


We are witnessing
a mass extinction.
An exotic fungus is
delivering the fatal blow
to many amphibians
already hit by habitat
loss, pollution, and
climate change.
But unprecedented
research and rescue
efforts may offer a
lifeline to species
on the edge.

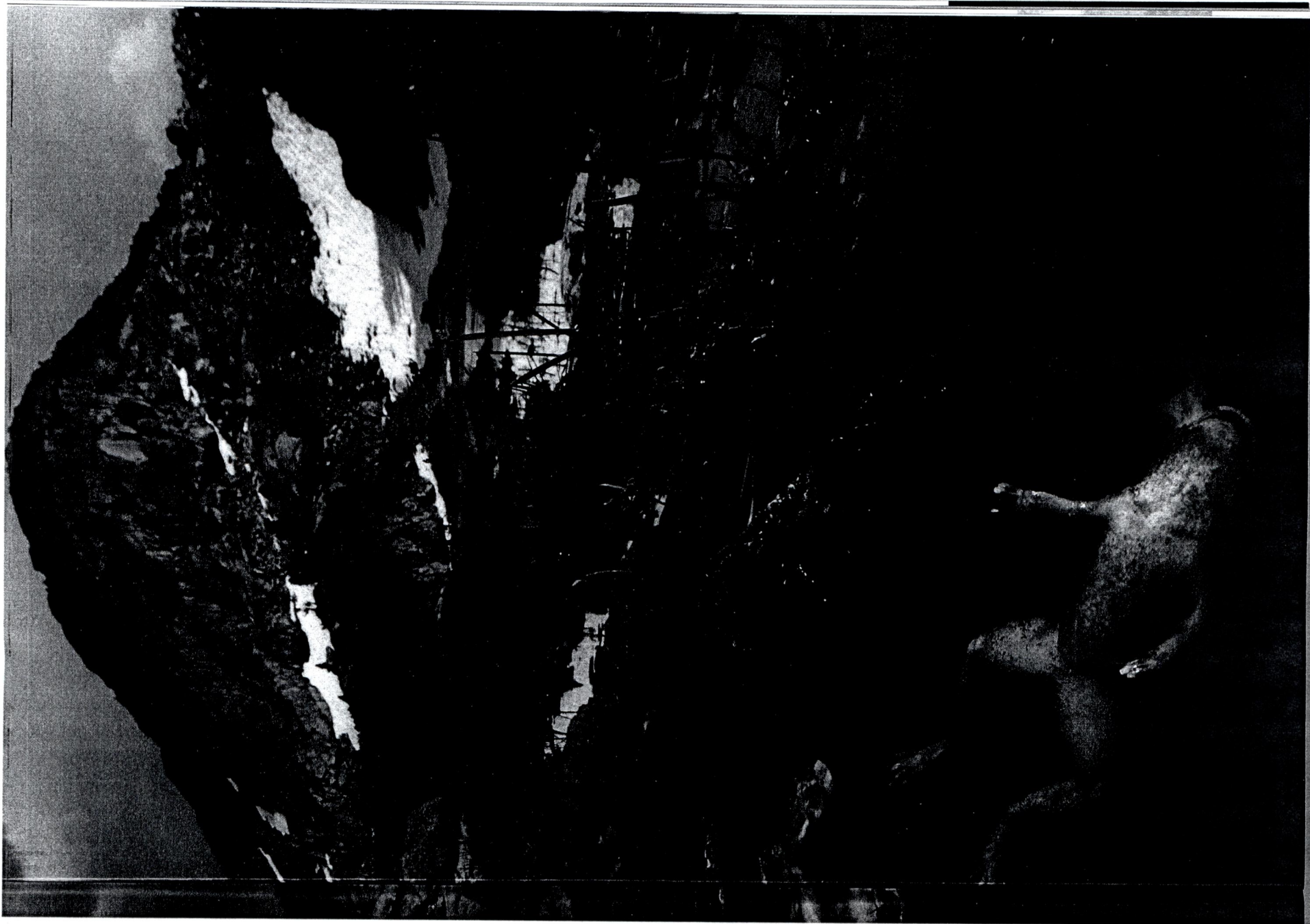
BY JENNIFER S. HOLLAND
PHOTOGRAPHS BY JOEL SARTORE



SURO STREAM FROG · *Hyloscirtus pantostictus*
At Pontificia Universidad Católica del Ecuador
UP TO 2.5 INCHES · SOUTH AMERICA · ENDANGERED

A dark, grainy photograph of a mountain landscape. In the foreground, a stream or waterfall flows over rocks. The background shows a steep, rocky mountain slope under a dark sky. The overall tone is somber and atmospheric.

Far from civilization, mountain yellow-legged frogs high in California's Sierra Nevada are dying in droves. The culprit: amphibian chytrid fungus, which first appeared here in 2004 and has since wiped out tens of thousands of animals.



HE GRIPS HIS MATE, front legs clasped tight around her torso. Splayed beneath him like an open hand, she lies with her egg-heavy belly soaking in the shallow stream. They are harlequin frogs of a rare *Ateolopus* species, still unnamed and known only in a thin wedge of the Andean foothills and adjacent Amazonian lowlands. The female appears freshly painted—a black motif on yellow, her underside shocking red. She is also dead.

Above this tableau, at the lip of the ravine, a bulldozer idles. Road construction here, near the town of Limón in southeastern Ecuador, has sent an avalanche of rocks, broken branches, and dirt down the hillside, choking part of the forest-lined stream. Luis Coloma steps gingerly over the loose rocks, inspecting the damage to the waterway. The 47-year-old herpetologist is bespectacled and compact in a yellow shirt dotted with tiny embroidered frogs. He hasn't bothered to roll up his khaki pants, which are soaked to the knees. Poking a stick into the debris, he says, "They have destroyed the house of the frog."

Frogs and toads, salamanders and newts, wormlike (and little-known) caecilians—these are the class Amphibia: cold-blooded, creeping, hopping, burrowing creatures of fairy tale, biblical plague, proverb, and witchcraft. Medieval Europe saw frogs as the devil; for ancient

Egyptians they symbolized life and fertility; and for children through the ages they have been a slippery introduction to the natural world. To scientists they represent an order that has weathered over 300 million years to evolve into more than 6,000 singular species, as beautiful, diverse—and imperiled—as anything that walks, or hops, the Earth.

Amphibians are among the groups hardest hit by today's many strikes against wildlife. As many as half of all species are under threat. Hundreds are sliding toward extinction, and dozens are already lost. The declines are rapid and widespread, and their causes complex—even at the ravine near Limón the bulldozer is just one hazard of many. But there are glimmers of hope. Rescue efforts now under way will shelter some animals until the storm of extinction passes. And, at least in the lab, scientists have treated frogs for a fungal disease that is devastating populations around the world.

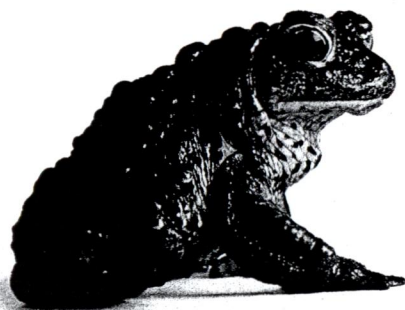
In Quito, Coloma and his colleague Santiago Ron have established a captive-breeding facility for amphibians at the zoological museum at Pontificia Universidad Católica del Ecuador. They admit it's a drop in the pond, offering safe harbor to a select few in hopes of stemming national losses. The facility houses just 16 species, although Ecuador is home to more than 470. And that's just what's on the books. Despite heavy deforestation across this country, every year new species are discovered. Coloma's lab has about 60 recently discovered species still

Jennifer S. Holland is a senior writer for National Geographic. Joel Sartore is a frequent contributor to the magazine, often photographing threatened species.

BOREAL TOAD

Anaxyrus (Bufo) boreas

At the Cheyenne Mountain Zoo, Colorado
UP TO 5 INCHES · WESTERN UNITED STATES · DECLINING



COMMON FIRE SALAMANDER

Salamandra salamandra

At the St. Louis Zoo, Missouri
UP TO 10 INCHES · EUROPE · DECLINING





Scientists in Ecuador's Andes test an *Atelopus* frog for chytrid fungus (result: positive). The frog's breeding stream was clogged with construction debris. Forest clearing, aridity, and infectious disease are proving a lethal mix for a host of species in the amphibian-rich Southern Hemisphere.

OOPHAGA SYLVATICA
At Pontificia Universidad Católica del Ecuador
UP TO 1.5 INCHES · SOUTH AMERICA · DECLINING

PRISTIMANTIS SP.
At Reserva Las Gralarias, Ecuador
UP TO 2 INCHES · ECUADOR · STATUS UNKNOWN

GOLDEN POISON FROG
Phyllobates terribilis
At Rolling Hills Zoo, Salina, Kansas
UP TO 2 INCHES · COLOMBIA · ENDANGERED



By 2000, teams were grabbing up animals to stash them away— at zoos, at hotels, anywhere space could be carved out.

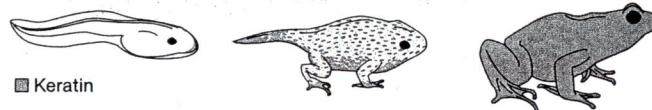
awaiting scientific names—enough to keep ten taxonomists hard at work for a decade.

Coloma and Ron, who have also initiated land purchases for habitat protection, hope to add room at the captive facility for more than a hundred species. But the pool of wild animals is shrinking fast. Where field scientists once had to watch their step to avoid crushing frogs moving in mass migrations, now counting a dozen feels like a victory. “We’re becoming paleontologists, describing things that are already extinct,” Ron says. At the Quito lab the evidence is stacked

the Limón stream. Both animals tested positive for chytrid fungus, and the male died soon after the female.

Chytrid was wiping out amphibians in Costa Rica back in the 1980s, although no one knew it at the time. When frogs started dying in big numbers in Australia and Central America in the mid-1990s, scientists discovered the fungus was to blame. It attacks keratin, a key structural protein in an animal’s skin and mouthparts, perhaps hampering oxygen exchange and control of water and salts in the body. African clawed

The protein keratin is the target of chytrid fungus. Frogs have more of it than tadpoles, making them more vulnerable to infection.



high. Coloma holds up one jar from a cabinetful. Two pale specimens bob in alcohol. “This species,” he says, his face distorted through the glass, “went extinct in my hands.”

IT'S NO WONDER some view our time on Earth as a mass extinction. Biodiversity losses today have reached levels not seen since the end of the Cretaceous period 65 million years ago. Yet amphibians were able to hold on through past extinction spasms, surviving even when 95 percent of other animals died out, and later when the dinosaurs disappeared. If not then, why now?

“Today’s amphibians have taken not just a one-two punch, but a one-two-three-four punch. It’s death by a thousand cuts,” says University of California, Berkeley, biologist David Wake. Habitat destruction, the introduction of exotic species, commercial exploitation, and water pollution are working in concert to decimate the world’s amphibians. The role of climate change is still under debate, but in parts of the Andes, scientists have recorded a sharp increase in temperatures over the past 25 years along with unusual bouts of dryness.

But a form of fungal infection, chytridiomycosis (chytrid for short), often administers the coup de grâce. It did for the mating pair in

frogs, exported widely for pregnancy tests beginning in the 1930s, may have been the initial carriers of the fungus. “It’s amazing we haven’t seen even more population crashes, the way we shuffle things all over the world, complete with pathogens,” notes Ross Alford of Queensland’s James Cook University.

Chytrid is now reported on all continents where frogs live—in 43 countries and 36 U.S. states. It survives at elevations from sea level to 20,000 feet and kills animals that are aquatic, land-loving, and those that jump the line. Locally it may be spread by anything from a frog’s legs to a bird’s feathers to a hiker’s muddy boots, and it has afflicted at least 200 species. Gone from the wild are the Costa Rican golden toad, the Panamanian golden frog, the Wyoming toad, and the Australian gastric-brooding frog, to name a few. Some scientists play down the importance of any single factor in overall declines. But in a 2007 paper, Australian researcher Lee Berger and colleagues, who first laid blame on the fungus, put it this way: “The impact of chytridiomycosis on frogs is the most spectacular loss of vertebrate biodiversity due to disease in recorded history.”

It’s been a time of desperate measures. For example, after Southern Illinois University researcher Karen Lips and colleagues reported

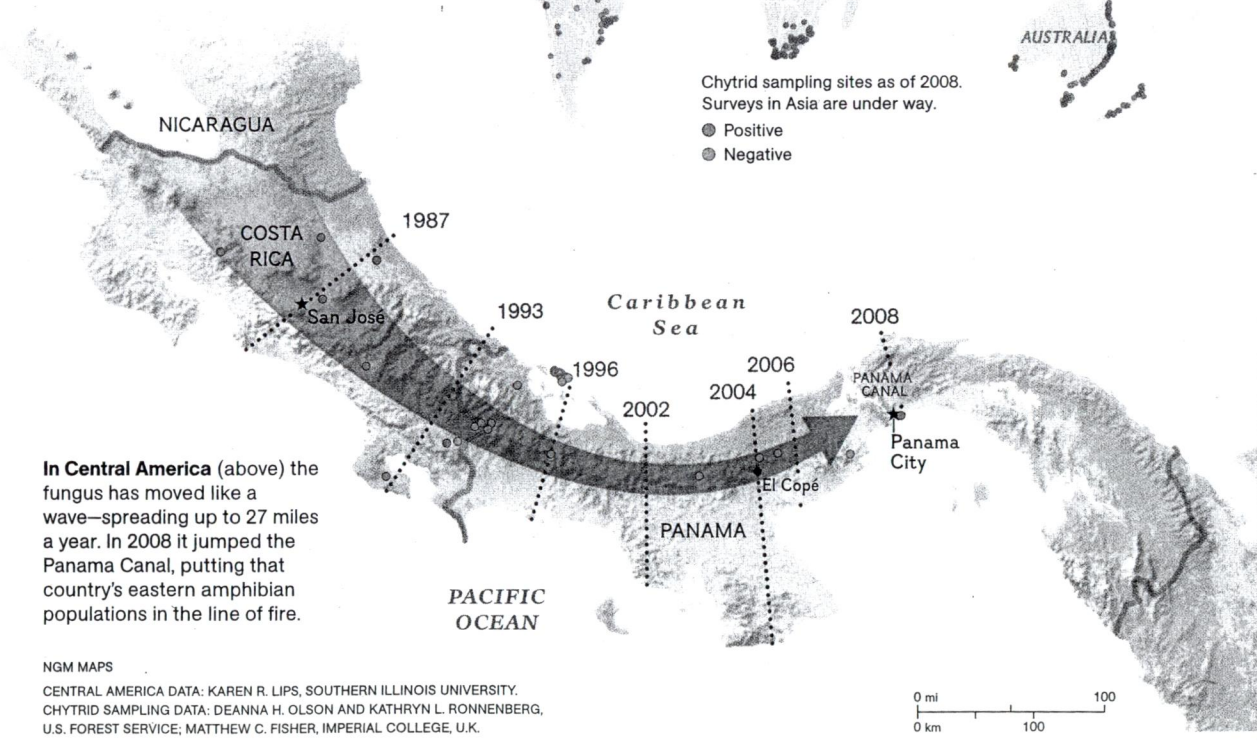
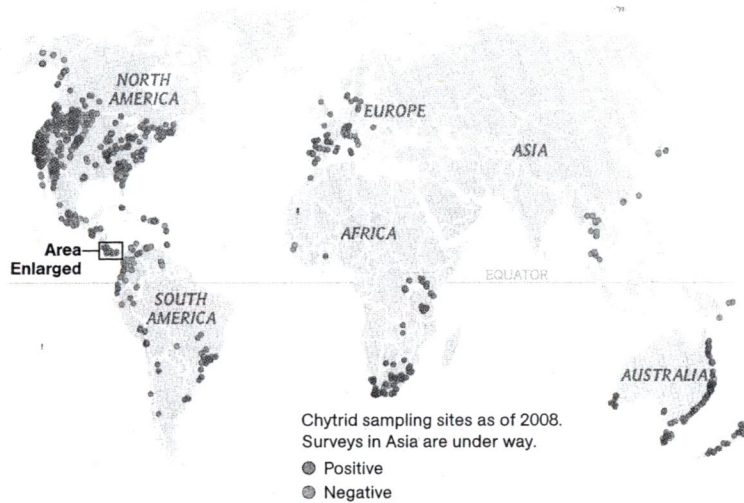
fungus-related declines in Costa Rica and Panama in the late 1990s, they began mapping chytrid's path and predicting its victims. By 2000, teams were grabbing up animals from the most vulnerable species to stash them away—at zoos, at hotels, anywhere temporary space could be carved out for stacks of aquariums. Sick frogs were treated and quarantined. Many were exported (with much political wrangling) to U.S. zoos, while a Panamanian facility was built to house nearly a thousand animals. So began the Amphibian Ark, a growing international

venture aimed at keeping at least 500 species in captivity for reintroduction when—if—the crisis is resolved. But the task is immense and expensive, and there's no guarantee how many healthy wild places will be left for amphibians to recolonize.

THE TROPICS, where conditions foster high amphibian biodiversity, have seen the most dramatic declines. But more temperate climates haven't been spared. Consider the cold, upper reaches of the Sierra Nevada of California. Here,

Chytrid on the March

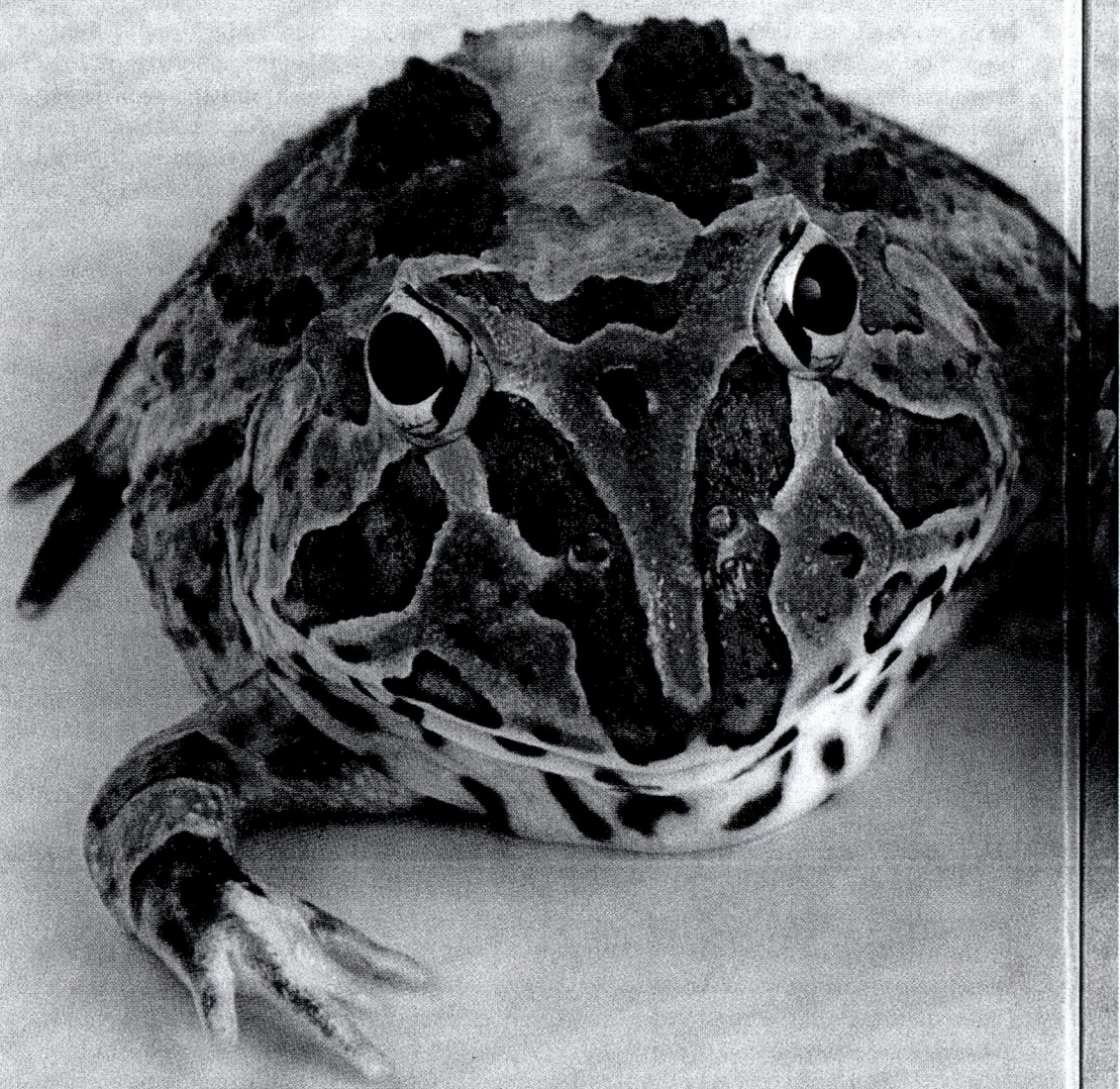
Global data reveal the alarming reach of amphibian chytridiomycosis, first reported in the wild in Australia, but likely originating in Africa.



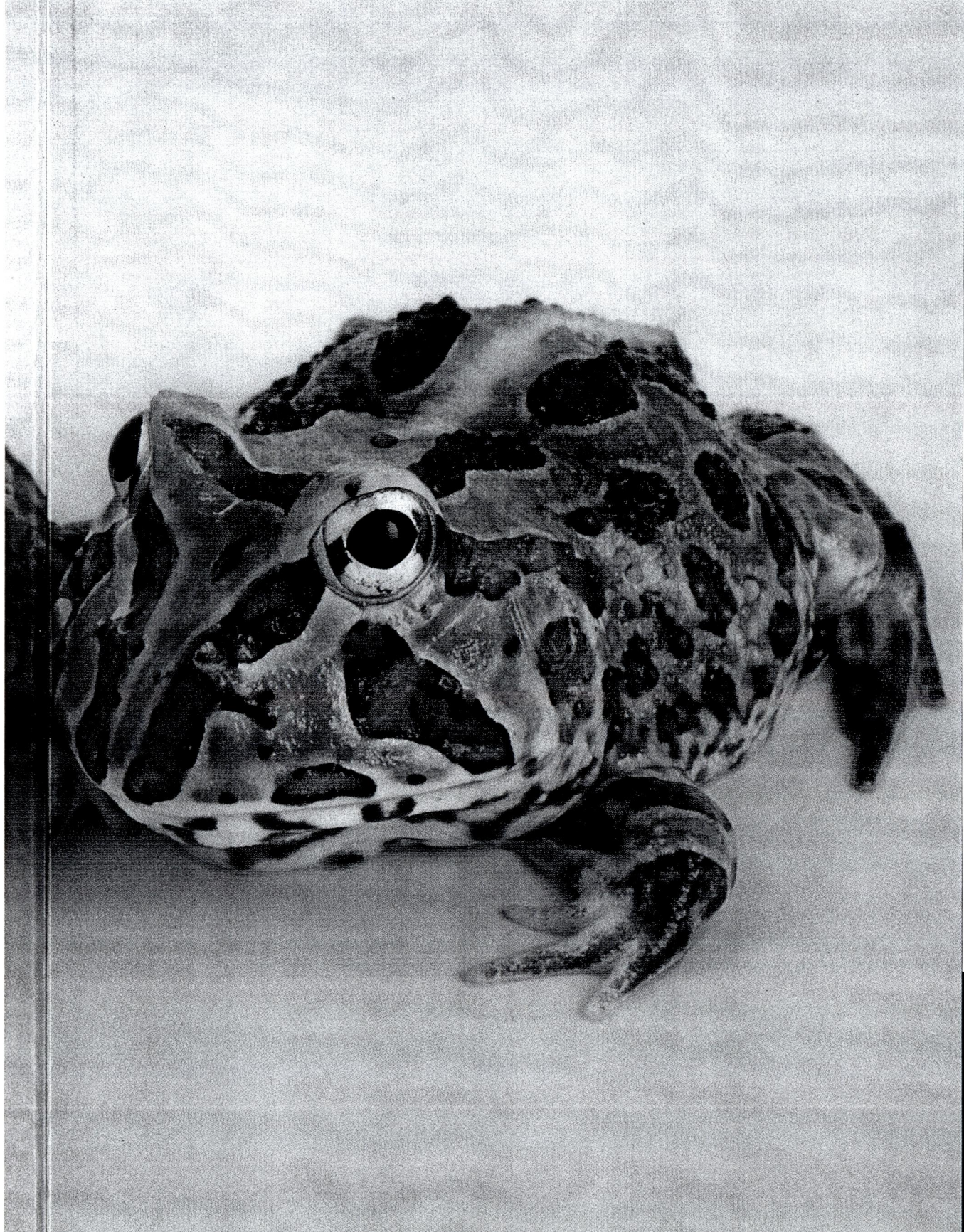
In Central America (above) the fungus has moved like a wave—spreading up to 27 miles a year. In 2008 it jumped the Panama Canal, putting that country's eastern amphibian populations in the line of fire.

NGM MAPS
CENTRAL AMERICA DATA: KAREN R. LIPS, SOUTHERN ILLINOIS UNIVERSITY.
CHYTRID SAMPLING DATA: DEANNA H. OLSON AND KATHRYN L. RONNENBERG,
U.S. FOREST SERVICE; MATTHEW C. FISHER, IMPERIAL COLLEGE, U.K.

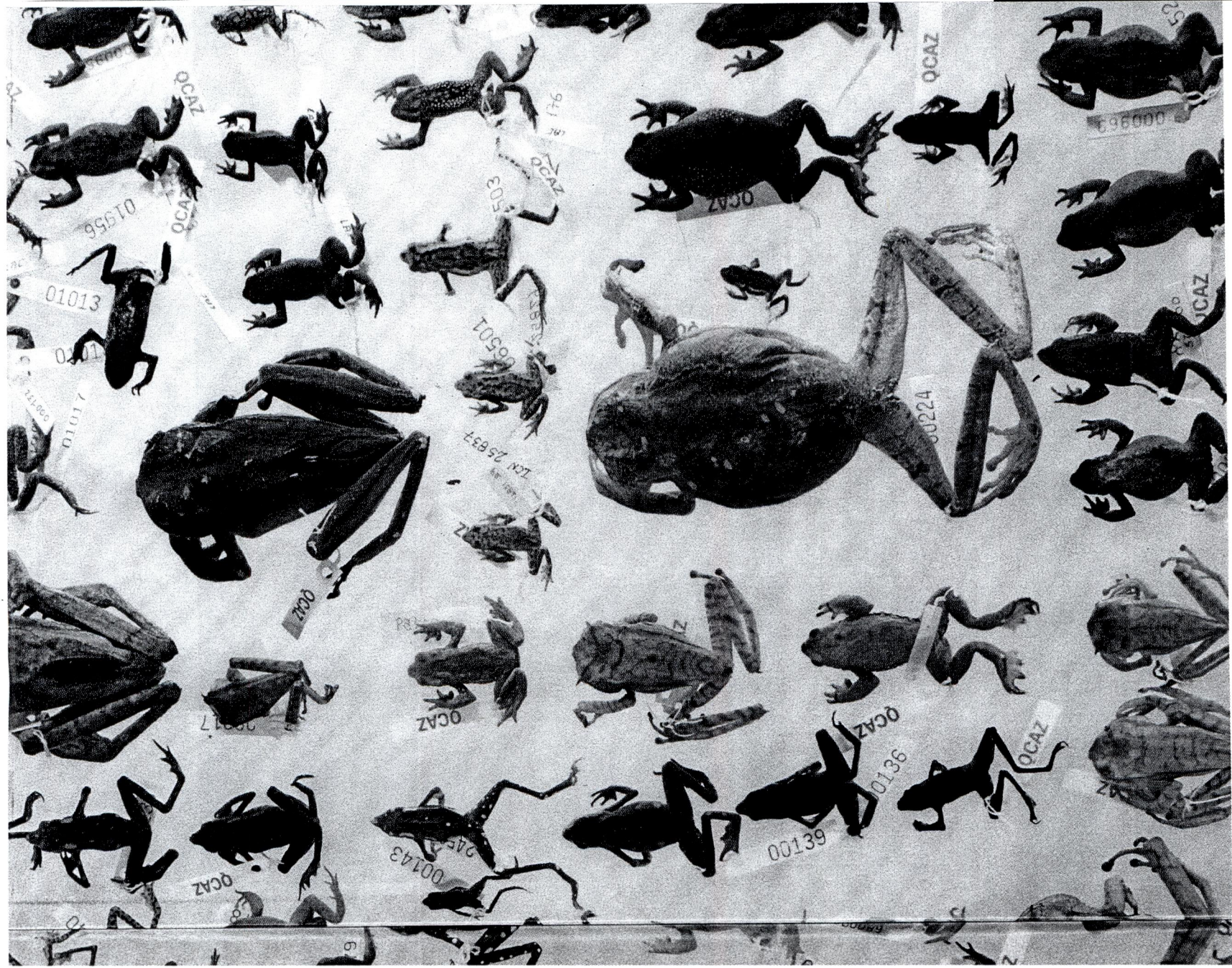


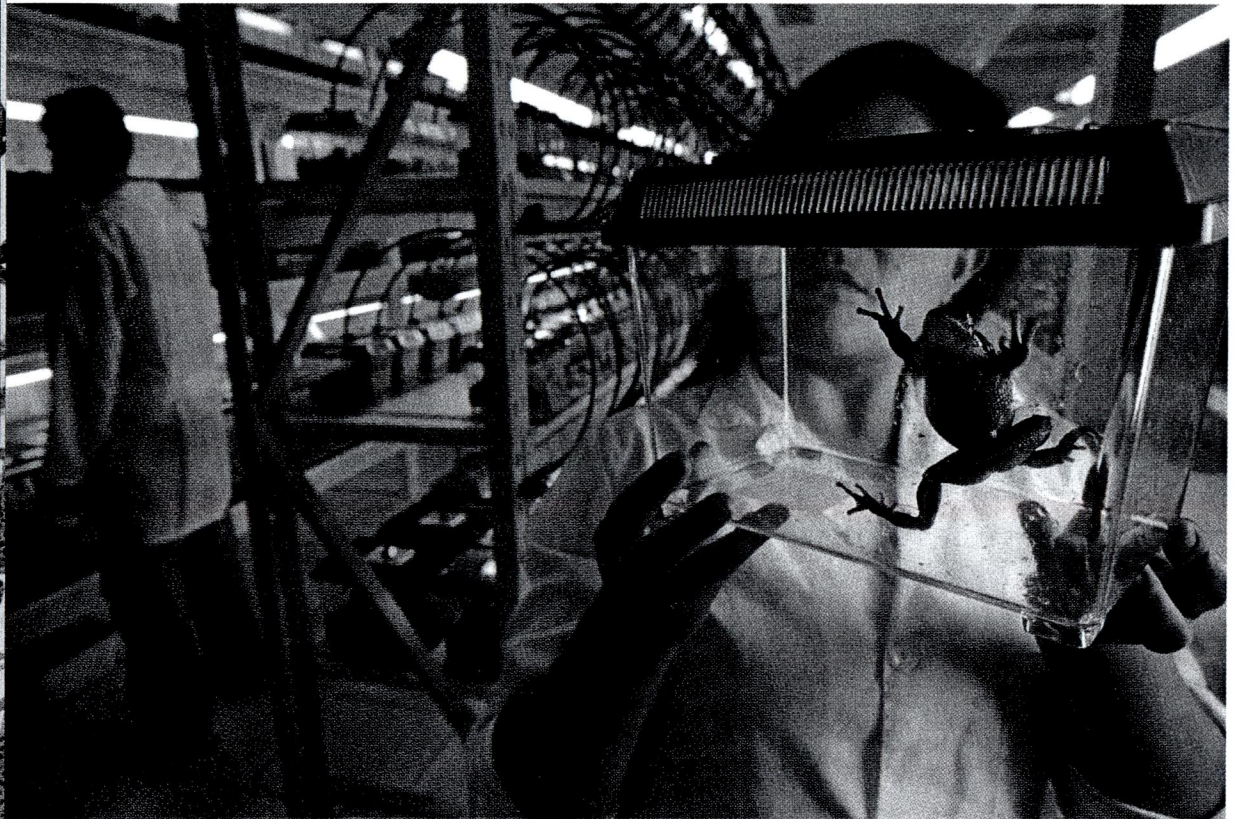


In the wild, Pacific horned frogs breed explosively during good rains and burrow underground most other times. Conversion of scrub and sandy habitat for agriculture is reducing frog numbers, but now the species is reproducing in captivity for the first time.



PACIFIC HORNED FROG - *Ceratophrys stolzmanni*
At Pontificia Universidad Católica del Ecuador
UP TO 3 INCHES - ECUADOR AND PERU - VULNERABLE





Captivity is the last resort for *Gastrotheca pseustes* (above) and 15 other endangered species, more than 900 individuals total, at Pontificia Universidad Católica in Quito. A staff of seven, a few volunteers, and about \$100,000 a year now support the breeding facility. Expansion plans will beg more funds.

ORNATE HORNED FROG

Ceratophrys ornata

At the Tennessee Aquarium, Chattanooga

UP TO 4 INCHES · SOUTHERN SOUTH AMERICA · DECLINING



REINWARDT'S TREE FROG

Rhacophorus reinwardtii

At the Knoxville Zoo, Tennessee

UP TO 2.5 INCHES · ASIA · DECLINING



MARSUPIAL FROG

Gastrotheca pseustes

At Pontificia Universidad Católica del Ecuador

UP TO 2.5 INCHES · ECUADOR · ENDANGERED



at 11,000-foot-high Sixty Lake Basin, stands a stark paradise of granite towers made famous through the lens of Ansel Adams, where alpine lakes once roiled in summer with hearty frog populations. The most common species is the mountain yellow-legged frog—subtly pretty, tinged yellow on torso and limbs, spotted brown and black. But recently this palm-size frog has been hard to find.

A slender man with a camper's stubble and a soft demeanor squats at the side of pond number 100, bordered by stoic rock walls and edged with pink mountain heather and tangled grasses. Vance Vredenburg is a biologist at San Francisco State University, and he's been studying the mountain yellow-legged frog for 13 years, slumming in a tent on the mountainside for weeks at a time as he monitors 80 different study lakes. Today, mosquito net balled up around his neck, he contemplates ten dead frogs, stiff-legged, white bellies going soft in the sun.

"It wasn't long ago when you walked along the bank of this pond," he recalls, "a frog leapt at every other step. You'd see hundreds of them alive and well, soaking in the sun in a writhing mass." But in 2005, when the biologist hiked up to his camp anticipating another season of long-term studies, "there were dead frogs everywhere. Frogs I'd been working with for years, that I'd tagged and followed through their lives, all dead. I sat down on the ground and cried."

Vredenburg's biggest remaining study population, in pond number 8, has about 35 adults.

Most of the rest of the animals he's known in this place are gone. What happened here is the perfect example of those multiple punches—a case study of how a thriving species can get knocked to its knees.

It started with the trout.

Until the late 19th century, the Sierra Nevada was mostly fishless above the waterfalls. But state policy of fish stocking eventually climbed to the high Sierra to transform those "barren" lakes into a fisherman's paradise. The California Department of Fish and Game began sending trout up the cliffs, first in barrels on muleback, and by the 1950s in the bellies of airplanes. (The planes would fly over the water and let drop their living cargo, much of which missed its mark and was left flopping on dry land.) All told, more than 17,000 mountain lakes were stocked.

As it turns out, trout eat tadpoles and young frogs. As trout multiplied, frogs disappeared.

Vredenburg's work in Sixty Lake Basin became an attempt to restore the lakes to their pre-1900s fishless status in order to bring back the frogs. He unfurled wide nets bank to bank, reeled them in, and disposed of the catch (often on the grill with a little salt and pepper). Eventually the National Park Service took over the project, and now 14 lakes are fish-free or virtually so. As more fish were netted out, Vredenburg says, the "frogs started to recolonize; the lakes were coming back to life."

But then came another blow. Chytrid, which had already invaded Yosemite National Park,

LEMUR LEAF FROGS

Hylomantis lemur

At Zoo Atlanta, Georgia

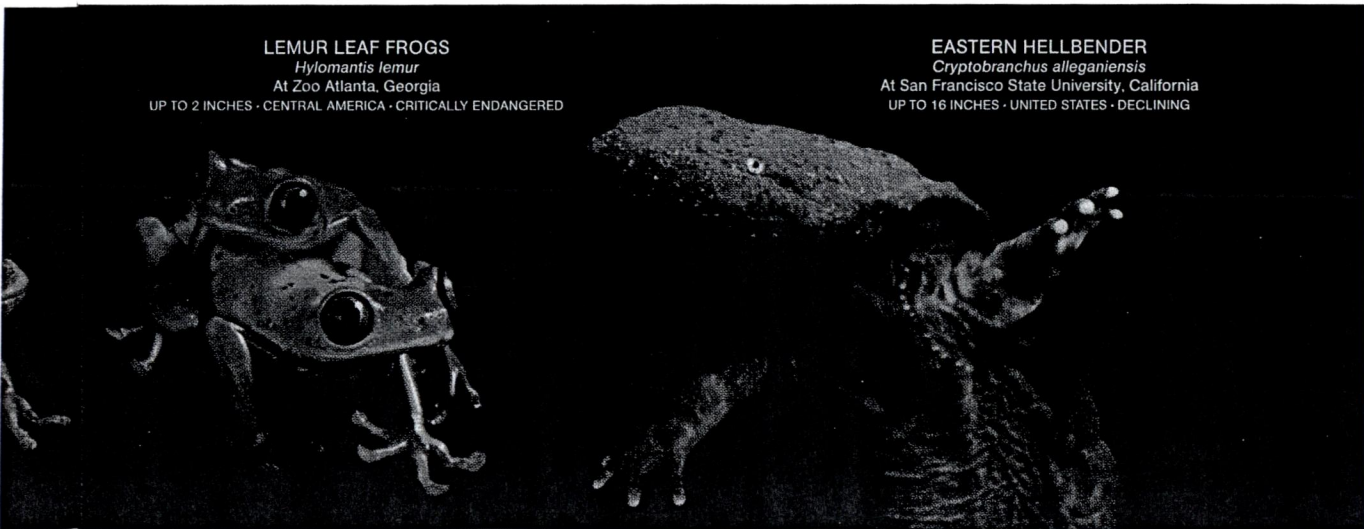
UP TO 2 INCHES • CENTRAL AMERICA • CRITICALLY ENDANGERED

EASTERN HELLBENDER

Cryptobranchus alleganiensis

At San Francisco State University, California

UP TO 16 INCHES • UNITED STATES • DECLINING





BUDGETT'S FROG · *Lepidobatrachus laevis*
At the National Aquarium, Baltimore, Maryland
UP TO 4 INCHES · SOUTH AMERICA · DECLINING

Amphibians have evolved into 6,000 singular species as beautiful, diverse—and imperiled—as any on Earth.

arrived in Sixty Lake Basin and swept from lake to lake, around a hundred of them, in a predictable and deadly line. After removing fish and restoring habitat, “to have this disease wipe the frogs out again—it breaks my heart,” he says.

Oddly, the fungus infects but doesn't kill tadpoles, which is why wriggling schools remain in otherwise lifeless ponds. Mountain yellow-legged frogs take some six years to mature. “Those tadpoles are from years ago—there's been no breeding in this pond since chytrid arrived,” Vredenburg explains. “As soon as they transform into frogs, they'll die.”

Yet Vredenburg remains doggedly optimistic. He calls pond number 8 his victory pond. When he saw the frogs start to die, he removed some of the adults and treated them with an antifungal medication, then put them back. The population—though tiny—has now been stable for three years running. Vredenburg plans to apply his painstaking capture-treat-release method to animals in other ponds in Sixty Lake Basin. (Recently announced, a similar treatment project by a U.K. team aims to mitigate disease in the Mallorcan midwife toad of Spain.) If enough fungal spores can be cleared from frogs' bodies, he says, the disease may lose its hold.

Other sites are also yielding good news. Some amphibians aren't affected by the fungus or can carry it without being hobbled. Certain Costa Rican tree frogs have skin pigments that allow them to bask in the sun without drying out, killing the fungus with heat. Most encouraging, Reid Harris of James Madison University and colleagues have found an innate defense in salamanders and some frogs: symbiotic skin bacteria that inhibit chytrid infection. (Some naturally occurring skin proteins show similar fungus-fighting properties.) “If we can augment the good bacteria to help lower transmission,

Gaping defensively, a single Budgett's frog stands among many in the fight for amphibian survival. Researchers have ramped up the search for solutions, and each small victory breeds new hope.

there may be time for the animals to ramp up their own immunity,” Harris says. “And we wouldn't be putting anything into the environment that isn't already there. Perhaps we can stop the epidemic outbreaks of chytrid.”

Upcoming Amphibian Ark projects may help researchers test these measures. In Panama, chytrid has only recently jumped the canal and begun a march eastward toward the still pristine Darién Province, where at least 121 amphibian species are known. One rescue facility is already up and running there; U.S. and Panamanian partners are now planning another—in part for research into how to boost enough healthful skin microbes in wild populations to stop the fungus cold. If the strategy works, the golden frog, for one, may be returned in healthy numbers to Panama's forests. Meanwhile, in frog-rich Ecuador, Coloma and Ron have petitioned the government for an environmental audit of the Limón road project. Construction has ceased for now, and some habitat restoration may be done. Though perhaps too late to save the choked stream's animals, media attention there could help future land preservation efforts.

WHY CARE ABOUT FROGS? “I could give you a thousand reasons,” says Coloma. Because their skin acts not only as a protective barrier but also as a lung and a kidney, they can provide an early warning of pollutants. Their insect prey carries human pathogens, so frogs are an ally against disease. They serve as food for snakes, birds, even humans, playing a key role in both freshwater and terrestrial ecosystems. “There are places where the biomass of amphibians was once higher than all other vertebrates combined,” says David Wake. “How can you take that out of the ecosystem without changing it in a major way? There will be ecological consequences that we haven't yet grasped.”

“The story is much bigger than frogs,” says Vredenburg. “It's about emerging disease and about predicting, coping with, and fighting things we don't fully understand. It's about all of us. Everyone should care.” □

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A Gordon's mossy frog plays dead at a South Dakota reptile center.
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PHOTO: JOEL SARTORE

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