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Sensitive Salamanders: How Salamanders are Impacted by Climate Change and Water Pollution

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How Salamanders are Impacted by Climate Change and Water Pollution

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Have you heard of a "canary in a coal mine?" It's an old idiom describing a practice in which coal miners would bring canaries into coal mines to alert the miners to dangerous gasses; canaries would succumb to toxic gasses before miners did, warning them to evacuate immediately. This idiom is analogous to the relationship between salamanders, water pollution, and climate change today.

Salamanders are of the class Amphibia: cold-blooded vertebrate animals like frogs, salamanders, toads, and newts. Salamanders are amphibians that resemble lizards, but in contrast to a lizard's scales and their strict use of lungs for breathing, salamanders have soft porous skin and have a greater range of breathing abilities through their gills, lungs, and skin. Some salamanders breathe through both skin and lungs!

Salamanders are typically found in temperate shady forests or in slow-moving creeks and headwater habitats: the small streams, brooks, and springs that are the beginning of most rivers. They require water to survive and lay their eggs in moist areas or under rocks in creek beds. They eat soft-bodied animals such as worms, snails, and slugs. At the beginning of their life cycle, most salamanders are fully aquatic and born with gills; they lose their gills and grow lungs during their development. Salamanders move from aquatic to terrestrial environments when they mature, though some will return to aquatic environments to lay eggs. Some salamanders lack lungs and gills and rely solely on cutaneous respiration, "breathing" through their skin. Since salamanders rely on water to survive, the introduction of pollutants or water evaporation due to extended drought can cause harm to salamander populations. This serves as an early warning of more detrimental impacts downriver. By studying salamanders closely, scientists can act quickly against potential threats.

In Ohio, you can find high numbers of salamanders as they emerge from their winter dormancy to find new places to mate and lay eggs. March and April are highly active salamander movement months in this region. If you walk on a creek bed and flip over a few stones, you will likely find a salamander or two! Spring temperatures average around zero degrees Celsius, but the water at the bottom of a lake or pond is four degrees Celsius, which is warm enough to keep the salamanders from freezing. As temperatures warm in the spring, salamanders increase their metabolic rate; an increased

metabolism means an increased caloric intake, so they become active and start hunting for food. However, most salamanders cannot tolerate extended temperatures above 25°C. They will spend summers in cool creek beds or underground to overcome this. Due to their reliance on clean water and cool temperatures, salamanders are the perfect "canary in a coal mine" for water pollution and climate change.

While salamanders are a very diverse species, living in small home ranges and many different habitats, they are sensitive and typically require a temperature range of 10°C – 25°C. Plethodon cinereus, the redback salamander, is strongly limited by temperature, actively seeking temperatures between 16-18°C. A recent study found that P. cinereus was significantly larger in warmer places in the United States, and their body size increased dramatically in such areas. Increased body sizes may also be driven by detection probabilities shifting in favor of larger salamanders under warmer, drier climate conditions. Wetter years have been correlated with increased clutch size in some salamanders, the total number of eggs a salamander will lay each nesting attempt. If temperatures continue to rise, we will see a decrease in the number of salamanders laying eggs and, instead, lower numbers of larger salamanders competing for space and food.

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Scientists have analyzed temperature impacts in Notophthalmus viridescens, or the red-spotted newt, which shares a similar habitat range to the redback salamander. A newt is a type of salamander that goes through the same life cycle as all salamanders, the only difference being most newts have webbed feet and a paddle-like tail, making it easier for them to live in the water. Newts are impacted by the temperature and rainfall of the environment around them because they are ectothermic. They have permeable skin and rely on external heat sources, so their body temperature changes with the environment. Dramatic changes in body temperature factor into essential functions, such as energy gain and reproduction. One study analyzed temperature relative to pond activity of N. viridescens and found that warmer air temperatures increased newt activity during the breeding season and that there was an increase in male newts during warm periods. Other studies have found that smaller newts become less active in cold temperatures. This signifies that with an increase in temperature, such as what we are currently experiencing, we will see an increase in salamander and newt activity. This will also result in a selection for larger body sizes. Extrapolating further, we may see a decrease in egg clutch size and a reduction in the number of temperature-sensitive species.

Fire salamanders, found in southern and central Europe, were active at temperatures as low as one degree Celcius and aestivate or go into a period of torpor during dry periods at temperatures above 16°C. Temperatures above 11°C have been found to cause metabolic depression and increased heart rate, causing high-calorie consumption. There is growing concern that climate change is occurring much faster than expected, moving from an increase of 0.08°C per decade from 1880 to 1980 to the current 0.18°C increase per decade since 1980. Fire salamanders can survive up to five days in temperatures over 25°C, considered warm for humans. Still, temperature ranges in the United States quickly reach record highs every summer. Long Periods of increased temperatures during times when salamanders are supposed to be breeding or foraging can cause alarming problems. Rising temperatures will also increase the amount of water evaporation, concentrating the number of pollutants in the water or eliminating entire water supplies.

Various water pollutants enter natural aquatic habitats through runoff or dumping, such as fertilizers, pesticides, heavy metals, and road de-icers. On-farm fields, over half a million tons of pesticides, 12 million tons of nitrogen, and four million tons of phosphorus are applied annually to reduce pests and enhance plant production, all of which run off to nearby creeks and streams as contamination. These excess nutrients lead to algae blooms, which in turn lead to the development of hypoxic (low oxygen) conditions that harm aquatic life. Effects of pollutants on salamanders range from lethal to sublethal effects, such as decreased growth and development, higher frequency of developmental abnormality, greater susceptibility to diseases, and behavioral alterations.

The impacts of certain pollutants vary depending on the developmental stage the individuals are initially exposed. The life cycle of the salamander goes through four stages. They begin as shell-less eggs before moving to the larval, juvenile, and adult stages. Salamander eggs are found underwater and have a vitelline membrane, and a jelly envelope collectively called the egg capsule. Oxygen is diffused through the capsule, allowing the salamander to respirate. Small chemicals in the water can pass through this membrane and contaminate the delicate ecosystem. This contamination can cause physiological alterations in embryonic and larval salamanders, including increased methemoglobin concentrations, modification of enzyme activities, and DNA damage. While a salamander may survive these impacts, their ability to forage and reproduce becomes impaired, affecting their population size.

Adult salamanders are less impacted by pollutants in the water if there are other clean streams around. Salamanders with and without lungs will be affected by water pollution, including sediment, agricultural runoff, and acidic seepage, and will relocate to cleaner water. Some salamanders can travel up to six miles for two hours without stopping during the breeding season. This allows salamanders some defense against water pollutants, as they can relocate to lay their eggs when they sense water becoming too contaminated.

Salamanders are experiencing heavy selective pressures. While there are various salamanders in different habitats, they all rely on strict temperature ranges and clean water. When one or both are thrown off, that disruption leads to species loss, drinking water contamination, crop contamination shortages due to drought, and more. Future research on salamanders should focus on field studies to analyze how the salamanders are adapting to current changes and should chart body size and egg clutch size to catch any red flags that may be appearing.