

## Predation-Induced Injuries in Wild Populations of Alpine Newt

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**Abstract.-** Animal species not at the top of the food pyramid, including most amphibians, are exposed to predation. To date, the frequency and types of injuries observed in European newts have not been analyzed. This article presents a study of this phenomenon conducted during 2007–2009 at three localities in the Czech Republic. Of 549 captured individuals, 9.3% had been injured. Wounds were found primarily to the tail (78.4% of injured newts) and to extremities in the form of missing toes (19.6%). Other types of wounds or their combinations occurred only exceptionally. The presence of injuries differed among localities, but was not affected by body length or sex. The complex life cycle and regenerative abilities of newts complicate drawing conclusions as to the ecological background of injury frequency. Therefore, future studies focused on this topic should utilize experimental approaches.

**Key words:** Wound, regeneration, amphibians, Caudata, Salamandridae, amphibian injuries, *Mesotriton alpestris*.

### INTRODUCTION

All animals living in the wild suffer injuries due to diseases, intraspecific aggression, and most of all predation, which thus influences their behavior (Lima and Dill, 1990). The two main strategies animals use to cope with this risk are to evade the predator or to survive its attack (Seligmann *et al.*, 2003). While it may be difficult to document instances in which an animal has successfully evaded a predator, survival after an encounter with a predator may be visible as an injury (Vermeij, 1982). This can also be used as an indicator of predator inefficiency (Reimchen, 1988; Mushinsky and Miller, 1993). Injuries are thus particularly studied in animals having the ability to autotomize a body part (Formanowicz, 1990; Maginnis, 2006) or to regenerate missing part, which is after this process different from original body part (Gvoždík, 2000; Maginnis, 2006).

European newts (*Triturus*, *Mesotriton*, *Lissotriton*) have great regenerative abilities (Henle *et al.*, 1997), but little is known about the type or frequency of injuries they suffer. There are studies dealing with the rate of wounds in larval (Vogrin, 2006) or freshly metamorphosed newts (Nemes, 2002), but the examination of injuries in adult newts has been still neglected. Definition of predators,

categorization of injury types, and the influence of injuries on the population characteristics of newts may be difficult to evaluate, particularly due to their complex life cycle during which adults alternate annually between water (where they reproduce) and land (where they spend the remainder of the year) (Griffiths, 1996). Unlike animals unable to regenerate (MacDonald *et al.*, 2004; Gregory and Isaac, 2005), newts do not retain injuries, and thus a wound may reflect a rather recently attempted attack by a predator.

Effect of predation on injuries will be probably connected with predators diversity, abundance and efficiency, then we can expect geographical differences in injury rates among populations (e.g. Placyk and Burghardt, 2005). Also sexual dimorphism of the Alpine newts, prominent mainly during breeding, may lead to the assumption that there will be intersexual difference in injury rates, like in other animals (e.g. MacDonald *et al.*, 2004). The aim of my study, therefore, was to analyze the effect of sex and geographical variation on frequency and type of injuries in Alpine newts (*Mesotriton alpestris*) from three localities in the Czech Republic.

### MATERIALS AND METHODS

Alpine newts were surveyed in three fishless water bodies with relatively different environmental conditions, all of which are located in the Pardubice Region of the Czech Republic.

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The locality Horní Morava (50°9′39″N, 16°49′16″E; 780 m a.s.l.) is a permanent pool (10 × 20 m, maximum depth 0.7 m) in an abandoned quarry, where Common toads (*Bufo bufo*) and Common frogs (*Rana temporaria*) also reproduce. Grass snakes (*Natrix natrix*) are common in this locality, and other potential predators of newts found there are bird species Black Stork (*Ciconia nigra*) and Eurasian jay (*Garrulus glandarius*), as well as mammals European polecat (*Mustela putorius*), Beech marten (*Martes foina*), European pine marten (*Martes martes*), European badger (*Meles meles*), and Raccoon dog (*Nyctereutes procyonoides*). The locality Zabítý (49°57′11″N, 16°23′54″E; 500 m a.s.l.) is located in a spruce forest and consists of 11 water-filled vehicle-track ruts, which are tiny (1 × 5 m) and shallow (maximum depth 0.2 m), and some of them are therefore temporary (i.e. desiccated during the breeding period). Alpine newts were the only amphibians observed to reproduce at this locality. Predators that can prey on newts in this locality are Grass snakes, Eurasian jays (*Garrulus glandarius*), European magpies (*Pica pica*), European polecats (*Mustela putorius*), Beech martens (*Martes foina*), and European pine martens (*Martes martes*). The locality Zhoř (49°54′7″N, 16°22′59″E; 480 m a.s.l.) is situated within a private, fenced garden in the village of Zhoř, where newts reproduce in a concrete permanent pool with water lilies (1 × 2.5 m, maximum depth 1.2 m). Alpine newts were the only amphibians observed to reproduce at this locality. The main predator of newts at this locality is the Domestic cat (*Felis catus*), while another potential predator is the European magpie. Dragonfly larvae of the genera *Libellula* and *Aeshna* were common at all localities, and *Dytiscus* larvae were also present in the locality Horní Morava.

The presence of potential predators in a locality was determined based on two surveys made each year and conducted within a diameter of one km from the locality. Various indications of animals' occurrence, tracks, and direct observation were used to ascertain the presence of predators. Range data from atlases for reptiles (Mikátová *et al.*, 2001), birds (Štátný *et al.*, 2006), and carnivorous mammals (Anděra and Hanzal, 1996) were also checked.

In each locality, newts were captured by hand or with a net every week throughout the breeding season (mainly from April to July) in the years 2007, 2008 and 2009. Every newt captured for the first time was measured to the nearest 0.1 mm and two body proportions, SVL (snout–vent length) and Lcd (tail length), were recorded. The newts were then examined for the presence of injuries. To eliminate the possibility that a particular individual would be examined more than once, all newts were individually marked using VIE elastomer tags (Northwest Marine Technologies, Shaw Island, WA, U.S.A.) (Davies and Ovaska, 2001). Two captured newts with polydactyly were excluded from the sample of injured individuals. In previous (2004, 2005) studies (Kopecký *et al.*, 2010, 2012), newts in these localities were marked by clipping the toes of the last two phalanges, and the process of regeneration after toe clipping could have caused these deformations (Denoël, pers. comm.). In addition, males missing the tip of the tail were also excluded from the analyses. A missing tip of the tail in a male can be caused by a female's bite in the course of mating, which has been observed during the spermatophore transfer stage known as distal lure (Denoël *et al.*, 2001).

The sex ratios in particular localities were tested by chi-square tests. To detect possible differences in SVL and in relative Lcd (Lcd / SVL + Lcd) between sexes and among localities, I used two-way ANOVA. The effect of sex and locality (as explanatory variables) on the presence of wounds (as response variable with binomial distribution) I analyzed by generalized linear model (GLM). The type of injury was not taken into account in the main analysis due to the small proportion of injured newts. The effect of sex and locality was controlled on newt's SVL, using body length as covariate. SVL was used as a covariate due to fact that Lcd and SVL are mutually correlated ( $r = 0.72$ ,  $P < 0.001$ ). Samples of SVL and Lcd have normal distribution. Statistical significance was determined at the level  $\alpha = 0.05$ . All tests were computed using Statistica 9.0 (Statsoft Inc., 2009).

## RESULTS

A total of 549 newts (267 males, 282

females) were captured during the study. The sex ratio (males : females) based on pooled data from particular years was unbiased in Zabitý (1.09:1,  $\chi^2 = 0.62$ ,  $P = 0.43$ ) and Zhoř (1.03:1,  $\chi^2 = 0.02$ ,  $P = 0.98$ ), but slightly female biased in Horní Morava (0.70:1,  $\chi^2 = 4.36$ ,  $P < 0.05$ ).

SVL differed between the sexes ( $F = 531.94$ ,  $df = 1$ ,  $P < 0.001$ ) and among localities ( $F = 34.05$ ,  $df = 2$ ,  $P < 0.001$ ), but the interaction of sex and locality was not significant ( $F = 1.52$ ,  $df = 2$ ,  $P = 0.22$ ), *i.e.* females were greater than males and this difference is similar in all localities. Females have relatively longer tails (44.6% of total body length) than do males (43.1%) ( $F = 46.01$ ,  $df = 1$ ,  $P < 0.001$ ), but the effect of locality ( $F = 2.20$ ,  $df = 2$ ,  $P = 0.11$ ), like the interaction of sex and locality ( $F = 0.90$ ,  $df = 2$ ,  $P = 0.39$ ) were not significant.

Fifty-one (9.3%) of all captured newts were injured (Table I). The variability of injury types was relatively low. The most commonly visible injury was a ragged tail (78.4%), and 19.6% of injured newts had missing toes. One to three toes were missing in injured newts, and, if toe loss had occurred, only one limb was affected. More injuries were found on fore than on hind feet (7:3). Two individuals were identified that did not fall within the main categories of injuries: one female from Zabitý was missing an eye and one male from Horní Morava had fresh scars on its back. A combination of wound types in a given individual was exceptional. Only one female from Horní Morava had an injured tail and was also missing a toe on a hind foot. GLM revealed that only locality (not sex, SVL or interaction between the factors) affected the occurrence of wounds in newts (Table II).

## DISCUSSION

With the exception of the two individuals with polydactyly, both with 5 digits on a forelimb (probably as result of the process of regeneration after the marking by toe clipping made in previous seasons 2004 and 2005), no morphological abnormalities in newts were observed. This suggests that pesticides or other agrochemicals that can cause deformations in amphibians (*e.g.*, Piha *et al.*, 2006) are present in the localities only at marginal concentrations or not at all. This hypothesis is also

consistent with the character of the localities. As parasites of the genus *Ribeiroia*, which also can cause deformities in amphibians (Johnson *et al.*, 2001), have not been found in Europe to date, the observed wounds are almost always the consequence of previous predation. Nevertheless, because newts may spend much of their time underground, in the burrows of small mammals, or in dense ground vegetation (Verrell, 1985; Schabetsberger *et al.*, 2004), and because movement in narrow spaces or scraping can tear the tail, mechanical damage cannot be fully excluded as the potential cause of tail wounds.

**Table I.-** Number of newts examined, by sex, locality and existence of injuries.

Locality	Sex	n	% injured
Horní Morava	M	64	15.6
	F	93	8.6
Zabitý	M	164	4.9
	F	150	6.0
Zhoř	M	39	18.0
	F	39	23.1

**Table II.-** Influence of variables on the presence or absence of injury in Alpine newts from the generalized linear model with binomial distribution. Significant values are in bold, SVL (snout-vent length) was used as covariable.

	<i>df</i>	$\chi^2$	<i>P</i>
SVL	1	3.00	0.08
<b>Locality</b>	<b>2</b>	<b>10.96</b>	<b>&lt; 0.01</b>
Sex	1	1.84	0.17
Locality * sex	2	1.96	0.38

While a previous study of snakes of the genus *Thamnophis* provides evidence for correlation between diversity of predators and tail stubs (Placyk and Burghardt, 2005), no such relationship can be inferred from the present study (the highest proportion of injured newts came from that locality with the lowest diversity of predators). This is not surprising due to a number of factors with variable levels that can influence the injury rate, such as newt density, density of other prey, density of

predators, predators' efficiency, predators' intensity, number and availability of shelters.

The observed proportion of wounded individuals may be also potentially affected by age structure of the population, whereby older animals accumulate injuries because they have been exposed to predation for longer time periods. In newts, the age of an individual is roughly associated with body size (Halliday and Verrell, 1988) and the largest newts were found in Zhoř. Nevertheless, the effect of SVL on the presence of an injury was nonsignificant, which is rather surprising because in similar studies of lizards (Gvoždík, 2000) and snakes (Gregory and Isaac, 2005) larger individuals bore injuries more frequently. Accordingly, the highest proportion of injured newts in Zhoř probably did not result from longer exposure to predation during life. Newts can regenerate quickly (e.g. after the toe-clipping process, toes can regenerate within months (Henle *et al.*, 1997)), and thus the rate of injured newts could actually reflect a higher rate of predation at that site at the particular time of the study. The fact that SVL does not affect the presence or absence of injury may also suggest that predators in the studied localities are not selective on the basis of size. Zhoř is the only locality where the capture of newts by a potential predator was observed directly, as domestic cats were seen catching newts as they swam to the surface for breath. If cats are the main predators of newts at this locality, then the highest frequency of injuries there may be influenced by hunting for purposes other than consumption. Due to the fact that newts are slightly poisonous (Duellman and Trueb, 1994) and cats are fed regularly by their owners, newts are thus caught, potentially injured, but not consumed. Unlike in a similar study focused on highly toxic American newts of the genus *Taricha* (Stokes *et al.*, 2011), no newt carcass was found during the present study.

Due to differences in body size between the predator and adult newt, the efficiency of mammals and great bird predators will probably be high. As sublethal predatory attacks often occur when predators are smaller than, or roughly similar in size to, their prey (Schoener, 1979), the originators of the wounds observed on adult newts are probably smaller vertebrates (like Grass snakes, Eurasian Jays

or European Magpies) and potentially also invertebrate predators. On the other hand, injuries visible on adult newts may have their origins in the larval stage. In a study on abnormalities of Western toads (*Anaxyrus boreas*) and Cascades frogs (*Rana cascadae*), the animals causing their injuries had been small (sticklebacks and dragonfly larvae), and the vast majority of wounds on adult toads and frogs had their origins in the tadpole stage (Bowerman *et al.*, 2010). In newts, predation during the larval stage can be intensified by potential intraspecific larval predation (Vogrin, 2006) and the rate of injuries can be high. For example, in one locality in Romania, Nemes (2002) found an injury rate reaching 24.5% among newly metamorphosed Common newts (*Lissotriton vulgaris*). Regeneration is generally an energy-demanding process (Maiorana, 1977; Maginnis, 2006) and it may be expected that for adults and larvae it comes at different prices. Larval newts need energy mainly for rapid growth to reach metamorphosis (e.g. Goldberg *et al.*, 2012), and energy can be mainly invested into growth instead of regeneration, while in adults other trade-offs may be possible. In other words, injuries inflicted in the larval stage may be more persistent than are injuries inflicted during the juvenile or adult stages.

A sex-dependent rate of injuries had been expected because males are brightly colored during the reproductive phase while females are blandly colored (Griffiths, 1996; Roček *et al.*, 2003), and therefore males may be more conspicuous to visually oriented predators. The data, however, contradicts this prediction because no intersexual difference in the presence or absence of injury was found. This supports the idea that efficiency of predators targeting adult newts is very high, and if there is some intersexual difference it will be rather expressed in survival rates. In addition, the complexity of the newt life cycle cannot be overlooked. Newts spend most of the year on land, and during this period sexual dimorphism is not so prominent (Roček *et al.*, 2003).

Due to the observational nature of this study, many interesting questions associated with this phenomenon remain unanswered. Among the open questions are whether injury increases the risk of lethal predation, and how injury affects non-

reproductive (e.g. growth, hunting) and reproductive (e.g. attractiveness, fertility) aspects of newts' lives. Furthermore, studies as to the adaptive significance of the relatively longer tails in females might yield interesting findings, especially in light of the fact that most injuries recorded during this study were localized to the tail.

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