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Figure 1. Photo Credit: Joel Sartore, Nat Geo Image Collection

Humans have released greenhouse gases at an unprecedented rate since the industrial revolution, resulting in climate change. Climate change is threatening species around the globe who may have already been under stress from other anthropogenic activities such as deforestation. Some people believe the planet is entering into the sixth mass extinction event, and this time it will be due to anthropogenic activities. Some of the most threatened species around the globe appear to be amphibians. As temperatures shift in habitats due to climate change, amphibians become more susceptible to many different diseases.

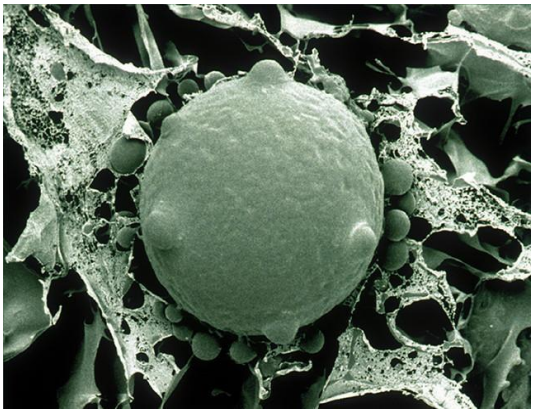

Figure 2. Photo Credit: MinnPost

"There have been hundreds of amphibian species that have gone extinct in the last five decades because of outbreaks of the chytrid fungus."

Batrachochytrium dendrobatidis (Bd), or the chytrid fungus, is a parasitic fungus which targets amphibian populations. As climate change continues to intensify, the chytrid fungus can spread to additional areas. Meanwhile, its hosts are already compromised by the changing environment. There have been hundreds of amphibian species that have gone extinct in the last five decades because of outbreaks of the chytrid fungus. For example, the Panamanian golden frog was wiped out in the wild by this pathogenic fungus.

Chytrid fungus causes the disease chytridiomycosis which infects the skin of amphibians, eventually sending them into cardiac arrest. The fungus infects in the form of a zoospore which becomes embedded in the skin, creating a cyst. Its preferred temperature is around 17-25°C. Colder temperatures may slow down the fungus's ability to infect a host amphibian, but it does not kill the fungus. Hosts have been observed to live longer in warmer climates before dying. Amphibians can raise their internal body temperature to combat the fungus. Even though this fungus produces asexually, which makes it less adaptive, chytrid fungus has had great success in spreading globally and driving many species towards extinction. There is currently no in-depth research into the time frame in which chytrid fungus spread.

The thermal mismatch hypothesis explains how amphibians across the globe are becoming weakened by new temperatures ranging outside their adapted optimum temperature. This makes amphibians more susceptible to parasites and pathogens such as the chytrid fungus. Temperature changes alone have made regions uninhabitable to species that have called those regions home in previous decades. Many have been forced to migrate to new areas. Heat Waves associated with climate change can cause ponds to dry up, leading to high larval mortality. Due to their biology as ectotherms, amphibians struggle to keep their body temperatures at their optimum level when their external environment undergoes a temperature change making them more susceptible to infection. Due to climate change, temperatures are shifting in environments, and many species must thermoregulate or migrate to a more suitable environment. Areas where the temperature is newly outside the range of the host, yet inside the range of the fungus, could be where susceptibility to chytridiomycosis is the greatest. Many parasites like the chytrid fungus tend to have a wider temperature range than their targets. One explanation for this wide temperature adaptation is the fast reproduction rates of parasites compared to hosts. If the host amphibian species is outside its optimum temperature, there is an increased chance of success of the chytrid fungus. Chytrid fungus can infect populations that must adapt to a new, warmer condition more easily than it can infect a population that is already adapted to warm

conditions. Researchers must ensure they are taking climate change temperature shifts into account when they study these amphibian populations.

Researchers have been trying to discover ways to protect amphibian species around the world from this deadly fungus. Certain skin bacteria may be able to defend the amphibian against the chytrid fungus. For example, *Janthinobacterium lividum,* has been used by researchers as a probiotic to decrease the spread and success of the chytrid fungus.While infection rates have not decreased with the probiotic, some frogs were able to clear themselves of chytridiomycosis after being exposed to *Janthinobacterium lividum* in one study.

Figure 3. Photo Credit: San Diego Zoo

Human-caused climate change has put wildlife at great risk due to changing conditions in their habitats. Since the industrial revolution, greenhouse gases have been released, progressively warming the Earth as the atmosphere fills with gas. Due to the increased gases, temperatures are shifting in many regions, and species are struggling to adapt to their new climate. Amphibians are having an especially hard time adapting, because they are ectotherms, meaning they must practice thermoregulation. They also face the ever-present threat of chytridiomycosis. Chytridiomycosis is caused by *Batrachochytrium dendrobatidis* (Bd), or the chytrid fungus. Amphibians are weakened because of their changing habitat temperature, which allows the chytrid fungus to be a more effective parasite. The further an amphibian is from its adapted optimum temperature, the weaker it becomes, and the more easily the parasitic fungus can take over. The chytrid fungus has driven hundreds of species towards extinction in the past few decades. More time and research must be devoted to studying the dynamics between climate change and pathogenic diseases such as chytridiomycosis. This could lead to a solution to the alarming rate at which amphibian extinction is occurring.

The effects of climate change will continue to worsen across the globe, putting all life at risk, including amphibians. A solution must soon be found to prevent the loss of more amphibian species.

Figure 4. Photo Credit: Matthew Fisher

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