

TADPOLES IN TROUBLE

Young yellow-bellied toads have to face a multitude of dangers.

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Spring is the perfect time to explore the lives of young amphibians. In Poland's climate zone, this is when these creatures, awakened from several months of winter hibernation, begin entering water bodies to breed. Water is crucial for this process because nature has not equipped their embryos with fetal membranes that allow for safe development on land. Therefore, the initial stage of an amphibian's development—the larva—is inextricably linked to water.

The amphibians living in Poland fall into two different orders: *urodeles* (amphibians with tails: salamanders and newts) and *anurans* (amphibians without tails: frogs and toads). The differences in their larvae are striking. Urodeles, represented in Poland

by four species of newts and the fire salamander, have larvae that look like miniature versions of the adults. They possess external gills, which appear as small, feathery protrusions behind their heads. Their mouthparts are similar to those they will have as adults, and they are just as effective as predators. When observing a urodele larva, one will always see two pairs of limbs.

In contrast, the larvae of anurans, known as tadpoles, look completely different from the adults. They have a prominent "head" (actually a cephalothorax) which ends in a long, laterally flattened tail fin. The English term "tadpole" actually derives from the "toad head" (while the alternative name "pollywog" comes from the Middle English for "head wiggle"). Tadpoles lack external gills; their respiratory system is enclosed within a specialized gill chamber. They are mainly herbivores, feeding on plant matter. They can filter it from the water or scrape it off surfaces using their horny jaws (rostrum) surrounded by bands of tiny, horny teeth. This herbivorous diet means that tadpoles have a long, coiled intestine, which can sometimes be



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Size comparison of three yellow-bellied toads (*Bombina variegata*): a tadpole, an individual in the midst of metamorphosis, and a post-metamorphic toad

MAŁGORZATA ŁACIAK

seen through their translucent bodies. Moreover, tadpoles have only one visible pair of hind limbs – their front limbs, although developing at the same time, remain hidden within the gill chamber.

Difficult life choices

Tadpoles' lives are inherently fraught with danger. In permanent water bodies (such as ponds or various types of water pools) rich in aquatic vegetation, predators abound, eagerly preying on these tasty, nutritious, and generally defenseless creatures. Essentially, any predator large or cunning enough to do so will seize and consume a tadpole. Conversely, in small, temporary water bodies such as large puddles or water-filled depressions, the danger is different. These ponds may dry up before tadpoles can complete their metamorphosis. Therefore, different species of frogs and toads, with access to both permanent and temporary water bodies, will choose a strictly defined type of aquatic habitat. Some species have adaptations that enable them to thrive better in one type of habitat or another, and the selection of the right egg-laying site can have a profound impact on tadpole survival.

In water bodies without fish, the greatest threat to tadpoles comes from predatory aquatic invertebrates.

In permanent water bodies, the number of predators per cubic meter of water is much higher than in temporary ones. When we think of predators, fish typically first come to mind. Indeed, these animals pose a substantial threat to amphibian larvae (hence, if creating an artificial for amphibians, it is advisable not to introduce any fish). Other vertebrates that may prey on tadpoles include reptiles (such as grass snakes, turtles), other amphibians (adult individuals or predatory larvae of urodeles), water birds, and occasionally mammals (such as water shrews). However, in water bodies without fish, predatory invertebrates are the primary menace. The larvae of dragonflies, larvae and adult beetles, and various heteropteran bugs are adept at preying on tadpoles and prove highly efficient in consuming them. We have found, for instance, that a single diving beetle (*Dytiscidae*) larva can devour between 300 to 900 tadpoles as it develops. Utilizing visual, tactile, and chemical cues, these predators easily detect their prey and hunt them down effectively. Some beetles even lay their eggs directly on amphibian spawn, providing their offspring immediate access to

abundant food. Dragonfly larvae actively pursue tadpoles or employ a “sit and wait” strategy to ambush unsuspecting tadpoles passing by.

However, it should be noted that developing in permanent water bodies also has certain advantages for tadpoles. It ensures the presence of water for a sufficient duration, allowing individuals to develop and metamorphose without interruption. Moreover, the food supply for tadpoles in permanent water bodies is typically abundant. Therefore, despite the risk of predation, many amphibian species opt to lay their eggs in such habitats. In these environments, tadpoles acquire various adaptations that aid in predator evasion. They might camouflage into their surroundings with specialized coloration, hide out among vegetation, or adjust their behavior based on predator presence. Some tadpole species exhibit *polyphenism*, an adaptation whereby they display different traits (phenotypes) depending on whether certain predators are present or absent. For instance, in the presence of predators, tadpoles may develop larger tail fins, enhancing their ability to swim swiftly and evade danger. When tadpoles come under attack, they may also emit chemical signals known as pheromones, which travel through the water to alert other tadpoles that predators are present.

To outsmart predatory aquatic invertebrates, some amphibian species instead prefer to reproduce in temporary water bodies. One notable example is the yellow-bellied toad (*Bombina variegata*), a species that has been extensively studied by our team at the Institute of Nature Conservation of the Polish Academy of Sciences. This species inhabits mountainous and foothill regions, where permanent water bodies are scarce. For breeding purposes, it selects various temporary water sources, including larger puddles, water-filled depressions, or seasonal pools found in the floodplains of river valleys.

Such water bodies are typically small in size and often lack aquatic vegetation. Predatory invertebrates and vertebrates are rarely observed in these environments. While yellow-bellied toads actively seek out predator-free habitats, invertebrates can swiftly colonize such areas. If predatory invertebrates do infiltrate a small pond, they can quickly decimate many young individuals. The grass snake (*Natrix natrix*) ranks high among the adversaries of yellow-bellied toad tadpoles and is frequently observed in puddles. Besides targeting tadpoles, it eagerly preys on metamorphosing individuals of this species and even adults, despite their potent skin toxins.

Washed away

The breeding of yellow-bellied toads is triggered by rainfall. Since ponds and puddles are freshest after rain, the toads quickly take advantage of the oppor-



MALGORZATA ŁACIAK

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tunity. Typically, the female does not deposit all her eggs in one pond but rather in batches at various locations. This minimizes the risk of all the eggs or tadpoles becoming dried out, being destroyed or eaten by potential predators. From this point, time becomes crucial. To minimize the time the tadpoles have to spend in water, yellow-bellied toads lay fewer but larger eggs compared to their lowland relatives (fire-bellied toads *Bombina bombina*), which inhabit larger, permanent water bodies. The developmental period of this larval stage is also significantly faster than that of closely related lowland fire-bellied toads (with a difference ranging from approximately two to four weeks).

In mountainous and foothill regions, river valleys are considered primary habitats for yellow-bellied toads. Historically, most Carpathian rivers flowed in braided channels, but this has changed drastically due to river channel regulation, primarily since the second half of the nineteenth century. Currently, most rivers are highly regulated, preventing them from freely overflowing into adjacent areas, which greatly reduces the formation of small, seasonal water bodies ideal for the development of yellow-bellied toads. Consequently, these amphibians have begun utilizing anthropogenic habitats. These include puddles and depressions formed on dirt roads or even artificial ponds in gravel pits. Today, even these habitats are becoming increasingly scarce, as roads are increasingly getting paved and repaired, filling in any holes and depressions, and small ponds are being filled in.

However, even when a yellow-bellied toad finds a suitable breeding habitat, there still remains another weather-related threat: heavy rainfall. Our recent research shows that local flash floods, caused by intense, short-lived downpours, can wash tadpoles out of the ponds they live in. Natural habitats are particularly at risk due to their proximity to stream channels, making them vulnerable to flood waves. Among anthropogenic habitats, those located on slopes suffer the most, as surface runoff can wash through them with great force. The least such damage occurs in anthropogenic habitats situated on mountain ridges.

Climate change may cause sudden heavy rainfalls to become increasingly frequent. Thus, aside from predation, the drying out of water bodies, and habitat destruction, this could be another significant threat to the survival of this species. Research indicates that amphibians are the most endangered group of terrestrial vertebrates on Earth, highlighting the importance of taking swift action to help particular species survive. Building various types of ponds for them is one of the most important measures that can benefit these animals. However, it is crucial to remember that the tadpoles in water bodies also face various threats, making the location of such artificially constructed ponds very significant. In practice, creating seasonal ponds on a larger scale is extremely difficult (if not impossible), so the best way to protect the habitats of the yellow-bellied toad remains the preservation of mountain river valleys. ■

Further reading:

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