Can a unique amphibian be saved after its environment has been transformed? Scientists do their best but fear the worst

The Lost World of the Kihansi Toad

BRONX ZOO, NEW YORK CITY—Past the snake exhibit, where gigantic pythons lurk behind thick glass, in the back rooms of the Reptile House, sits a humid, low-ceilinged isolation chamber. Here in five plastic terraria, 159 mustard-colored, fingernail-size amphibians are making what could be their last stand on Earth.

The Kihansi spray toad is 12,800 kilometers from home: Kihansi Gorge, in Tanzania's remote Udzungwa Mountains. For millions of years a great waterfall filled this gorge with perpetual spray and wind, creating a singular environment where the toad and other endemic creatures lived. In 2000, a hydropower dam cut off 90% of the water, and the ecosystem withered. Since then, scores of scientists in many disciplines have performed elaborate, unprecedented deeds to salvage the toad and its lost world. They have managed to raise the toads in captivity, documented the ecosystem's myriad responses to the dam, and engineered in the gorge what may be the world's largest sprinkler system. Their story shows that although human technology can easily upset nature, even the best science may not suffice to restore it.

In splendid isolation

The cool, high peaks of the Udzungwas jut from a sea of dry savanna, forming part of the Eastern Arc Biodiversity Hotspot, a crescent-shaped archipelago of nine mountain ranges. Here are some of the world's oldest rainforests, where long isolation and stable climate have given biota tens of millions of years to evolve. Thousands of plants and animals are endemic to the nine ranges, to one range, or, as in Kihansi, one locale. The spray toad has what may be the smallest range of any vertebrate—2 hectares. Some biologists think it has lived in the gorge or nearby for at least 10 million years.

The gorge begins where the Kihansi River plunges 100 meters off an escarpment, then rushes another vertical 750 meters through 4 kilometers of violent twists and cascades. The river flows year-round, whereas the region's other streams disappear in dry season. The slippery cliffs and the water's ferocity long excluded people, allowing the mist-world creatures to live undisturbed and undiscovered.

Steep drop and dependable flow also are ideal for hydropower. In 1983, engineers envisioned diverting water via a dam above the gorge to a turbine-filled tunnel; flow would bypass the gorge and return to the riverbed at the bottom. A survey of the modest 20-hectare proposed reservoir suggested an environmentally benign project, and in 1994, construction began on the $270 million effort, initially funded by World Bank loans. Development banks in Norway, Sweden, and Germany later joined but insisted that downstream biota be surveyed too.

Thus in 1996, with the dam infrastructure already partly built, biologists including herpetologist Kim Howell of the University of

CREDITS: J. GIBBS/SUNY-ESF; T. HERMAN/BOWLING GREEN STATE UNIVERSITY (TOAD)

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Out of water. After a sprinkler system (*left*) replaced the waterfall (*inset*, *right*), Kihansi toads (*inset*, *left*) became vanishingly rare.

Dar es Salaam managed to climb down into several steep, mist-engulfed meadows. Here they found an estimated 50,000 of the skinny, endearing toads, hiding in deep moss mats. Although they have relatives in the region, several unusual features set the toads apart, including flaps over nostrils (possibly to keep out excess spray) and live births (eggs might wash away). Their *chit-chit-chit-chit* call can ramp up to high frequencies inaudible to humans, possibly to overcome constant low-end waterfall roar, says evolutionary biologist Corinne Richards of the University of Michigan, Ann Arbor. The toads ate hundreds of wetland insect species, most still unidentified. Biologists also found at least four new endemic plants in the gorge, including a new coffee species, plus rare trees and threatened primates and birds.

But even as they explored the gorge world, biologists had scant hope for preserving it. "As soon as we found this place, we knew it would be going extinct," says one foreign consultant—who, like several others, feared being quoted by name because of the fierce politics surrounding the dam. To compensate, biologists sought possible toad transplant sites but turned up nothing. They recommended letting half the river's flow continue to the gorge, but that recommendation was not followed. In 1999, European newspapers got wind of unpublished studies, along with the published description of the toad, *Nectophrynoides asperginis*. Groups such as Friends of the Earth accused the banks and Tanzania of violating the International Convention on Biological Diversity, which forbids projects that would wipe out species.

The government and lenders compromised. With an added $6 million loan to cover conservation studies and mitigation, the gorge would get 10% of its previous flow. Part was to be channeled into a several-kilometer-long, gravity-fed pipe system snaking down rock walls to the toad meadows, where hundreds of spray nozzles would spurt mist—a setup meant to mimic natural spray with a fraction of the water. Covering a quarter of the toads' original habitat, the sprinklers are "probably the most highly engineered recovery system for any species ever," says William Newmark, a conservation biologist at the Utah Museum of Natural History advising the World Bank.

But the sprinklers were not ready when the water was to be choked off in early 2000. The shutoff proceeded anyway, and by the time the sprinklers came on 9 months later, the ecosystem had dried up catastrophically. Common plants from adjacent dry areas had invaded former spray meadows; mosses had declined almost 95%; insect diversity had dropped; and only 2000 toads were left alive.

Doing the downstream conservation work only after the dam was well under way was a "huge mistake: Planning was not preceded by a thorough and complete environmental impact assessment," admits conservation biologist Wilfred Sarunday, coordinator of Tanzania's Lower Kihansi Environmental Management Project, which oversees studies and mitigation at the gorge.

In captivity

Fearing the toads would soon be extinct, in December 2000, the Tanzanian government allowed the Wildlife Conservation Society to collect 500 animals for breeding in a half-dozen U.S. zoos. But captive amphibians are difficult to raise, and the animals soon were plagued with lungworms, infections, bone problems, intestinal parasites, and nutritional deficiencies. They would not breed predictably. By spring 2004, the Bronx and Toledo (Ohio) zoos had the only survivors—about 70.

The Bronx Zoo took two unusual steps. It called in the Coriell Institute, a Camden, New Jersey, human genetics outfit that preserves cell lines for research. Their staff created cell lines from dying toads, in hopes that technology would one day permit cloning the cells back into whole creatures. But the cell lines all died. The zoo also farmed out a dozen tiny corpses to Valerie Clark, a Cornell University chemist who studies potentially valuable bioactive substances harbored by amphibians. It was "our last chance" to analyze the toads, says Clark, who plans tests.

Then, in 2005, the captives perked up. Keepers had devised treatments for various ailments and discovered that although the standard zoo ultraviolet lamps were too big and crude, the toads liked basking in the narrow beams of little 12-volt track-light bulbs. Slowly, the toads started having babies—so small that keepers at first thought they were ants. Now there are about 300 toads between the two zoos.

Meanwhile, in Kihansi, things briefly got better—then much worse. After the sprinklers came on in early 2001, wetland plants slowly regenerated, according to a paper last year in *Biodiversity and Conservation* by Claire Quinn of the University of York, U.K. Some severely affected toad prey such as an endemic *Ortheziola* scale insect also increased, says Peter Hawkes, a consulting entomologist in Pretoria, South Africa. Most encouraging were the toads; internal reports indicate that by June 2003, some 20,000 were hopping about.

A month later, the toads crashed. In August 2003, 40 were seen; in January 2004, only five. Since then, they have virtually disappeared. Once or twice a year, site workers say they hear calls, and in May 2005, a biologist claimed to see one individual. Some scientists say it is still too early to talk about extinction in the wild, but many are pessimistic. "Seeing one spray toad is like … [seeing] one passenger pigeon," says James Gibbs, a herpetologist at the State University of New York at Syracuse who monitors the gorge for the World Bank. "The

Holding on. Kihansi toads now thrive only in zoo terraria (*top*), where keepers managed to get them to breed.

CREDITS (TOP TO BOTTOM): T. HERMAN/BOWLING GREEN STATE UNIVERSITY place is not what it used to be. Nobody wants to say it out loud, but it may be too late."

Biologists point to several possible suspects. The immediate cause may have been chytrid fungus, a deadly skin infection implicated in amphibian crashes around the world, says herpetologist Ché Weldon of North-West University in Potchefstroom, South Africa. His data show that the fungus was absent earlier but present by the crash. One candidate for bringing it in: the imported sprinkler pipes. Another: the boots of dozens of scientists, who traveled in from four continents. Others point out that the 2003 crash coincided neatly with a brief opening of the dam's floodgates to flush sediments. Tests showed these contain pesticides used by a growing number of maize farmers upstream, in concentrations that could kill the toads.

But these are just immediate causes. At bottom, many believe that the gorge environment is broken and can't be reassembled: The changes weakened the toads, and chemicals or infections just finished them off. For instance, the waterfall had constantly replenished spray-meadow soils with wet silt; the sprinklers just sprinkle water, leaving soil crumbly and susceptible to erosion. The waterfall's force also generated ceaseless wind—not supplied by sprinklers—whose now-vanished role in the ecosystem remains unknown. "It's not clear how successful the artificial system is," says water-resources engineer John Gerstle of Hydrosphere Resource Consultants in Boulder, Colorado, who managed much of the environmental work at the gorge until 2004. "It is hard to mimic a situation when you don't necessarily understand it."

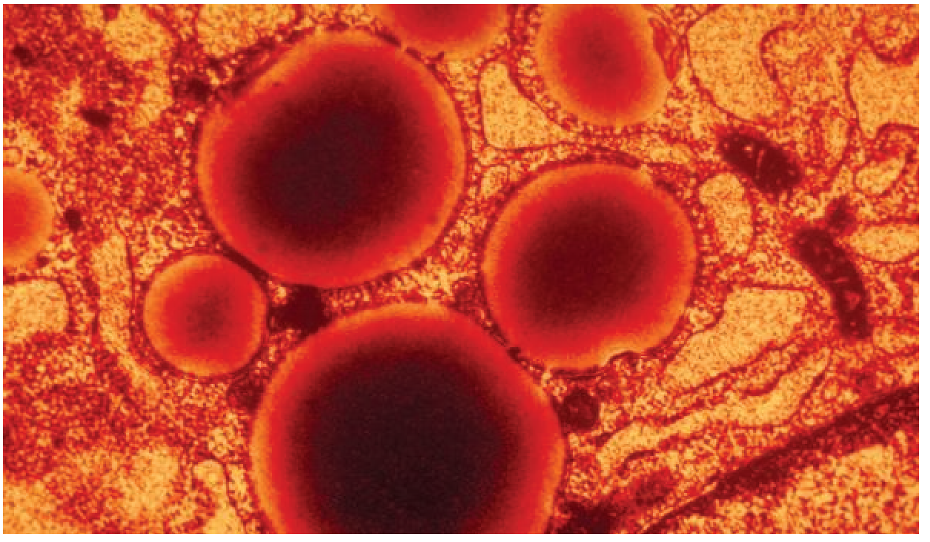
The situation has brought down continuing ire on scientists and their employers. Friends of the Earth President Brent Blackwelder recently wrote to the World Bank: "[Y]our monitoring team is passively documenting the extinction of this unique ecosystem." Sarunday, who still hopes that the system will recover, insists that the banks and Tanzania have "acted in good faith." In one letter to the group, then–World Bank Vice President for Africa Callisto Madavo wrote that measures at the gorge were "designed to ensure an optimal balance between biodiversity conservation and economic development."

The gorge also highlights tensions between developed nations, who funded the dam, and Tanzania, which now gets a third of its electricity from it. Tanzania is one of the most conservation-oriented African nations, but most observers doubt it would have borrowed $6 million for environmental work without pressure from "donor" nations, who want the money repaid. "Most [Tanzanians] say: Who cares about a toad? We want our electricity," says Tanzanian ornithologist Norbert Cordeiro, now at Chicago's Field Museum. When the captive toads were flown on a jet to New York, one Tanzanian newspaper pointed out that few human citizens could expect to do the same. Others question the presence of a seven-person crew doing daily care on the sprinkler system without proof that the toad is there or could ever safely return.

There is perhaps one positive outcome. Tanzania is still rich in biodiversity, and Kihansi has helped develop homegrown expertise to preserve it. The loan has helped Tanzanian and foreign scientists study the gorge together, plus train Tanzanian grad students, hire professors, and buy textbooks and computers. This has "played an important role in capacity-building for local scientists," says Henry Ndangalasi, a botanist at the University of Dar es Salaam. The nation is "mindful of the importance of scientific knowledge," says Sarunday. "The goal of Tanzania is to achieve economic prosperity and have a protected environment at the same time."

–KEVIN KRAJICK

Kevin Krajick is the author of *Barren Lands: An Epic Search for Diamonds in the North American Arctic*.



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CELL BIOLOGY

Great Balls of Fat

Lipid droplets, long-ignored globules inside cells, are earning recognition as possible organelles involved in cholesterol synthesis and much more

In the breast cells that produce milk, they're called milk fat globules. In plants, they go by the name oil bodies. In fruit flies, lipid storage droplets. Yeast, lipid particles. Cell biologist Richard Anderson prefers the name adiposomes. Immunologist Peter Weller baptized them eicosasomes.

Whatever their name, these intracellular blobs of triglycerides or cholesterol esters, encased in a thin phospholipid membrane, are catching the attention of more and more biologists. It turns out these lively balls of fat have as many potential roles within cells and tissues as they have names. Pockmarked with proteins with wide-ranging biochemical activities, they shuffle components around the cell, store energy in the form of neutral lipids, and possibly maintain the many membranes of the cell. The particles could also be involved in lipid diseases, diabetes, cardiovascular trouble, and liver problems.

This is a far cry from earlier perceptions of lipid droplets, the name most scientists use for the particles. Biologists once considered lipid droplets just inert storage vessels for energy-rich fats. Yet recent studies indicate that the cell keeps a tight rein on their function with molecules that regulate what the particles do, where they go, and what other cellular compartments they cavort with. And a new technique that allows better imaging of lipid droplets in live cells promises even more surprises.

"I've been in cell biology for more than 30 years, and lipid droplets have always been this bag of lipid," says Anderson, who conducts membrane research at the University of Texas Southwestern Medical Center in Dallas. "What is new is the focus on the droplet as an organelle."

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