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A Crisis for the World's Amphibians: an Issue in Biodiversity Science

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During the 1980's biologists around the World independently began noticing that many species of amphibians, especially frogs, were less abundant than they had been previously. Only during the First World Congress of Herpetology, held in Canterbury, England, in late 1989, did these researchers have an opportunity to compare experiences and to discover that their observations were similar to those of others. Yet, many species seemed to be unaffected, and in some regions there were no reports of declines. At first there was a suspicion that only normal cycles of population density were involved, and some biologists thought others were over-reacting. The other common explanation was that habitat modification accounted for many instances of decline.

By the time of the mid-1990's accumulated information supported the earlier impression that something unusual was taking place and that amphibians around the world were indeed at risk. Curiously, amphibian declines and disappearances were being recorded from relatively protected areas, including large national parks in Australia and the United States of America, and the renowned and well protected Monteverde Cloud Forest Reserve in Costa Rica. By 1997 solid evidence of the disappearances of some species and the declines of many others had been published in highly respected scientific journals, and there was no longer any doubt that a crisis was at hand.

Researchers were puzzled because frogs in some of the most highly modified habitats were not evidently affected. Frogs remained abundant in agricultural districts of India, Vietnam, Indonesia, China, Japan, eastern United States and western Europe. What could explain the apparent stability of frog populations in areas where they co-occurred with humans, but declines and disappearance where frogs were living under protection?

One possibility is that frogs in areas of intense human occupancy have co-evolved with slowly growing human populations for a long time, perhaps several thousand years in the case of Japan, southeastern Asia and western Europe, and survivor phenotypes have been heavily selected in these areas for agricultural habitats (such as rice paddies, which provide opportunities for feeding, breeding and a good life for many frogs). However, those species in protected areas had never experienced much habitat change; they might be the best biological indicators of some recent environmental change that has implications for organisms other than frogs as well.

Many attributes of frogs suggest that they might be effective as indicators of the state of health of the environment. They typically have a bimodal life cycle, being aquatic as larvae and semiaquatic to terrestrial as adults, and thus experience a range of environments during a single life span. As larvae they are herbivorous, whereas as adults they are carnivorous, so they are sampling a variety of food. They have moist, semipermeable skins, and they respire through their skin, thus placing them in a very direct relationship with the environment. Attributes of their life history (e.g., large clutch sizes and ease of experimental
manipulation) make them suitable subjects for ecological studies of the impacts of environmental variables. However, they are an ancient group (ca. 200 million years old); if something is happening to them during our short life spans, we should be concerned.

What we do know is that several species have completely disappeared. Chief among these are the famous Golden Toad (Bufo periglenes) of Costa Rica, and the Stomach-brooding Frogs (Rheobatrachus) of the Amazon, Brazil; but there are also a number of other less well known species. Declines are severe in Costa Rica and Panama, and in the eastern United States. As many as 90% of known frogs now lack frogs as a result of environmental changes.

As scientists studied this phenomenon in greater detail, a confusing number of potential factors responsible for the declines emerged. For example, there is strong evidence that the declines and disappearances of about 50% of the frog species in the Monteverde Reserve coincided with a period of exceptional drought associated with an El Niño climatic effect. But to many biologists it seems extraordinary that species that have existed so long should be wiped out by a period of weather that is only extreme in our experience. Surely there have been more severe climatic events during the past one million years, one supposes. And this event will not account for the disappearance of aquatic frogs in Australia, or for the montane frogs in California.

Many, but not all, of the declining species occur in montane areas. There has been much concern about the ozone hole above the Antarctic Continent and the possibility of increased ultraviolet light (UV) and its impact on living systems. Biologists have demonstrated in rigorous experiments that some species in the mountains of Oregon are negatively affected by ambient levels of UV-B. Eggs fail to hatch normally in some species, whereas other species in the same ponds have an enzyme (photolase) that is capable of repairing the damage done by UV-B and there is less evident harm. This factor may be of importance in different parts of the world, but it, too, will not explain all cases. Synergistic effects complicate the story: eggs damaged by UV-B are more susceptible to attack by an algae that is capable of rapidly destroying eggs.

A perplexing fact is that sick frogs and corpses are rarely found. Only recently have deformed, dying and dead frogs been reported, and these offer the hope of discovering what is happening and then taking corrective actions. Recently public attention has been drawn to a phenomenon possibly related to the decline of amphibians. In North America, in particular, there have been numerous instances of the discovery of frogs that have severe developmental anomalies, such as missing limbs, and cycloptic eyes (single median eyes), but also with multiple limbs, multiple digits, or both. The multilegged frogs have received a lot of publicity, and several suggestions have been made to explain their occurrence. One group of workers has argued that environmental pollutants are the cause, because a group of chemicals known as retinoids result from the breakdown of pesticides and herbicides and these are known teratogenic chemicals that will cause limb abnormalities in laboratory experiments. Pollutants could be having other impacts on frogs. Another group of workers argues that the multilegged frogs, and even frogs with missing legs, are the result of high levels of infection of the larvae of frogs by larvae of trematode worms, which encyst in the vicinity of the hind limbs. Abnormalities overwhelmingly affect hind limbs, and in frogs the forelimbs are protected from the environment during their development within the operculum, which covers the gills. The argument is that the cysts mechanically interfere with normal limb development, either obliterating the limb bud entirely, or causing it to split early in development and form two or more limbs, or digits, where there should have been only one. Why parasite loads are so high is unclear, but it could signal a weakening of the frog immunological defense mechanisms.

Frogs of many different species have been discovered to be dead or dying, initially in eastern Costa Rica and then in western Panama. These were discovered to be infected by a previously unknown fungus, belonging to a group known as chytrids. This fungus infects the skin and may interfere with normal respiration, among multiple effects. At about the same time a similar, possibly even the same, fungus was found in a number of Australian frogs, and the fungus has also been found in California. This raises the possibility that a recent and maybe new infectious agent is responsible for many of the declines and disappearances. However, as with all of the other potential explanations, there are reasons to question if this is a general explanation. For example, there is no reason to expect this explanation to work for the Monteverde Reserve, where dying frogs were not seen.

There are many reasons to expect that whatever is happening to frogs is related in some way to human activities. In the Sierra Nevada of California there is a striking correlation between distance from the heavily agricultural Central Valley and the presence of frogs, with frogs persisting in only the most distant mountains. Pesticide, herbicide and fertilizer residues have been implicated. In California the negative impact of alien species (introduced bull frogs and trout) on frog populations has been demonstrated. Humans play a role in climate change that is changing levels of UV-B, and humans may have been involved in moving the chytrid fungus around the world.

Frogs exemplify the general biodiversity crisis that is impacting the entire world. Within the next century we will certainly see an enormous amount of extinction, perhaps equivalent to the mass extinctions known in the paleontological record. Perhaps the frogs will serve as an example and as a warning, and help us understand some of the causes of extinction beyond the obvious direct impact we as humans have as a result of our rapidly growing population and associated dramatic modification of natural environments.