SPECIAL REPORT

Bagged and boxed: it's a frog's life

As many amphibians face the very real threat of being completely wiped out by disease, climate change and pollution, **Emma Marris** looks at a controversial approach to save some of them in glass boxes.

With bright orange freckles and tiny proportions, the Carrikeri harlequin frog population spotted earlier this month delighted its discoverers with more than its good looks. The creatures (*Atelopus carrikeri*), found in the remote mountainous Páramo region of Columbia, had not been seen in 14 years and were feared extinct. Their rediscovery — and that of another species of the same critically endangered genus in 2006 — brings rare cheer to amphibian biologists.

These are desperate times for frogs, toads, salamanders and caecilians, whose sensitivity to climate disturbance means they provide an early window into the way that other biodiversity could be affected. The numbers are shocking: it is estimated that half of the world's 6,000-odd species of amphibians are now threatened by disease, pollution, habitat destruction, the consumer trade or climate change; about one-third of all amphibians are at risk of extinction (1,896 species).

Among the more than 100 species of amphibian thought by some experts to have become extinct since 1980 are Australia's southern gastric-brooding frogs (*Rheobatrachus silus*), which carried their young in their stomachs, and the golden toad of Costa Rica (*Bufo perigrinus*). Only 34 species are officially declared extinct, as it is very difficult to prove that there are no individuals left. One of biggest threats these animals face is a species of chytrid fungus called *Batrachochytrium dendrobatidis*, which is thought to have originated in South Africa. The infection is often fatal to whole populations and has spread across the globe with devastating consequences (see 'Fatal fungus').

Faced with the incredible scale of the problem, biologists have embarked on an experiment of last resort. Rather than letting the animals become extinct, a number of conservationists have started gathering up frogs believed to be doomed — in some areas collecting every last individual of a species — in an effort to enable some to persist in captivity. Some believe it would be worth causing the extinction of a species in the wild if it prevents the species from disappearing altogether.

"It is absolutely our obligation," says Jeffrey Bonner, president of the Saint Louis Zoo in Missouri. He chairs an enterprise called Amphibian

Bagged for life: workers at Panama's frog hotel hope to conserve the creatures. One researcher describes the animals in the facility as "kind of ghosts".

Ark, under the aegis of the global conservation body, the IUCN, which is to transfer 500 members of 500 species into protective custody within five years.

It is a melancholy task; there is something pathetic about species that exist only in glass boxes. And it is not without controversy. Although no one is calling for captive breeding to be abandoned, some amphibian specialists feel that it has been oversold as a solution. "Let's assume for the moment that the spiralling decay, including global warming, continues unabated," says Alan Pounds, an ecologist at the Monteverde Cloud Forest Preserve in Costa Rica. "I would say that under such circumstances captive breeding programmes can save amphibian diversity in about the same sense that a museum of Incan art can save Incan culture."

Still, biologists feel they have to do something — and fast. "These creatures have no chance," says Joseph Mendelson, a curator of herpetology at Zoo Atlanta, talking about frogs threatened with the chytrid fungus. "If you can't protect them and there are only a few left,

they've got to come in." Mendelson was one of a team of conservationists who made emergency collections of frogs in 2005 in El Valle, Panama, an area that researchers predicted would soon be hit with the fungus. The 35 species collected were sent to a zoo and botanical garden in Atlanta with the permission and support of the Panamanian authorities. By January 2006, the fungus had arrived in El Valle.

Another conservation team, supported by Houston Zoo in Texas, collected frogs in the same region for a planned captive-breeding centre at a local Panamanian zoo, called the El Valle Amphibian Rescue Center. But construction delays and the arrival of the fungus sooner than predicted meant that several hundred frogs spent a year

in a couple of rooms at the Hotel Campestre in El Valle during 2006. The hotel guests included the Panamanian golden frog (*Atelopus zeteki*), a national symbol of luck, which was last seen in the wild in June 2006. Some species began to breed well, including the kohl-eyed lemur leaf frog (*Phyllomedusa lemur*) and the marsupial frog *Gastrotheca cornuta*, which carries its eggs on its back until they hatch. In all, 600 individuals of 40 species were collected over the course

"There is a wave of death moving through Central America."

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of the past two years, says Paul Crump, a herpetologist at Houston Zoo.

The future is hazy for these 'saved' amphibians. At the moment, the El Valle Amphibian Center employs four full-time staff to keep the animals alive and is funded by three zoos. But what if funding runs out? Even if the project continues, no one has any idea when or under what circumstances these creatures could return to the wild. And the same is true of any of the captive-breeding programmes around the world. "Any commitment to long-term captive maintenance of a species is effectively an infinite commitment of time and resources. The idea that we have any hope of doing that for more than a tiny handful of particularly charismatic species is clearly wrong," says Ross Alford, a herpetologist at James Cook University in Townsville, Australia.

One concern is that captive breeding will have an effect on the amphibians' genomes. They may become genetically adapted to domesticated life, rendering them less able to live in the wild. A recent study showed a measurable decline in fitness in hatchery-raised steelhead trout (*Oncorhynchus* spp.) after just one generation¹. "Nobody knows how general this effect will be," says Hitoshi Araki, an ecologist at Eawag, the Swiss Federal Institute of Aquatic Science and Technology in Kastanienbaum, who carried out the study on hatchery fish. "We could see something similar in frogs."

Amphibian Ark partner projects are taking

Hotel residents: the Panamanian golden frog (*Atelopus zeteki*), now extinct in the wild, and *Dendrobates auratus*, below.

steps to avoid one cause of reduced fitness: inbreeding. "We are aiming to maintain 90% of the genetic diversity of the group over 100 years," says programme director Kevin Zippel.

A problem of equal complexity is what will happen to an amphibian's native ecosystem in the amphibian's absence. It may be that the things it ate will immediately increase in number and the animals that fed on it will become fewer. Such adjustments may lead to other changes in an unpredictable cascade through the ecosystem. Depending on how long the amphibian is gone, its ecological niche might not be there when it returns. And, adds Pounds, climate change is reshuffling which species are found where, especially on mountains. "That's another reason why amphibians that are reintroduced decades down the road

may encounter an alien world," he says.

There is reason for hope, though. In 1998 after a chytrid infestation, the last spotted tree frog (*Litoria spenceri*) in the Australian state of New South Wales — a male — was brought into captivity at the Amphibian Research Centre near Melbourne. There the optimistically named Dirk Diggler was mated with captured females from an endangered population in a neighbouring state. Happily, Dirk proved quite the stud and the centre has released many hundreds of his progeny back into his ancestral creek. Follow-up surveys of the tagged captive-reared frogs found 150 of them doing well in the past year.

The reality is that successes like this and the unexpected rediscovery of the harlequin frogs are rare glimmers in the otherwise bleak future facing amphibians. Without urgent interventions to address pressures such as climate change and habitat destruction, the only frogs left may be ones in glass boxes.

Additional reporting by Nature staff.

1. Araki, H. et al. *Science* **318**, 100–103 (2007).
2. <http://www.cdc.gov/ncidod/EID/vol10no12/03-0804.htm>
3. Youngs, S. et al. *Int. Zoo Yearbook* **41**, 85–95 (2007).
4. Pounds, J. A. et al. *Nature* **439**, 161–167 (2006).
5. Alford, R. A. et al. *Nature* **447**, E3–E4 (2007).

Fatal fungus

Commerical trading of the African clawed frog (*Xenopus laevis*) probably spread the chytrid fungus *Batrachochytrium dendrobatidis* that is destroying amphibian populations. From 1934 until the 1950s, this frog was used as a living pregnancy test — the urine of pregnant women stimulates the production of the frog's eggs — and it remains popular in labs².

More than 100 species worldwide have been infected by the chytrid fungus. Its spores infect the outer layer of the amphibian's skin and kill the frog through an unknown mechanism, perhaps by secreting toxins or by disturbing the moisture balance in frogs³.

Scientists disagree about how predictable the fungal spread is. "Chytrid is going to cover the planet," says Jeffrey Bonner, chair of conservation group Amphibian Ark and president of Saint Louis Zoo in Missouri. It is particularly lethal at

certain altitudes and temperatures. "In those places, it is going to kill 85% of the population, and the rest are walking dead because they can't find each other to mate."

But others including Alan Pounds, an ecologist at the Monteverde Cloud Forest Preserve in Costa Rica, find the 'lone-killer model' of the fungus to be an oversimplification. Pounds believes that the mortality of infected frogs is linked to climate change and local factors⁴. But Kevin Zippel, programme director at Amphibian Ark, disputes Pounds' theory. "If it were climate change then why is there a wave of deaths gradually moving through Central America at 26 kilometres a year?" he asks.

Ross Alford, a herpetologist at James Cook University in Townsville, Australia, says that in his country "the evidence for the 'wave-like' nature of outbreaks is extremely equivocal." He has found

GLOBAL SPREAD OF CHYTRID FUNGUS, 2007

cases where the fungus infected the population but did not kill any frogs for a year⁵. The fungus can be killed through sun exposure, Alford says. But a cloudy spell of three to four weeks could be long enough to prevent the frogs' normal sun-basking, he says, allowing chytrid populations to build to lethal levels. There is at least one species of

frog that chytrid infection does not kill: African clawed frogs. In other species, a few individuals have lived to croak another day. Studying these exceptions might eventually lead to a cure. And even if the mechanism of resistance is never found out, the individuals that survive could start a breeding pool of chytrid-resistant frogs. **E.M.**

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