Tree-dwelling frogs are less likely to develop chytridiomycosis than frogs that live in moist environments.

Conquering Chytrid

The habitat of frogs and the company they keep may expose them to a deadly fungus, reveals Jodi Rowley.

I'm in the middle of Australia's tropical rainforest, waist-deep in a rapidly flowing stream, manoeuvring through a tangle of prickly vines, covered in leeches and waving an antenna in the air. It's a typical day at the office when you are attempting to find out why some of Australia's native frog species have declined dramatically in the last several decades while other frog species appear to be doing just fine.

In recent decades, frog populations around the world have declined dramatically, with many species becoming extinct. To date, scientists have reported the decline of well over 200 frog species, with more than 30 species thought to have disappeared completely. While these results are alarming enough, what caught scientists most by surprise was the location in which many frogs disappeared. The majority of population declines in other animal species have occurred right under our noses and been caused by obvious threats such as habitat destruction or modification. In the case of frogs, the situation was extremely different. The most dramatic declines occurred in remote rainforest streams in protected areas. These streams were far from any obvious human impacts and in areas previously thought of as safe havens for wildlife.

The unusual pattern of declining frogs perplexed scientists for some time, until scientists in Australia and the USA simultaneously identified a previously unknown form of fungus from dead and dying frogs collected from around the world. This fungus was named *Batrachochytrium dendrobatidis* (Bd), and is now known to be fatal to amphibians, producing a disease called chytridiomycosis.

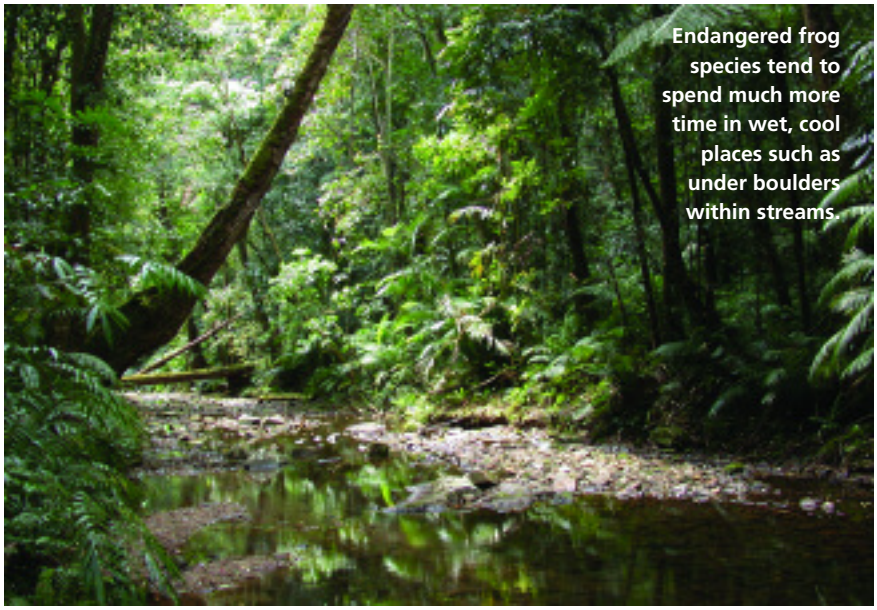
Bd is capable of rapidly killing frogs, with infected frogs in captivity dying in as little as 3 weeks. The disease is highly contagious because the fungus has motile, waterborne spores that travel in the water until they reach a frog or tadpole. Bd then invades the skin of the frog, feeding off the animal protein keratin, which is found in frog skin and tadpole mouthparts.

Chytridiomycosis has since been attributed to the decline of frog populations around the world, and has been recognised as a serious threat to biodiversity at both a global and local scale. Frog population declines attributed to the disease have resulted in the extinction of up to half of the frog species at particular sites and large reductions in the abundance of remaining species.

However, in almost all cases, frog populations that have disappeared or declined due to the disease coexist with non-declining species. Therefore, one of the most pressing mysteries concerning amphibian declines is why chytridiomycosis is driving some frog species to extinction but not others.

It is just this question that leads me and a team of volunteers into the middle of the tropical rainforest for weeks at a time to investigate. Specifically, I've set out to determine if it is simply differences in behaviour between different species of frog that explains why some frog species are declining while other co-occurring species are not.

Just as a human who is exposed to the common cold virus will not always develop a cold, a frog coming into contact with Bd will not necessarily become diseased. One of the factors that



Endangered frog species tend to spend much more time in wet, cool places such as under boulders within streams.

determines whether an animal will become diseased once it comes into contact with a pathogen such as Bd is the environmental conditions that a frog chooses to spend time in.

For frogs coming into contact with Bd, the temperature and moisture levels of the local environment are likely to affect the chances of a frog developing chytridiomycosis. This is because Bd is killed when conditions are too dry, so frogs infected with Bd are cured at temperatures of around 30ºC. Therefore, it follows that a frog that sits 20 metres up a tree, basking in the sun, is likely to be less affected by chytrid than a frog that spends most of its time hiding under a boulder in a cool rainforest stream.

Also, frogs that are in frequent contact with each other might be expected to come into contact with Bd and hence develop chytridiomycosis more often, just as people are more likely to get a cold when spending times in crowded areas.

Although the above theory might seem pretty obvious, the fact is that we simply don't know where frog species spend their time. Although most of us think of frogs as spending most of their time in the water, and indeed some do, many species don't spend much time in the water at all. Exactly how much time is spent away from water, and where, is still a mystery to scientists. This is because it's a lot harder to find a tiny frog in a vast tangle of tropical rainforest than it is to find a frog sitting exposed in the water. That is, unless technology lends a helping hand.

With the help of a tiny electronic device, individual frogs can now be located even when they are hiding in the most cryptic places or moving large distances away from the stream or into the treetops. I am using this technique to find out where several species of endangered and non-endangered rainforest stream frog are spending their time.

The tiny tracking devices, or radio transmitters, weigh only 0.6 grams and are attached to frogs by a specially designed waist band. Once fitted, they have a lifespan of 3 weeks, during which time they emit a signal that can be heard when picked up by a hand-held radio receiver attached to an antenna.

The signal is louder when the antenna is pointed towards the frog, allowing me to locate frogs several times throughout the day and night. By measuring the time between the individual signals emitted by the transmitters, I can calculate the temperature of a frog even when it is in places that are impossible to reach, such as 20 metres up in the rainforest canopy.

Up to 15 frogs of several species are located once during the day and once at night, and their temperature and details of their location are recorded.

Although this all sounds relatively simple, navigating a large antenna through fast-flowing and unpredictable rainforest streams is not always conducive to frog-finding, and the surrounding dense vegetation choked with spiny vines is similarly hard to navigate. Somehow, frogs always seem to go up the biggest boulder and through the densest patch of prickly plants.

After many months tracking frogs in the rainforests of northern Queensland, I have discovered differences in where frogs spend their time. Non-endangered frog species appear to be spending their time in warm, dry places such as trees, which are unfavourable to chytridiomycosis development. In fact, the temperatures that non-endangered frogs reach are often much higher than Bd can tolerate, probably eliminating any Bd infections in these frogs.

In contrast, endangered frog species tend to spend much more time in wet, cool places such as under boulders within the stream. These frogs typically stay at the perfect temperature for Bd growth, never reaching temperatures that would kill the pathogen.

Endangered frogs also appear to have much more contact with each other, sharing hiding places a lot more than their non-endangered counterparts. As Bd is likely to be transmitted by direct contact, this is another bad move for endangered frogs when it comes to avoiding chytridiomycosis.

These insights gained into the private lives of frogs will be invaluable in understanding the reasons why chytridiomycosis is driving some frog species to extinction but not others. To date it appears that non-endangered sunbaking species of frog may be unknowingly killing their Bd invaders while their endangered, moisture-loving counterparts are being much too disease-friendly for their own good.

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