# The Case of the Missing Anurans

Suggested Grades: 5-8

**Concepts**

Requirements for survival; environmental change; influence of change on populations; declines in populations

**Time**

90 minutes to several days

**Catalyst Question**

Where have all the frogs gone?

**Background**

My name is Sheerluck Biomes. One Sunday afternoon, I was sitting in my favorite chair reading the newspaper. With me on this day was my assistant, Dr. Newt Watson. While reading the paper, I saw an article about the decline in amphibian populations, also known as frogs, toads, and salamanders. This article piqued my interest and I discussed this information with Dr. Watson. It seems that although there were no firm data on the actual numbers of amphibians past and present, herpetologists (scientists who study amphibians and reptiles) and other scientists noted that there were not as many of these creatures in ponds, marshes, forested areas, and along some streams where they used to be found. We decided that we wanted to know more about this problem.

It did not take long for Dr. Watson and me to discover that an investigation of this type was an enormous undertaking. So we decided to concentrate our investigation only on frogs and toads also called “anurans.” We decided to call this “The Case of the Missing Anurans.”

A proper inquiry into this situation would require the services of some top investigators. They would be responsible for delving into the different aspects of this case to form a complete picture for the solution of this mystery.

There are various clues available in “The Case of the Missing Anurans” otherwise known as declines in anuran populations. These include acid precipitation, predators, human consumption, habitat loss, climate change, which may act on a local or global basis. These are outlined in greater detail in the clue sheets.

However, it is important when examining this issue to remember some additional points. For example, when discussing declines it should be remembered that there are two types of decline: declines in size of a population (affecting the number of individuals in a population) and declines in the number of populations (impacting diversity of species). In addition, declines can occur at a local and global level. So, when examining a decline, which angle are you investigating? Other points to be considered: population fluctuations do not necessarily indicate a decline and while local habitat destruction may be detrimental to some species other species could thrive. So, how do all these clues play out in this mystery? Let’s investigate and see!

**Life Cycle of Amphibians**
Amphibians are cold-blooded vertebrates that lack scales. They usually begin their lives in the water (with gills) and live on land (with lungs) as adults. Most amphibians mate in water, where the females' eggs are deposited and fertilized by sperm from the males. The eggs of amphibians are covered with one or more gelatinous coatings that protect against shock and drying, and make attacks by enemies more difficult. Frogs and toads are now more commonly grouped into "anurans"—tailless amphibians. It is these animals that we will concentrate on.

Frog and toad embryos form in eggs and then develop into tadpoles that remain in water, slowly changing into adults. During the tadpole period of their lives, they have some characteristics similar to fish—gills for breathing and tails for swimming.
The larval stage may last from several weeks to even years for larger anurans, but the final metamorphosis from tadpole to juvenile frog usually occurs in a few days.

**Habitats**
The place in which an animal can be found is called its habitat. Anurans need two distinctly different habitats, within fairly close reach of one another, to complete their life cycle. The first is suitable dry land providing cover from predators and a supply of small-animal food; the other is a pond to lay their eggs in and allow their tadpoles to develop. During the winter, most anurans hibernate either on land or at the bottom of a pond.

Frogs and toads both need an aquatic environment to lay their eggs. However, in the rush to lay eggs, they may be laid in a puddle of water or in temporary pools/ponds of water. Aquatic habitats without fish are preferable, since fish will eat most of the tadpoles. Toad tadpoles are equipped early in life with poisons in their skin that quickly persuade fish to leave them alone. Frog and toad tadpoles require algae of some sort to feed on at an early stage in their development. However, as their development continues they also can eat meat. In overcrowded situations, they have been known to nibble on each other.

**Pond Conditions**
Ponds are very important in the life cycles of anurans. Anuran breeding ponds are generally small, with varying amounts of decaying plant and animal material (humus). As the humus breaks down in the ponds, it produces acidic conditions in the water. The pH (measure of the acidity) may also be lowered (which means the water becomes more acidic) for short periods following snowmelt or major rainstorms. Because of the presence of humus, it is difficult to tell if the acidic conditions in the ponds are from atmospheric or natural sources.

Scientists are studying the acidic conditions in the ponds used by anurans. Most anurans can adapt to a slight change in the pH of the pond water; but if the pH becomes too low, serious problems arise. In a small pond, pH can be lowered rapidly, and anurans may be unable to adjust quickly enough for survival.

Anurans are most vulnerable when they are embryos and larvae. Some of the most significant effects of a lower pH on anurans occur because growth rates are slowed. Under laboratory conditions, tadpoles exposed to low pH grow much slower than those exposed to neutral conditions. The embryos and tadpoles of anurans are formed in the spring and must reach a certain size before the pond dries out in the summer. Size at metamorphosis (the change from tadpole to frog) affects survival in the land environment during the summer, and ultimately reproductive success in adulthood.

Scientists studying amphibian larvae in acidic ponds note:
1. increased need for food;
2. lower food quality available;
3. lower rates of food processing in the intestine;
4. behavioral changes, such as reduced attraction to food odors or reduced activity; and
5. larvae can withstand lower pH's than embryos.

Scientists state that pond acidity is currently having a major effect on the abundance of anurans. Continued monitoring is necessary to determine how natural processes and human activities affect the acidity of ponds.

**Objectives**
After completing this study, each student will be able to:
1. describe environmental changes that can affect anurans.
2. state a hypothesis about the cause of a large change in anuran population size.

**Materials**
Paper; pencil; copies of "clue" sheets for groups; presentation materials.

**Procedure**
1. Form a group of four to five investigator scientists. Give each investigator one of the "clue" sheets and background information so that all clues are available to the team. Alternatively, each team might receive only the clue title, i.e. UV radiation, and do all the research on this topic. Teams should check the reference and resource list for additional sources of information on this topic. In addition, they should contact state or regional wildlife staff for information on local and state amphibian populations.

2. Each team writes a scenario describing why anurans may be declining in numbers. The team develops a hypothesis on the declines based on their information and should be able to present and defend this.

3. Each team then designs a controlled experiment, which could be done by scientists in a laboratory or in the field to test the team's hypothesis. (A "hypothesis" is a credible idea to be tested by experimentation and a "theory" is a concept well established by much experimentation.)

4. Each team presents their findings and proposed experiment in the following possible scenarios.

5. Each team represents a group of herpetologists and other scientists who have gathered together for a meeting to discuss the declining frog and toad populations around the world. Each team presents their hypothesis and experiment designs to the entire group.

Presentations should be creative and can be of a multimedia nature or a final report to the group.

Perhaps team members could become the characters of Sheerluck Biomes and Dr. Newt Watson and give their report as these type of investigators do when they find the solution to a "mystery."

The students can compare their results with other class members to note similarities and differences. Is it possible to try any of the experiments? Why/why not?

**Evaluation**

There is no single solution to this problem. There is a need for more concrete data from field observers, but this activity gives clues as to some of the causes for the decrease in the numbers of anurans.

Evaluation should be performed on the following criteria:

1. the amount of research beyond that in the various clues and background information;
2. sources of additional information (i.e. books, journals, Internet—and assessment of the sources by the students); and
3. team presentations to the other students.

**Extensions**

1. Locate information on the amphibians in your local area/state/country. Check resources to determine how the populations are surviving in your area—are they steady, declining, increasing?

List the frogs, toads, and salamanders found in your local area. Ask your parents/ grandparents if they see as many of these animals now as they did when they were growing up. If a change has/has not occurred, ask them if they know why.

How could you help the amphibian populations in your area? Some people go out during the spring when the frogs are migrating from the lakes, etc. where they spent winter to the breeding ponds and help the frogs get across obstacles such as roads. Could you organize a group of students to do this?

2. Using various resources find as many stories, anecdotes, folktales, and movies about amphibians. Why do you think they were used so much in art and literature? Were they portrayed in a positive or negative way? Were the characteristics given to these animals true? From what you have learned in this activity, write a short folktale about one or all types of amphibians.

**References and Resources**

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Pierce, Benjamin A. and Jeffrey Montgomery. 1989. “Effects of Short-Term Acidification of Growth Rates of Tadpoles.” *Journal of Herpetology* 23(2): 97–102.*

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**Media Resources**

*Cane Toads—An Unnatural History*. New York: First Run Features.

An extremely interesting and humorous video presentation of an invasion of an alien species. This toad is also causing many problems in Florida.

*The Frogs*. ABC Nightline Program. September 30, 1997.
To order, call 1-800-CALL ABC

This program is an excellent resource about the deformed amphibian issue and the scientific quest to determine what is causing this phenomenon. It examines the situation not only in Minnesota, but in other states where deformed amphibians are being found. In addition, it discusses the various scientific hypotheses behind this issue.

**Internet Resources**
*A Thousand Friends of Frogs* Project
http://cgee.hamline.edu/frogs

This web site has an extensive list of links in its Frog Resources section to other relevant state, regional, national, and global anuran and amphibian web sites. It also has a "Frogs as Bio-Indicators Science Corner," which examines many of the factors influencing declining populations.

*Declining Amphibian Populations Task Force*
http://acs-info.open.ac.uk/info/newsletters/ FROGLOG.html

This is another organization with excellent information on the web. The organization's newsletter, FROGLOG, is also available on-line and has some interesting research reports from scientists around the world.

**Education Standards**
**Minnesota**
1 Write and Speak (writing, interpersonal communication)
5 Inquiry (direction observation; accessing information, controlled experiment)

**National**
Content Standard A Science as Inquiry

Grades 5–8:
Content Standard C Life Science (structure and function diversity and adaptation of organisms)

Grades 9–12:
Content Standard E Science and Technology (abilities of technological design)

*may only be available at a university/college library

## CLUE #1

## Acid Precipitation
## (Rain, Snow, Sleet)

Acid precipitation, generally called acid rain, can fall in different forms but mainly as rain and snow. It is both a natural product and a product of today's industrialized world. Precipitation can become acidified or more acidic by combining with carbon dioxide and other gases in the air. Also, following volcanic eruptions precipitation can become more acidic through its combination with various sulfur oxides.

However, the biggest continuous source of acid precipitation is from burning fossil fuels. Coal, especially "soft" or high sulfur coal, and other fossil fuels contain sulfur impurities. When a fossil fuel is burned, sulfur combines with oxygen in the air to form various sulfur oxides. When sulfur oxides react with moisture in the air, droplets of weak sulfuric acid form in the atmosphere. The droplets eventually mix with rainwater to form acid rain.

Although much air pollution comes from the industrial burning of coal and other fossil fuels, the most significant source of air pollution is motor vehicles. Gasoline and diesel fuels do not burn completely in the engines of cars, buses, and trucks. Unburned fuel vapors and carbon dioxide are released into the atmosphere.

Other pollutants contained in the exhaust of motor vehicles are nitrogen oxides. Nitrogen oxides are compounds in which nitrogen is combined with oxygen. In the atmosphere, nitrogen oxides may combine with water vapor to form droplets of weak nitric acid. The nitric acid may fall to the earth as acid precipitation in the same way sulfuric acid does.

When these droplets of sulfuric acid and nitric acid fall to the earth as acid rain or acid snow, they change the acidity, or pH level, of the waterways fed by the acid precipitation. Most aquatic organisms can survive in only a narrow range of water acidity. By increasing the water's acidity, acid precipitation kills many of the small organisms living there. Young organisms may be deformed, and adults may suffer if their food supply has been damaged. Aluminum and other metals may leach out of the soil and damage fragile gills.

Acid precipitation begins as air pollution. As precipitation falls to the earth the problem becomes water pollution. Then as the acid precipitation seeps into the soil, land pollution results. In the "pollution chain," all aspects of the environment are damaged. The acid precipitation affects the entire ecosystem of an area—the predators, the prey, and the vegetation.

What other sources of pollution may impact air and water quality?

## CLUE #2

## Predators and Prey

The diet for tadpoles of toads and frogs is different than that of adults. Algae and protozoa are the main foods for the tadpoles. They also scavenge dead animals. In overcrowded conditions, they may even nibble on each other!!

Adult frogs and toads are hunters. Vegetables are not part of their diet. They stalk their prey among the insects that swarm about their habitats. They also eat worms and small mollusks. The bullfrog sometimes catches small fishes, birds, or mammals, and big anurans will devour smaller individuals of their own or other species.

Anurans have many enemies. Tadpoles are target prey for almost every carnivore in or around the ponds. Many tadpoles do not survive for more than a day. The list of predators is long: water beetles and their larvae, dragonfly nymphs, water boatmen, and water scorpions will eat all kinds of tadpoles. Other predators include newts, fish, water shrews, and birds.

As adults, frogs and toads are the staple foods of turtles, snakes, herons, certain hawks, raccoons, and large fishes.

Toad skin glands have secretions that make them unappetizing to most predators. Importantly, toads DO NOT cause warts. However, if you rub your eyes after handling toads, these skin secretions can irritate the eyes. Toads also have toxins located in parotoid glands behind the head, which can release these toxins when the toads are threatened.

But anurans are part of the chain of life and natural predation should not be a large factor in their declining populations in such a short period of time, otherwise amphibians would have died out millions of years ago. Yet they survived many global catastrophes for hundreds of millions of years.

What about unnatural predation (introduction of non-native species, etc.)?

## CLUE #3

## Global Climate Changes

In the hydrologic cycle the earth circulates all the water there is on the planet through a system of storage sites, flow channels, and changes in state (solid, liquid, or gas). Storage sites include plants and animals using water to grow and conduct their body processes, rock layers porous enough to hold water, and ponds, lakes, and oceans (these are the most visible reservoirs). The amount of water available to an ecosystem is a result of the precipitation (bringing water from the atmosphere to the earth) and evapotranspiration (the combination of biological and physical processes that return water vapor to the atmosphere).

In the temperate zones of the earth, if there is more precipitation than evapotranspiration, the area will have dependable ponds for anuran habitat. If evapotranspiration exceeds precipitation, any ponds that form will probably be temporary. Temporary ponds create difficulties for anurans. If precipitation is acidic, the entire pond may immediately take on the same level of acidity, with resulting damage to the gills and bone development of tadpoles. With a high rate of evapotranspiration, the young anurans may not get to develop at all. Their pond may dry up before they are developed into their land-dwelling forms. Their deaths would mean an interruption in the anuran population of that year and would decrease the number of reproducing adults in the coming years.

Our global climate has changed over millions of years and has allowed life to evolve on this planet. With the aid of the “greenhouse effect” (which allows enough energy in to warm the planet and allows energy reflected by the planet to escape) life has evolved, adapted to planetary conditions and in many cases flourished. However, humans may be enhancing this greenhouse effect, causing more energy to be trapped in the atmosphere with the probability of raising global temperatures resulting in major climatic changes.

Scientists estimate that much of the northern latitudes’ temperate zone will become increasingly warmer over the coming decades because of the enhanced greenhouse effect. Extremes of climate, such as droughts, El Niño events, blizzards and the like, may become more frequent. How will anurans respond to such circumstances, given their dependence on ponds and streams?

## CLUE #4

## Habitat Fragmentation, Elimination, and Alteration

Anurans are locally based populations, they generally do not travel great distances. So, impacts on a local habitat can have detrimental results on local populations. As humans continue to push their way further into undeveloped or less developed areas—such as forests, swamps, and other habitats—thousands, if not millions, of species are displaced from their homes. This factor is still extremely important in population declines of most animals including anurans. In many cases, habitat may not be destroyed completely, but only fragmented, making it difficult for the anurans to get to breeding ponds.

For example, some species of frogs only go to ponds to lay eggs and breed, spending the remainder of their life in wooded or prairie areas. If a road is placed in between the ponds and the woods or prairie, the frogs may not be able to get to the breeding ponds. Or the young adults or metamorph can not make it from the pond to the habitat they require as adults. Faced with a new obstacle or a whole new environment, many of these organisms die off or become road-kill. But, some species are more tolerant of humans and do learn to live in this new habitat type, although their population numbers are greatly reduced. But, eventually this population may become too small to be sustainable.

Development of a local area may not always be the most direct influence on the anuran populations in that area. For example, at the 1998 Midwest Declining Amphibians Conference, Minnesota scientist Dr. David Hoppe from the University of Minnesota-Morris made a surprising and distressing statement about frog populations in some areas of Minnesota. He visited 14 sites which another herpetologist, David Merrell, has collected frogs from during the 1950s. In 1997, Dr. Hoppe found frogs only in five of the sites!!! Many of these sites had not been developed and were in a similar condition from the 1950s. Had other conditions altered in the area to impact these populations?

Overall, anurans in temperate areas are more fortunate than their tropical cousins. There may be a higher diversity of anurans in tropical regions but they have a small, limited geographic range while temperate amphibians have a larger range. This means that the destruction of tropical rainforests has a greater impact on animals and will lead to the extinction of a large number of anurans and other creatures.

Another example: by clear-cutting forests and filling in swamps to create farming areas, humans inadvertently introduce salts (minerals) into the soil. This salt can be transported by water from the soil to the anuran breeding sites, which become saturated with salt. Eggs and tadpoles of anurans cannot handle this extra salinity and they die.

What other ways can habitats be changed?

## CLUE #5

## Pathogens—
## Parasites and Fungi

Various pathogen theories have been put forward as playing a role in declining anuran populations. The pathogens may include some types of parasites or fungi. Researchers found that a fungus called Saprolegnia is infecting many amphibians in the lakes and ponds of Oregon.

In 1997, Dr. Karen Lips found dozens of dead and dying frogs in the Fortuna Forest Reserve, Panama, a protected area without any direct human disturbance. The same scene appeared in 1998 when she returned to the reserve. She and other scientists examined the dead and dying frogs and detected a previously unknown fungus on the body. As you know, frogs and toads have very permeable skin. This fungus grows on the outside of the frog, covering the skin of the animal and effectively suffocating it. According to a scientist from the National Institutes of Health, this fungus is causing an epidemic to sweep parts of Central America, Australia, and other areas in the world.

But how could this epidemic sweep different parts of the world, unconnected by any land? Could the fungus travel through the air or in the oceans…probably not and survive all that distance. Nothing else connects these areas…except research. How could the research be a factor in this? Could the scientists transport the fungus on their research equipment or even on their boots? Well, this is what the scientists now fear…that in their quest to find an answer to declining frog populations they have transported this fungus from infected to pristine areas. Do you think this is possible? Why/why not?

Many scientists now believe that ultraviolet rays have impaired the anuran immune system (which fights diseases), reducing the ability of anurans to resist fungal infections. What other factors could be involved in this lack of resistance to fungi/parasites?

## CLUE #6

## Consumption

Consumption can come in many forms for anurans. They are an important part of the food chain, hunting and eating many insects, etc. and being hunted and eaten by various animals, including humans. For example, tadpoles are target prey for almost every carnivore in or around ponds. Many tadpoles do not survive for more than a day. The list of predators is long: water beetles and their larvae, dragonfly nymphs, water boatmen, and water scorpions will eat all kinds of tadpoles. Other predators include newts, fish, water shrews, and birds. As adults, frogs and toads are the staple foods of turtles, snakes, herons, certain hawks, raccoons, and large fishes. In Australia, feral pigs kill many frogs and in Switzerland, polecats destroy many frogs.

However, one of the largest consumers of anuran populations
is us: humans. People typically eat only one part of the frog—its legs. In the late 1800s and early 1900s the hunger for frog legs decimated the wild red-legged frog populations of Oregon and California. Later in the 20th century, Midwestern states (Minnesota, Iowa, etc.) decimated the wild Northern Leopard Frog populations for human consumption. In France, average annual consumption of frog legs requires up to 60 million frogs. Even if these frogs are raised on farms and actual human consumption may be insignificant relative to the decline, it does affect the anuran populations.

In addition, humans consume anurans in other ways. They are used for fish bait and for biological work in laboratories and schools. Wild populations are still used as a source for these activities, although they may also be farmed for this purpose.

Examine frogs from birth to death and note all the points where and by what they are consumed. Can populations sustain these levels of consumption?

## CLUE #7

## Deformities in Anurans

In recent years, a phenomenon has begun to affect amphibian populations more seriously than in the past.

In 1995, Minnesota students found a large number of deformed frogs in a pond. As anurans are good indicators of the quality and health of the environment, scientists and the media began to take notice of these reports. These deformities included extra or missing limbs, branching limbs, extra or missing eyes, and missing or deformed internal organs. Scientists feared that these deformities could impact the survival rate of affected organisms. Possible causes for these deformities include contaminated water sources, UV radiation, and parasites. However, following years of research by scientists, the cause of these deformities has not been pinpointed, but people are worried that whatever is causing the deformities in frogs could impact human health. Do you think this deformity phenomenon has an impact on declining populations? Why/why not? Are more deformed frogs being found because more people are looking for them?

## CLUE #8

## Ultraviolet Radiation (UV-B)

When scientists began to notice the decline in anuran populations, another environmental phenomenon was also reported. A thinning in the ozone layer, that protective covering around the planet, which shields life from harmful sun rays. Even though the chemicals, which caused this problem, have been banned, their impact will be felt for many decades to come. Most countries now broadcast warnings of UV during particular times of the year, so that we can protect ourselves from the harmful effects of these rays. We can wear long sleeves, hats, and sun block—all of which protect our skin from this radiation. Scientists began to speculate that perhaps there was a connection between these two incidents. However, while we can protect ourselves, anurans cannot apply sun block to protect from radiation.

Anurans are extremely fragile in many stages of their life cycle, particularly in the egg stage. Many species lay egg masses in the water, eggs, which do not have a strong protective covering. Eggs are exposed to a great deal of UV in this situation. Also, the ozone layer is generally at its weakest in spring, allowing more UV to pass through and cause damage to eggs.

In the 1980s, studies were performed to investigate the disappearance of anurans in the Cascade Mountains of Oregon. Researchers hypothesized that increasing UV was slowly decreasing anuran populations. Western toads were selected for the studies. Researchers believed that many fertilized eggs were dying. To prove this point, they conducted a laboratory experiment with fertilized western toad eggs. From the results, they stated that under UV, 40 percent of the fertilized eggs did not hatch. On the other hand, when protected from UV, only 10 percent of the eggs failed to mature. But this was performed in a laboratory, what about out in the field? What about factors such as water pollution or lake acidity, which are encountered in ponds and lakes? These factors did not seem to alleviate the mortality rates and so the scientists deduced that ultraviolet light had a detrimental affect on anuran eggs.

Other studies showed similar results. In fact, this pattern continued. However, something else was noticed—species eggs that were high in an enzyme called photolyase had higher survival rates.

So, what role did this enzyme play? Enzymes are special types of protein, which help in some chemical reactions. In this case, photolyase removes harmful, damaged DNA sections. From this knowledge, scientists speculated that the UV was destroying the DNA of anuran egg cells, killing them before they mature. In addition, if the UV light does not kill the cell, it may maim it by causing a deformity. If they reach maturity, adults from these cells will have suppressed immune systems, making them susceptible to attack from parasites and fungi. Scientists found that a fungus called Saprolegnia is infecting many anurans in the lakes and ponds of Oregon. What other impacts could UV radiation have on anurans?