Risks of Extinction of Frogs and Toads as a Result of Environmental Changes

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Frogs and toads belong to the order Anura and are conspicuously present in the Brazilian fauna and culture (Figure 1). These animals and the sounds of their choirs are explored in rural scenes of movies and usually associated with folkloric beliefs and legends. Nonetheless, their fascinating biology is totally unknown to most lay people. Thus, in contrast to what several of us may think, not all frogs are green, nocturnal, nor do all frogs call; not all of them lay eggs in the water or go through a tadpole stage. An infinity of colors distinguish them, there are voiceless species, diurnal species, species that move their limbs to communicate with specific individuals, species that carry their tadpoles and tiny juveniles on the back and even those that hatch already as perfect miniatures of the parents.

To date, there are more than 5600 species of anurans in the world, and 849 of them occur in Brazil. These numbers qualify our country as the world leader of anuran diversity, a status that requires considerable responsibility. Almost 500 of the Brazilian species are endemic, that is, exclusively present in our lands. Therefore, if any of them becomes extinct, the world as a whole will lose part of its diversity. However, at least for a good proportion of the lay public, the term "extinction" is restricted to the past; one may think that the last widely known victims of extinction would probably have been the dinosaurs, giant reptiles that dominated the planet around 250 to 150 million years ago, disappearing abruptly and catastrophically. Unfortunately, such a scenario could not be farther from the truth. The specter of extinction remains a threat to the living biodiversity, especially due to environmental changes provoked by man. But what does extinction have to do with frogs and toads, which are the main subject here? This paper refers exactly to the fragile state of conservation of many species of these animals.

Nowadays, anurans are recognized as one of the most threatened animal groups in the world, and have been under a serious biological crisis since the decade of the 1980s. Around 30% of the species may disappear in the next few

years; approximately 25% are so poorly known that their conservation status cannot be precisely determined; finally 35 species are already extinct in nature (IUCN, 2009).

Estimating the threats to anurans is far from an easy task, and it is sad to realize that most of the threatening factors are totally out of our control. Their effects over the anuran populations spread much faster than the progress of our knowledge and capacity to outline proper conservation strategies. The main reasons for the decline and extinctions of anurans are related to environmental changes generated by man. In other words, even unintentionally, we are directly responsible for the dramatic scenario of extinction risks to which anurans are exposed at present.

We are used to hearing the names of threatening factors, such as destruction of natural habitats, introduced species, increase of ultraviolet radiation, pollution, global warming and epidemics. These apparently unbeatable villains are incorporated within our daily life and, with the aid of our indifference, may cause catastrophic environmental problems.

The exploitation of nature by man is chaotic and provokes significant environmental changes. To date, in Brazil and in several other countries, natural environments are somewhat reduced into small remnants or altered fragments increasingly isolated from each other. The area reduction, associated with isolation, affects the whole biodiversity and is one of the main causes of the world decline of amphibians.

Due to the environmental changes caused by habitat destruction, crucial conditions for the survival of many species may become no longer available, a fact that may lead to local extinctions. For example, a species of poison dart frog that lays its eggs in water-holding bromeliads depends on the presence of these plants to continue reproducing. If the bromeliads disappear, breeding will fatally cease and the population will decline until it becomes completely extinct. In an indirect way, the isolation of populations favors inbreeding among closely related individuals, reducing genetic diversity. When it occurs, chances of developmental problems increase, as well as the chance of a population becoming seriously affected by infectious agents. Thus, fragmented amphibian populations are less stable and more subject to significant fluctuations over time. Fragmentation can also result in the isolation of amphibians from the environments they use during different stages of their lives. One example is represented by fragments of Atlantic Forest restricted to highlands and far from the water bodies available in the lower areas. Since most amphibians reproduce aquatically, several species that remain isolated in the highlands may be directly affected by the lack of reproductive sites.

Many exotic species introduced in our country feed on native frog species and may also compete for important resources, such as reproductive sites and food. Besides predation and competition, foreign species can bring diseases from other regions that may cause serious impact on the local fauna, since the latter may lack any sort of immunity. Actually, this problem is as old as our history, if

we recall that the Brazilian natives that inhabited our land frequently perished from the common flu brought by the European colonizers. It is no different with frogs, and the pathogens brought by exotic species can decimate populations in an extremely short period of time.

Ultraviolet radiation (UV) at adequate levels is beneficial to the organisms. However, over exposure can cause mutations and immunological deficiencies. In humans, we know that the incidence of skin cancer has increased due to the exposition to increasing levels of UVB radiation resulting from the destruction of the atmospheric ozone layer. The ozone layer is a natural filter for UV rays and has been destroyed by pollutants that contain chlorine and fluorine (the CFC: chlorofluorocarbons). Regarding frogs, UV rays affect eggs and embryos, threatening the normal development, generating anomalies and causing problems to the immunological system; the latter effect reduces the resistance of specimens to infectious agents.

In large urban centers, pollution by solid residues – trash – is the most obvious and easy to detect. However, notwithstanding its usual invisibility, chemical pollution is highly prejudicial to human beings and is particularly destructive to anurans. Especially in urban surroundings, liquid and gaseous substances are thrown in the air, in the soil and in the water. The effects of several chemical pollutants are often unknown, but the compounds resulting from reactions that occur in the environment can be highly toxic. Moreover, such toxic substances are easily transported over large distances by winds, rain and flowing water. If humans suffer from headaches, itchy eyes, respiratory problems and allergies when exposed to these pollutants, what to say about frogs and toads, that live constantly immersed in this cocktail of toxic substances?

In the last few years, the media has largely emphasized global warming. Gases related to the greenhouse effect (especially CO_2) provoke gradual elevations in the annual average temperature of the globe. Such gases are naturally present in the atmosphere; all breathing organisms are major sources of CO_2. The world's temperature was not significantly affected only by our breathing, but after the Industrial Revolution the use of fuels and other relevant emitting sources have elevated the levels of atmospheric CO_2 to inacceptable levels. As a result, a thick layer of gases derived from carbon has formed, preventing dissipation of heat and resulting in global warming. But to say that the average temperature is increasing does not necessarily mean that that the earth as a whole is becoming warmer. The movement of winds and evaporation of water are influenced by the temperature, but rainfall and movement of air masses also depend, among other things, on relief. Therefore, the climate is indeed changing throughout the world, but in different ways in each particular region. The present scenario is reflected by extreme climatic events becoming more common, i.e. summers are increasingly warmer, and winters are increasingly colder.

Independent of the projections and pertinent responsibilities with respect to global warming, its consequences can be very serious. It has already been

verified that the ice in mountainous areas and the polar caps are melting. This ice increases the volume of the rivers and carries fresh water to the oceans; fresh water changes the level of salinity and the density of sea water; the difference in the density of the salt water generates the movement of maritime currents which, being hot or cold, influence the temperature of the coasts. If we add this to pollution, we know that particles in suspension can maintain droplets of water in suspended the air for a longer time. If this happens, the incidence of mists and fine drizzles is reduced, leading to an increasing incidence of heavy rains. In addition, these particles also reduce the isolating capacity of the air to electrical charges, increasing the frequency of lightning. The consequences of these climatic changes to the society are drastic, with economic and social symptoms that are already detectable.

But let's go back to the frogs. We learn in school that frogs and toads are amphibians. The word (*amphi* = double and *bian* = bios = life) refers to animals that spend one part of their life cycle in the water and another part on land. Although there is some variation to this general rule, the life and the reproduction of all amphibians depend on humidity (Figure 2). Most species deposit their eggs in aquatic environments and go through a larval phase (the tadpoles) characterized by intense morphological transformations – metamorphosis – until it becomes a juvenile with an adult appearance, which continues growing until it starts to reproduce. If, during all stages of life, anurans depend on water to survive, it is correct to state that the cycle of rains is important for the life cycle of these animals. An unexpected dry period in the middle of the rainy season could dry up small water bodies and kill all the eggs and larvae deposited in these environments. On the other hand, major storms wash the puddles and carry eggs and larvae through the flowing water towards predators, like several fish species. In addition, hot and dry days wither the sensitive skin of these animals, which even at night would have to remain hiding in humid shelters, rarely coming out to eat. If the dry periods are longer than usual, individuals may get weaker, and that may affect their reproduction and immunological system.

New disease-causing agents or those which become increasingly more contagious and/or provoke intense infections are becoming more and more common. Some groups of organisms have had epidemics that may exterminate entire populations. To cite some examples, coral reefs have been attacked by a mysterious decimating illness around the world; many species of native Hawaiian birds are becoming extinct after being affected by a virus transmitted by introduced mosquitoes; another type of virus, the mobilivirus, has caused epidemics among sea mammals; a contagious disease that provokes facial tumors has already caused a decline of about 90% of Tasmanian-devils populations in Oceania (Smith et al., 2009). Epidemics caused by viruses have also reached our society with relative frequency; who has never been concerned by the avian flu and, more recently, with swine flu?

Photo Felipe. F. Curcio

Figure 1 – Sapo-cururu (*Rhinella icterica*).

Photo M. T. Rodrigues

Figure 2 – Couple of frogs (*Dendropsophus branneri*) spawning.

Regarding amphibians, the most important infectious agent thought to be responsible for the decline and extinction of populations is the aquatic fungus *Batrachochitrium dendrobatidis* ("Bd"), of the family Quitridae. Bd is apparently the greatest and most immediate threat to amphibians in tropical regions. The major difference between illnesses and the impacting factors discussed above

lies in the speed with which they act and the difficulty of combating them. How can an epidemic be controlled in the natural environment? Detecting the pathogen, recognizing its effects on organisms, extent of activity and the dynamic of interaction with its host are difficult tasks. Bd lives exclusively on the skin of adult amphibians and in the mouth of tadpoles, feeding on keratin. Keratin is a protective substance produced by skin cells. Our nails and hair, for example, are composed of keratin. But Bd is a fungus that exclusively attacks amphibians. The illness that causes quitridomicosis is considered a serious threat to these animals because it has some characteristics that favor contagion and intensive dispersion. The fungus affects tadpoles and adults of several frog species. In addition it can occur without causing any symptoms in two of the most commercialized species in the world, the bullfrog (*Lithobates catesbeianus*) and the African aquatic frog (*Xenopus laevis*); in other words, it is present in asymptomatic hosts that may act as living reservoirs. Considering that these species are among the most common foreign species introduced into the natural environment, they obviously represent efficient dispersion vehicles. Bd has already been found on all continents and there is evidence that its arrival can cause local extinction of populations.

But how can a fungus that lives only on the skin of an animal get to kill its host? The long lasting lack of response to this question was one of the reasons that led many researchers to become skeptical about the actions of Bd. Only in 2009 we started to understand that infected amphibians may die. The skin of amphibians is an extremely important organ because, besides providing protection, it is responsible for a considerable percent of absorption of oxygen (a process called cutaneous breathing) controlling of influx of water and other substances. Bd affects these skin functions and changes the concentration of vital blood substances in the animals, which wound up dying of heart insufficiency. Understanding this mechanism took nearly 10 years after discovery of the fungus.

Not unreasonably, many amphibians are considered bio-indicators. The permeable skin and the life cycle in aquatic and terrestrial environments are characteristics that make them vulnerable to physical (e.g. humidity and temperature) and chemical (e.g. pollution) environmental changes. The sensitivity of some species may be informative with respect to the quality of the environment; if such species are not present in an area where they should occur, environmental quality may be put into doubt. Therefore, the decline of so many amphibian species is an alarming symptom of the environmental crisis as a whole. Even if an area is apparently well preserved, the disappearance of particular amphibian species represents an important warning. If amphibians are the first to suffer from environmental changes, humans may be the next.

How could we detect the consequences of each one of so many threatening factors over the affected species in time and space? Unfortunately, this question remains to be answered. The more complicated cases are those occurring in natural reserves where the habitats were apparently well preserved. Some factors were generally observed in all cases: distantly related species were affected; not all

the populations of the same species were affected in the same proportion; larger species and species with some degree of reproductive specialization, which live in tropical highland forests, and associated with streams, were more affected than those from lower areas that reproduce in puddles and ponds. These standards are repeated temporally and geographically.

The Brazilian diversity of anurans is still poorly known and the lack of inventories in several areas of our country deters precise diagnostics regarding declines. However, in at least some of the well inventoried areas in the Atlantic Forest of southeastern Brazil, there are unequivocal records of local declines and extinctions of frog species. Distantly related species were affected at the same time in the same place, and it happened in several different localities in the beginning of the 1980s. The biological characteristics of these species fit with the patterns described for similar cases of amphibian declines in the rest of the world.

We require more data to provide an accurate estimate of how many frog species were actually affected, in which sites and for which reasons. On the other hand, we already have enough information to assert that their occurrence in apparently well protected conservation units did not prevent them from being affected. We must emphasize that such uncertainties may represent a problem from the conservational point of view; if the one assumes that the conservation status of a species is not obviously determined to be threatened, social and economic appeals may overcome the environmental conscience. Unless the conservational arguments are objective in order to prevent irreversible declines and local extinctions, it will not be possible to convince the public that some areas must be protected at the expense of destructive undertakings.

Investigations regarding the conservation status of the various amphibian populations and the precise threats over these animals depend on extensive studies that demand long term projects. On the other hand, processes in decline are apparently too fast and conservational decisions cannot wait too long to be put into practice. In such a scenario, despite the uncertainty regarding which species may be at stake, where and why, we must use the data at hand - whether they are conclusive or not - to guide conservational decisions. Therefore we reiterate that the *principle of precaution* must always be considered, i.e., if there is any probability suggesting that a species may be at risk, we must assume that it *in fact is at risk*, until convincing contrary evidence is presented.

In Brazil, the economic cycles have brought exploitation and destruction of habitats since the Colonial period, with the massive extraction of the native tree "pau-brazil". The vast majority of the population got established in the coastal areas of the east of the country, spreading to the west throughout the uplands, following the establishment of miners, coffee plantations, sugar cane and cattle ranching. With the industrial development, basically concentrated in the southeast, the process of environmental destruction intensified and, after the 1960s and 1970s, it extended towards the central and northern regions. The Atlantic Forest, which originally covered an enormous extension of eastern

Photo Felipe. F. Curcio

Figure 3 – Bullfrog (*Lithobates catesbeianus*). Specimen found in the "Parque Estadual de Campos do Jordão".

Photo Felipe. F. Curcio

Figure 4 – *Hylodes magalhaesi*, one of the first Brazilian species to be diagnosed with quitridiomicosis.

Brazil, is presently restricted to 12% of its original coverage (Ribeiro et al., 2009). Around 160 of the 183 million inhabitants of the country live in this region, in areas that were extensively occupied by these forests (Santos & Câmara, 2002).

The Cerrado is impacted by cattle ranching, expansion of agricultural borders and establishment of hydroelectric power stations; its present area corresponds only to about 35% of its original coverage. Similar activities also threaten the Amazon Rainforest, which retains 85% of its area, but is increasingly affected by the destruction of forests for agriculture, cattle ranching and exploitation of wood.

The introduction of foreign species of various animal groups in our country began in the 1930s to 1940s, associated with aquiculture, even in the case of the bullfrog (Figure 3). There are estimates of approximately two thousand bullfrog breeders in the country in the 1980s; in 2001 this number fell to 600. There are no precise records of what happened to the specimens raised in the 1400 deactivated units, but there are indications that at least part of them would have been released in nature. Breeders, as well as the records of bullfrog populations in the wild, are most common in the states of the southeastern and the southern regions of the country, which are exactly the regions where amphibian declines have been registered. The date of the presumed release of the frogs into nature also matches the occurrence of the declines in the 1980s.

An increase of UV radiation incidence was detected by the scientific community between the 1970s and 1980s. The highest levels of this radiation in Brazil, qualified as very high, were found near the Tropic of Capricorn and increased even more in the direction of the Equator.

The major Brazilian urban centers are located in the southeast, including the Metropolitan Region of São Paulo, which alone is inhabited by nearly 19 million people. The amount of solid, organic and chemical residues generated by this population has long been considered a public health problem. For example, in 1984, before restrictive measures were adopted to control pollutant emissions, the petrochemical pole of Cubatão (in the coast of São Paulo state), was responsible for the emission of approximately 316 tons of pollutants per day. More recent data indicate a reduction of these values of around 60% (Cetesb, 1990, 2005). In addition, the agro-industry is well developed in this region making extensive use of agro-chemicals (fertilizers or pesticides) which contaminate water bodies, affecting amphibian populations. Finally, the heat generated by activities in these major centers makes them act like islands of heat, altering the atmospheric circulation and thereby exerting some influence over the regional rain patterns.

The oldest record of the Bd fungus in Brazil dates from 1981, but until today it has already been detected in 21 Brazilian species of 15 different localities, all in Atlantic Forest areas (Toledo et al., 2006) (Figure 4). There is still no direct link between the fungus and frog declines in these localities, but dying specimens have already been observed in the wild and the fungus was detected on their skin.

As an applicable example regarding the principle of precaution, lets consider the Brazilian frog species which have its conservation status designated as “data deficient”, presenting a well-established taxonomy, reproductive specializations and with distributions restricted to the Atlantic Forest of southeastern Brazil. Since these species occur in areas where the Bd fungus

has been already recorded, where large bullfrog populations are apparently well established, and where the incidence of ultraviolet radiation and pollution are higher than the acceptable levels, it seems reasonable to consider that *all these species could be threatened with extinction*. Therefore, such species should be treated as "endangered" by environmental agencies, until specific studies provide convincing evidence suggesting they are indisputably not at stake. This is an explicitly preventive posture aiming to protect the biodiversity even in the absence of specific information about biological responses of the species to environmental changes.

Finally, more important than knowing these problems is bearing in mind that we are all responsible for the biodiversity crisis in the world. We are part of this society that is making increasing use of natural resources and causing fast and astonishing environmental changes. The individual efforts of each one of us, added one by one, will hopefully make the difference.

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ABSTRACT – Approximately 30% of the species of frogs and toads are threatened with extinction, and 35 of these species are already extinct. Since anurans have a thin and permeable skin and, in most cases, pass through an aquatic larval phase, these animals are very sensitive to environmental changes of water, soil and air. The greatest threatening factors over amphibians are the life style of our current society – which produces high pollution levels – global warming, introductions of exotic species, increasing levels of ultraviolet radiation, and the rise of epidemics. If there are no changes in human life style take, this threat will affect all species, including man.

KEYWORDS: Anurans, Conservation, Amphibian declines.

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