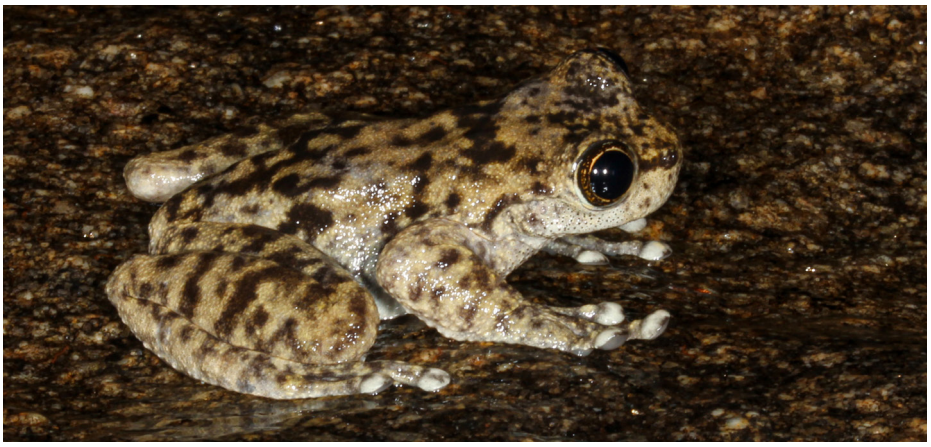
The armoured mistfrog (*Litoria lorica*) was discovered and named from the uplands of Thronton Peak in 1979. The common name refers to the large, spiny nuptial pads of the males (i.e., 'armoured') and the fact the frogs were only known from the misty uplands (i.e., 'mistfrog'). The species is completely restricted to waterfalls, where all life stages live. It appears to be the only mute frog in Australia – I have spent many hours around the frogs at night and never once heard a male call. Instead, males and females occur at high density on the waterfalls and probably find each other and interact visually. It is one of a small number of frogs in the world that live entirely on waterfalls.

Males amplex with females ('amplexus' is the breeding embrace), and the spiny nuptial pads at the base of the male's thumbs function as a none-slip-grip on the female in rushing water. The clutch of eggs is 'glued' to the rock surface in shallow flowing water (including on vertical rock surfaces), and the tadpoles hatch out into the flowing water. They then develop in the flowing water, moving along the rock surfaces using a large suctorial disc around their mouth. They feed on algae and other materials on rock surfaces. They then metamorphose as very small, mottled grey frogs that blend in perfectly with their granite background. From there, it is a life around the crashing water of the waterfalls, feeding on insects and other invertebrates. The armoured mistfrog co-occurs with a similar species of similar ecology called the waterfall frog (*Litoria nannotis*) – a familiar species to many who spend time on Wet Tropics streams at night.

The armoured mistfrog disappeared from the Thornton Peak uplands around 1990 and was not seen for eighteen years. When I turned up in the Wet Tropics, it was believed to be extinct, gone in the first wave of chytrid disease impacts. It was the missing species that always intrigued me the most and the species I always wished I had seen. The intrigue was that it was so poorly known when it disappeared and that it was essentially a small version of the waterfall

Top: An armoured mistfrog (*Litoria lorica*) in a splash zone at the new site. Image: Conrad Hoskin.

frog, living side-by-side with that species. Then the first unexpected thing happened. A researcher called Michael Cunningham (then doing his PhD at the same institution as me, The University of Queensland) found specimens of the armoured mistfrog in an American Museum, mislabelled as juvenile waterfall frogs. Interestingly, these specimens were collected (before the disease declines) from the upper Mossman River on the Carbine Tableland. This discovery extended the historic range south of Thornton Peak and greatly increased the possible area that an overlooked population may have been hiding out.



A male armoured mistfrog (*Litoria lorica*). Image: Conrad Hoskin.

Further targeted searches failed to find the species. Indeed, to this day, it has never been found at any of its historic sites in the upland rainforests. Then, out of the blue, it was rediscovered in 2008 after eighteen years of being missing. A PhD student, Robert Puschendorf, was researching how waterfalls frogs were co-existing with chytrid disease in stretches of the stream flowing through rainforest and adjacent open forest on the western side of the Carbine Tableland. A number of us had noticed that some declined species, including waterfall frogs, survived better in open canopy areas than in the upland rainforest. We suspected it had something to do with disease tolerance in these hotter environments. One day, Rob looked further downstream than usual and, among the numerous waterfall frogs, found some small frogs that looked like juveniles of that species, but some had nuptial pads. He wondered if they were armoured mistfrogs, and he contacted me. Fortuitously, I was in the nearby lowlands at the time, up from Canberra (I was at Australian National University at the time) for my sister's wedding at Cape Tribulation. I met up with Rob, and over the following weeks, we determined they were indeed armoured mistfrogs, surviving at high density at that one site.

A female armoured mistfrog (*Litoria lorica*). Image: Robert Puschendorf.

Rob and I received a National Environmental Research Program grant from the Australian Government to survey the region more extensively and hopefully find other populations in similar open canopy and waterfall areas. We would identify sites from Google Earth, walk or helicopter in, and survey the ideal habitat and upstream into the rainforest. Our surveys were thorough, but we did not find any other populations of armoured mistfrogs. However, we found numerous unknown populations

Nuptial pads of a male armoured mistfrog (*Litoria lorica*). Image: Robert Puschendorf.

Armoured mistfrog (*Litoria lorica*) habitat at the translocation site. Image: Conrad Hoskin.

L to R: Dr Robert Puschendorf and Dr Conrad Hoskin swabbing frog for chytrid disease. Image: Eridani Mulder.

of waterfall frogs and common mistfrogs, both endangered species at the time. We also detailed the extent of the single population of armoured mistfrogs. We found that the remaining population was restricted to a four-kilometre section of the stream and probably totalled less than 1,000 adults. Disease swabbing revealed that almost every frog has chytrid on its skin. Thermal imaging revealed that the frogs probably survive chytrid at the site because they emerge onto warm rocks at night, elevating their body temperature above the optimal range for chytrid fungus to proliferate. The species was probably saved from extinction by the heat from the lower elevation, westerly aspect, and open canopy at this site. Hot rocks equal healthy frogs.

The obvious question was what to do next to improve the chances of survival. First, a long-term monitoring transect was established to keep tabs on numbers, and I have kept doing this two or three times a year for over a decade. Second, the decision was made to translocate a small number of adults to a nearby site of similar habitat, to try establishing a second wild population. This translocation was a collaboration between myself, the Threatened Species Group of the Queensland Government, and the Western Yalanji People. In 2013,

Dr Conrad Hoskin inspects the habitat at a new potential site for the armoured mistfrog (*Litoria lorica*). Image: Conrad Hoskin.

the first forty frogs were moved – twenty males and twenty females. The translocation was done within a few hours at night, and the frogs hopped off together into their new home. The site was chosen because the stream habitat is ideal and thermal characterization of the site had shown it was also warm and, hopefully, a refuge from chytrid disease. In 2014, another twenty frogs were translocated to the same site; in 2015, a final forty frogs were moved.

I have monitored this site two or three times a year to learn how the frogs fared. The establishment was slow, with the first few metamorphs being found in late 2014. Finding the first youngster at the site was very exciting! Over the subsequent years, numbers have steadily increased (with natural fluctuations), and many juveniles have been seen. The adult population at the site is currently at least one hundred individuals, and I doubt any of these are the frogs we put there nearly ten years ago. The translocation is deemed a success, and fingers are crossed the population continues to grow.

That first translocation provided some 'insurance' for the species – two wild populations are better than one. But the new population remains small and, importantly, it is in the same catchment as the main population. The issue is that any threat introduced to that catchment, for example, another disease or invasive fish, could quickly impact the entire species. Therefore, approvals are currently being sought for another translocation. The next translocation site has already been identified – a habitat of similar environmental characteristics in a neighbouring mountain range. This translocation is planned for 2023, with generous financial support from the Australian Wildlife Society.

Compared to when I started research in the Wet Tropics, things are looking incomparably more positive for the armoured mistfrog. The main population persists, a second wild population is established nearby, and a third is planned. However, threats remain at the main site, which needs to be urgently addressed. An impact on that population would impact roughly ninety percent of the species, and the nearby second population would soon feel the same impact. Every effort must be made to ensure the protection of the main population, or this time we will lose the armoured mistfrog forever.

The first juvenile found at the translocation site. Image: Conrad Hoskin.

A cluster of armoured mistfrogs (Litoria lorica) in the splash zone beside a waterfall. Image: Conrad Hoskin.

Upland stream habitat from which the armoured mistfrog (*Litoria lorica*) and several other Wet Tropics frogs disappeared. Image: Robert Puschendorf.