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First noticed in 1990, amphibians in Costa Rica are disappearing at an accelerating rate. It was the decline of the country's trademark golden frog that first made news, but further study showed that the Monteverde harlequin frog, Atelopus, disappeared in the 1980s. Since that time, at least 110 species of the brightly colored animals that once lived in the tropics of Central and South America have ceased to exist, leaving behind a number of hypotheses of why this has happened.

A new study provides the first clear proof that global warming is causing outbreaks of an infectious disease responsible for these losses. The study, published in the Jan. 12 issue of the journal Nature, reveals how warming may alter the dynamics of a skin fungus fatal to the animals. "Disease is the bullet that's killing the frogs, but climate change is pulling the trigger," said the study's lead scientist, J. Alan Pounds. "Global warming is wreaking havoc on amphibians and soon will cause staggering losses of biodiversity." Pounds is affiliated with the Tropical Science Center's Monteverde Cloud Forest Preserve in Costa Rica (see NotiCen, 1997-11-06).

Another scientist on the project, Bruce Young of NatureServe, said that if there is any good news at all in these findings, it is that they will open new avenues of research that could save the amphibians still surviving. The study demonstrates the complex nature of global climate change and how climate affects the spread of disease. Beyond the threat to these species, global warming and the accompanying emergence of infectious diseases are a real and immediate threat across the board, to all species, according to Sam Schiener, ecology of infectious diseases program director for the National Science Foundation's (NSF). Pounds and co-workers used records of sea-surface and air temperatures to show, with a high degree of confidence, that the disappearances of harlequin frogs correlate with changing climate. In this case, a high degree of confidence means that the likelihood the correlation arose by chance is less than one in a thousand.

In the Monteverde area and in similar regions, rising temperatures enhance cloud cover on tropical mountains, bringing cooler days and warmer nights. These conditions favor the growth and spread of the chytrid fungus, the agent shown to be killing the animals. The fungus grows and reproduces best within a range of 17 to 25 degrees centigrade.

One of the key findings of the study embraces the counterintuitive observation that global warming results in localized cooling in places like Monteverde, accounting for the difficulty scientists have had in pinpointing the proximal cause of the extinctions and establishing the causal links. Prior to this observation, available data could be, and were, used to deny a connection between warming and the decline of the populations.

As recently as 2000, Science Daily reported, "A NASA-funded study to search for links between local climatic variation and the beginning of specific amphibian declines that have occurred in three areas of the world in the past several decades has turned up no significant correlation between the two." The fungus attacks the keratin layer of the skin of amphibians, and damages it. Since these species use their skin for respiration and hydration, it is thought that interference with these processes is the mechanism by which they die of asphyxia and dehydration.

Also, earlier work showed that elevated body temperatures, reached naturally by basking in the sun or seeking warm microenvironments, can rid frogs of the fungus. But recourse to these defenses is compromised by changing climatic conditions. It is also possible that a toxin produced by the fungus might contribute.

The Global Amphibian Assessment of 2004 found that nearly one-third of the world's more than 6,000 species of frogs, toads, and salamanders are headed for extinction, a greater proportion than for any other animal group. Some doubt, more confidence in the findings Schneider admitted to some uncertainties in the new work but said the study was nevertheless significant. But other workers in the field are less impressed.

Cynthia Carey, amphibian disease expert at the University of Colorado, said the evidence offered in the paper was circumstantial. "It is difficult to prove cause and effect on the ground where multiple factors interact in complex ways," she told The New York Times. Carey co-authored the NASA-funded study that found no links to climate change in 2000, which was presented to the American Association for the Advancement of Science that year and which the Times did not mention. But for Schneider, who collaborated in the present study, "It's like anything else that's complex. When you're in the early phases of learning you look for multiple lines of argument and, when they converge with basic theory, you increase your confidence in a connection."

In this instance, confidence has also been bolstered by the observation that the observed patterns of extinction vary with altitude, as do the effects of climate change. Montane Atelopus species that live at altitudes between 1,000 and 2,400 meters show higher rates of extinction than do those that live only in lowlands or just in the highest elevations.

Commenting on the Pounds paper in a companion article in Nature, ecologist Andy Dobson and zoologist Andrew Blaustein emphasize these facts in concluding that the work is a breakthrough because it "offers a theory to explain the widespread enigmatic declines of Atelopus and other amphibians. The authors combine two disparate approaches into one unifying theory, simultaneously explaining how shifting temperatures are the ultimate trigger for the expansion of a pathogenic fungus, and that this infection is the direct cause of Atelopus extinctions."

Dobson and Blaustein also note what they call a "tragic irony" in the demise of these creatures. They recount that the earliest hosts of the pathogen Batrachochytrium dendrobatidis are African clawed frogs, Xenopus, first recorded in South Africa in 1938. In the 1950s, a global trade in these frogs followed the development of a pregnancy test that used their tissue. "So it seems that the expansion in one frog species through trade may have led to the extinction of other amphibian species a totally unexpected, indirect consequence of human ingenuity," wrote the scientists.

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They also note that frogs and fungi are not the only example of synergistic interactions between pathogens and climate change affecting biodiversity. They give as examples modification of the life cycle of nematode parasites in musk oxen in the Arctic and warming in the western US allowing the mountain pine beetle to double its life cycle, become more abundant, and spread the fungus they carry to pine trees in the highest elevations of the Rocky Mountains, where pine blister rust has become serious.

Few of the current models used to forecast extinctions include these interactions, and, without taking account of these variables, Dobson and Blaustein predict limited success and overly optimistic prognoses of how biodiversity will be affected by climate change. "The frogs," they write, "are sending an alarm call to all concerned about the future of biodiversity and the need to protect the greatest of all open-access resources, the atmosphere."

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