

The impacts of climate change on amphibian distribution

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Abstract: Amphibians are a unique group of species that are sensitive to their environment and are currently being affected by the effects of climate change. This study analyzed the effects climate change has on diverse aspects of the survival of amphibians. Results show that rising temperatures increased the infection potential of diseases. Changes in the environment caused threat to prey of amphibians such as insects, decreasing the food availability. Global warming has been shrinking the pond and wetland environment amphibians depend on. Habitats have been fragmented due to differences in humidity and temperature, affecting continuation of the population's survival. These changes have generally threatened the survival of amphibian species around the world, and are predicted to continue doing so in the future.

1. Introduction

The influence of environmental factors on organisms has always been a major question in studies of ecology [1]. Climate change is a factor which has been becoming a great threat to species around the world over the past decades. At the moment, global extinction rates are estimated to reach 1000 times higher than the background rate in the fossil record. Among them, amphibians are the group which has the largest proportion of species under threat [2] with reports of them declining has been becoming more and more frequent around the world. In 2004, one third of the known amphibian species to humans were classified as 'threatened with extinction' by the IUCN red list of threatened and endangered species. Those declines of amphibian populations were much more widespread and severe than their usual fluctuations under normal conditions [3]. Climate change can greatly affect the average temperature, humidity, and annual precipitation of an area. Amphibians are very vulnerable and sensitive to those changes due to a variety of factors.

Amphibians are a very unique group of species, and some of their attributes make it more challenging to design and conduct controlled experiments on them. For example, many temperate amphibians remain inactive for a rather long proportion of the year to avoid cold winters and hot summers as they are cold blooded. They will be triggered to emerge by subtle changes in humidity and temperature [4], which means they are very sensitive to their environment, and especially temperature changes. Humidity is a crucial factor as amphibians stay hydrated by absorbing water through their moist, permeable skin instead of drinking water directly. They are also a unique group as they are adapted to both an aquatic and terrestrial environment. Amphibians lay fragile unshelled eggs and undergo huge changes growing from larva to adult, making them extra vulnerable as they will have lesser tolerance to changes.

The purpose of this paper is to identify the known direct and indirect influences of climate change on amphibians around the world, and overall summarize how these influences will affect the survival of the species as a whole, and discuss whether some phenomenon can be generalized amongst diverse species. Earlier studies were generally focused on a specific type of influence, or species from specific

region or one species only. This study will aim to cover the major influences among amphibians across the globe instead. The major areas of effects of climate change are, (1) shifts to their distribution, (2) changes to their habitat, (3) survival rate of the larva, (4) and increased amount of new emerging diseases [1].

2. The effect of climate change to the amphibians

2.1 Diseases of amphibians

With the climate change, there will possibly be quite a lot of new diseases which is deadly to the amphibians show up. The reason is that with the change of climate, the living condition might change to an area where is suitable for the fungi or other microbials to survive. Once these fungi or other microbials can grow in this area, the amphibians have to face another threat for the fungi disease. For example, in Park California, Monteverde Cloud Forest Preserve Costa Rica, and Eungella National Park, there were huge number of amphibians affected by the Bd disease and died.

The amphibians are quite sensitive to the temperature and critical for the living condition. From the studies, with the increase of the number of streams at high elevations in the tropics, the number of decline amphibian species increases. On contrast, the amphibians will decline when it is the case that the water runs stilly and the elevation becomes low. In addition, the virulence of the fungal disease chytridiomycosis (Bd), one of the most commonly cited causes of enigmatic declines, is greater at higher elevations and among streamside species. Most enigmatic declines occur from the Americas south to Ecuador and Brazil, Australia, and New Zealand, even spreading to Peru, Chile, Dominica, Spain, and Tanzania. As the graph shows below, quite a lot of amphibians are affected by this disease.

Even though people remind the danger of the disease, they still underestimated its extent of harm. Indeed, these declines tend to be so rapid that people even couldn't get aware of them [3]. Bd has been implicated in the decline of over 500 amphibian species and 90 presumed extinctions. (Figure 1)

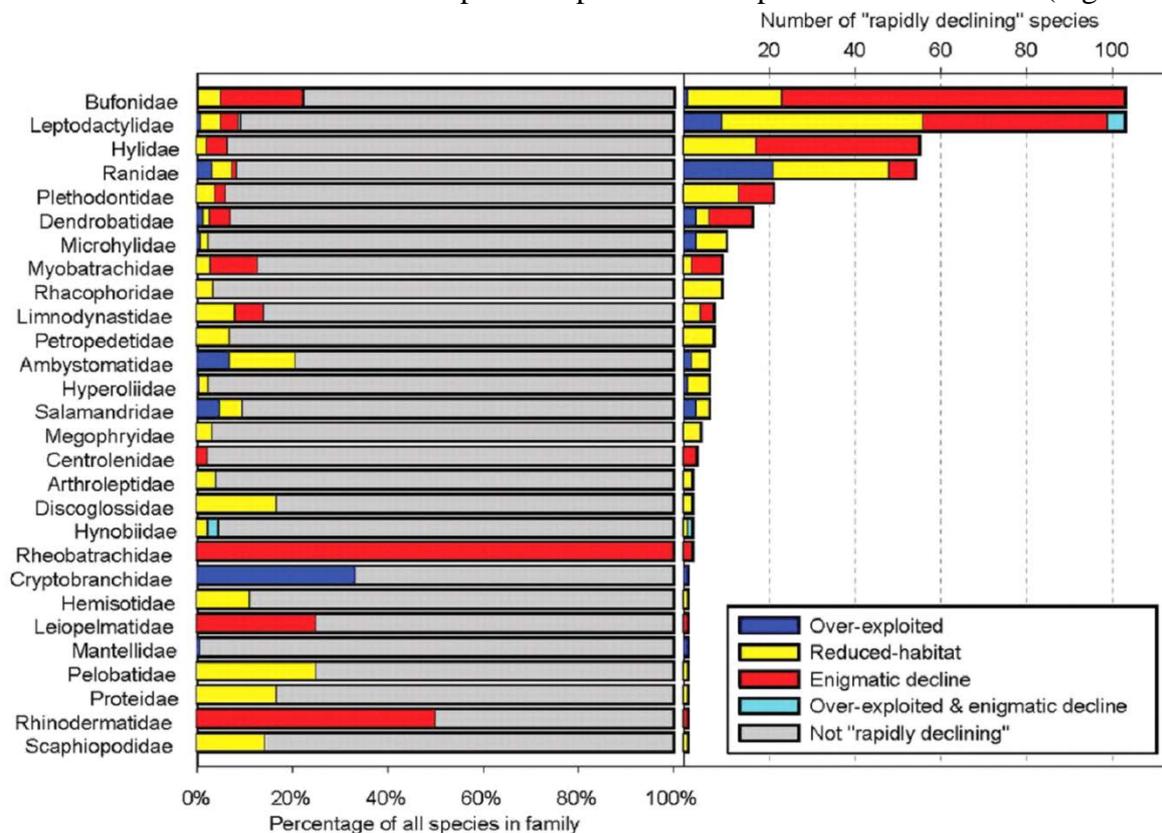


Figure 1. Percentages and numbers of rapidly declining species in amphibian families (with at least one rapidly declining species), broken into groups reflecting the dominant cause of rapid decline: overexploitation; habitat loss; or enigmatic decline [3]

It is inferred that changing temperatures have been shown to influence Bd infection potential. Even though the Bd fungi disease is deadly to the amphibians, the amphibians in Northwest of America seemed not to be so influenced by the diseases since there was no mass mortality. As a result, the disease defense mechanisms may help the amphibians to resist the Bd. However, the climate change may cause the amphibians' disease defense mechanisms to be disrupted. That may cause the rapid decline of the number of amphibians because of the disfunction of the disease defense system [3]. What's more, not only the amphibians in Northwest America were affected, the Bd fungi disease has spread to other places as well.

These cases show the danger of the fungi and other microbials to the amphibian. Not only the fungi will affect the survive of the amphibians, the ancient virus will probably do huger damage to the species. With the climate warming, the frozen land melts and the dead bodies buried there may carry the virus. Once the virus spread, not only the amphibians but also all the other species will be affected.

2.2 Food availability of amphibians

The main food resource of the amphibians is the insects. The climate change will have huge impact to the insects since quite a lot of aspects of the insects are influenced by the climate change such as the reproduction time, the food source and the predators. However, the insects will not stay unchanged and wait for death. Because of their fast reproduction pattern and short life span, they can quickly respond to the climate. The most possible way for them to adapt to the climate change is to change their habitat [5].

The increasing temperature due to global warming will result in larger insect populations because the insects will advance their reproduction time while the temperature increase. The possible reason is that with the temperature increases, the growth rate of the plants, which is their main food source will become faster than before [6]. Moreover, the insects will also increase their number of generations per year. For example, many pests which are limited by cooler temperatures at higher latitudes will be able to expand their ranges into further areas as air temperatures become warmer. However, even though the number of insects will increase, as a result of global warming, insects may find suitable alternative habitats at greater latitudes and higher altitudes. Thus, the amphibians will have not enough food to eat since the insects all moved away from their formal habitats.

As the graph shows, the insects will migrate from lighter points to darker points. The light lines mean the present line of migration of the insects and the dark lines pridict the future. Besides climate change results in movement of the insects, it will also cause the extinction of insects, leading to food loss of amphibians. Climate change will become a major factor for the extinction of arthropod species as well. Mountain species and those restricted to high latitudes are most likely to become extinct as a result of climate change. Since some species lived in the frozen area have already adapted to the environment there. Once the temperature increases, the insects will probably have to move to higher altitudes. However, the height of the habitat is limited and some species will finally face the problem of running out of habitats. Thus, these species will become extinct in this area. Between 1970 and 1999, the number of the butterflies in the United Kingdom rapidly changes. Because of the climate change, mainly the rising temperature, quite a lot of UK butterflies lose their habitats and face huge survival challenges. What's more, 4 kinds of species even died out because of the loss of habitat. This does not happen just in UK, in Spain, thanks to the global warming, the average location of the habitats of the butterflies increases for more than 200 meters in order to avoid the rising temperature. Once these species become distinct, even though the amphibians can migrate to higher altitude, they still can't find enough food. (Figure 2)

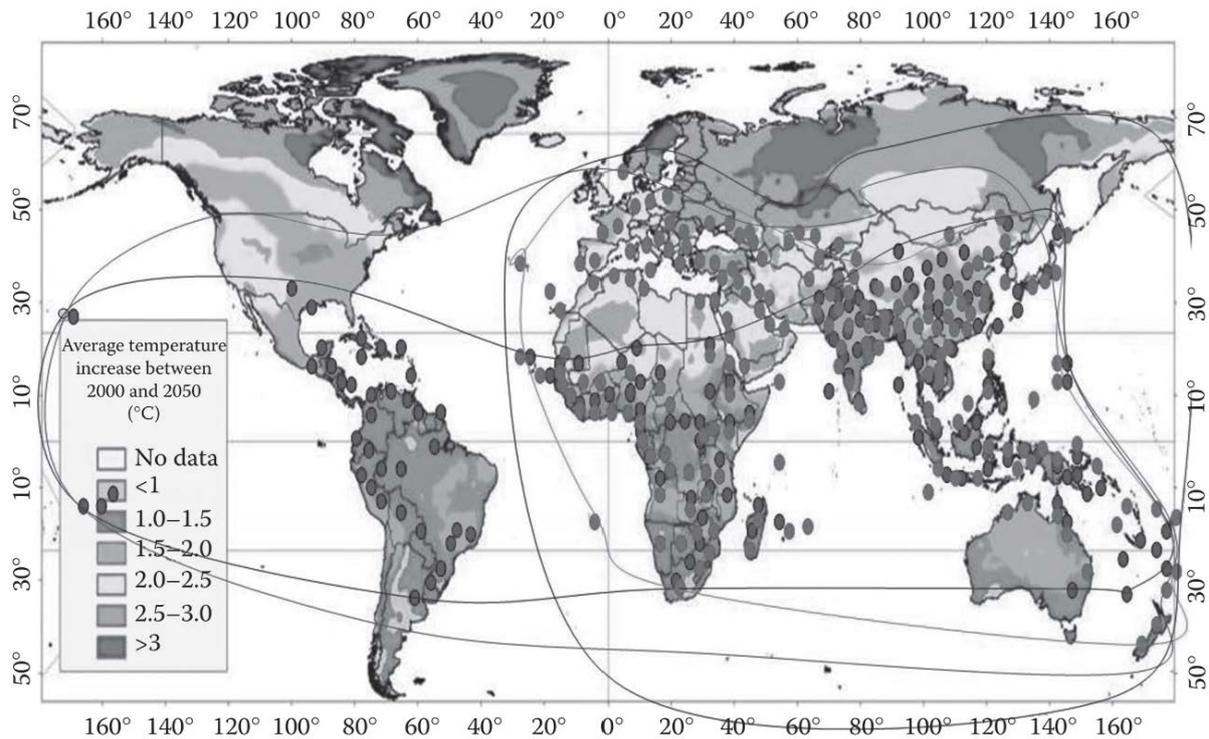


Figure 2. Likely changes in geographical distribution of *Helicoverpa armigera* [5]

In addition, with the rise of the global temperature, the rate of the evaporation of the pond will increase rapidly. That means where the amphibians lay their eggs will dry out quickly. If the water level drops because of the rising temperature, the successful reproduction of amphibians will decrease as well. For example, the tadpoles are species that live nearby pond. If the pond gets dry out as a result of global warming before the larvae develop their lungs, they will die before they get mature [6]. Over past century, the pattern of rain falls changed. The summer rains decreased and the fall rain increased. This climate change causes the rising temperature, especially in winter. Even though not all the species will be affected by this, the amphibians will be. Amphibians have a more complex reproductive strategy than the mammals do. The species breed in different seasons, and their tadpoles vary in rates of development and the timing of metamorphosis. For example, eastern spadefoot toad tadpoles will become mature and live in juveniles in as little as two weeks, while southern leopard frog and gopher frog tadpole need several months or more in order to get their lungs developed. However, studies show this factor will cause minor influence to the amphibians. What really matters is the evaporation. For five of the six species studied, reproductive success was highest if the wetlands still have proper or higher amount of water for the amphibians to ensure their larvae to grow up. Besides the condition of habitats, the amount of precipitation will also be essential for the survival of the five main species which include the southern toad, oak toad, eastern narrow-mouthed toad, southern leopard frog and the gopher frog [6].

2.3 Amphibian habitats

In most cases, the change of habitats is thought that due to changes of land use resulted by increase of human population, such as deforestation, occupation of wetlands or water pollution, which reduces the size and range of amphibian habitats. The threat of habitats loss to amphibians has been studied a lot, as has much studied about direct impact of climate change on amphibian populations. However, the link between climate change and habitat change has rarely been reported. Climate is usually measured by precipitation and temperature. At the same time, in this research, any change in the geographical range of activity, the number of organisms, or the density of organisms is considered a change in the distribution of amphibians. Amphibians generally have low dispersal, which means they can't move for long distances. In other word, they mostly stay close to where they were born [7]. Once

the habitat changes, it will affect the population of amphibians, which will affect their distribution. Habitat under the influence of climate change, habitat condition becomes harsh, habitat turns fragmented and the area is constantly shrinking.

2.3.1 Habitat shrinking

There is no doubt that warming will make little pond habitat and wetland habitat shrinking, which is a typical scope reduce that affected the distribution of biological activities. Since most amphibians choose to breed in this environment, if the ponds and wetlands get smaller, it is surely that will affect the amphibian breeding, resulting in the change of the number and distribution of amphibians. For example, in a 60-year climate monitoring of Yellowstone Park, four species of amphibians were found to be in serious decline. The original 49 ponds were reduced to 38 in 2008 due to rising temperatures and reduced rainfall, and of the original 43 ponds capable of supporting amphibians, only 21 were left, with the number of amphibians species declining in each pond. Moreover, even if dry ponds are rehydrated, not all can be restored to support amphibians [8]. Warming causes the rising of sea levels, and then flood coastal wetlands, resulting that amphibians lose their habitat and the richness and the number of species are influenced by it.

2.3.2 Habitat fragmentation

Because the skin of amphibians is very sensitive, amphibians are more sensitive to temperature and humidity. If the climate is not suitable, their ability to move will be reduced. *Triturus cristatus* and *Triturus marmoratus* in France have been observed to be reluctant to risk moving between habitats in a warming climate, despite changes in suitable habitat locations, resulting in reduced habitat connectivity [9]. This leads to less contact and communication among habitats, which means that a large habitat range can become fragmented. Humidity is lower in the logged areas of the forest compared to other areas, and *Rana aurora* adults avoid cut areas if precipitation is low [10]. Studies have shown that habitat fragmentation greatly reduces both the effect of dispersal and the survival rate of larvae. Habitat fragmentation and loss make it difficult for larvae to disperse, which also reduces the communication among populations and affects the continued survival of populations [2].

2.3.3 Habitat loss

Due to climate warming, species will spread to high altitude and high latitudes, which may cause the more suitable for the wider survival of the species range. However, amphibians are poikilothermal animals and hard to resist the cold, and most amphibians choose hibernation to save energy for living through cold winter. The arrival of warm winter makes it difficult for them to hibernate, which increases the energy consumed during the winter that reduces the resource allocation for their later growth and reproduction [11]. In this case, amphibians will migrate due to the pressure of energy distribution and trade-offs in their life history. In other words, their habitable range is likely to become narrower rather than larger. At the same time, amphibians on isolated islands have difficulty migrating to cooler latitudes, their existing habitats are no longer suitable, and they are more vulnerable to climate change as the climate affects the habitat.

2.3.4 Habitat condition

Amphibians in China would lose an average of 20 percent of their original habitat, while distribution outside their current range would increase by 15 percent [12].

Climate impacts on habitats not only directly make habitats smaller or disappear, but also affect the condition of soil and vegetation in a habitat. Many terrestrial amphibians are very sensitive to changes in soil moisture and environmental temperature, which in turn will bring about changes in vegetation. Changes in vegetation composition mean a series of changes in light intensity, temperature, water, leaf litter, decomposition and so on. Amphibians probably depend on the environment provided by these plants for reproduction. In other words, changes in vegetation affect species numbers of amphibians [10]. Besides, climate changes make it drier for longer, warmer temperatures and less precipitation, which increases the likelihood of forest fires, which reduce the size of forests that in turn leads to soil

erosion. Soil loss to nearby water bodies such as streams, which may cause water blockage water eutrophication. So even if amphibians survive from the fire, it is difficult to adapt to the habitat change after the fire, their number and species will greatly decline [13]. Therefore, the environment of the habitat can also affect the distribution of amphibians. As habitats change, amphibian populations change, affecting distribution.

3. Conclusion

This review discussed and summarized the impacts of climate change on the survival of amphibians.

Climate change does not only affect amphibians by creating shifts in the environment and creating changes in their own behavior and abilities, but also by changing factors around them. It can threaten their prey's population and vegetation in their habitat, pressuring their survival further. The amphibians' reproduction and severe change of the larvae are greatly affected due to their habitat shrinking. There is less space for them to breed and for the larvae to survive due to habitat fragmentation. At the same time, larva is even more sensitive to environmental changes than the adults, placing them in a very vulnerable position. This forces them to move to higher altitudes and latitudes, where they are unable to cope with the colder temperatures.

As the aim is to look at amphibians around the world, this study also analyzed changes that can be generalized across different species and regions. The combination of these threats has caused great damage to amphibians already. As the results show that the changes will continue to occur, and more amphibian species are likely to be under threat or become extinct in the near future along with the disappearance of their habitat. It is necessary to pay more attention to the survival of amphibians. For this purpose, future studies on amphibians could be done on areas concerning their survival such as the ways amphibians have been adapting to changes in their habitats, whether those adaptations are effective for benefitting their survival, as well as further exploration on the topics that have already been researched. This type of information would be useful for us humans when taking actions against their disappearance, as it is important to know what is already happening in response to those threats.

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