TÜBİTAK

Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Short Communication

Turk J Zool
(2014) 38: 114-117
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doi:10.3906/zoo-1212-36

Facultative paedomorphosis in a population of *Lissotriton vulgaris* (Amphibia: Salamandridae) from the Danube Delta Biosphere Reserve (Romania)

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Received: 28.12.2012 • **Accepted:** 09.10.2013 • **Published Online:** 01.01.2014 • **Printed:** 15.01.2014

Abstract: Facultative paedomorphosis refers to the simultaneous expression of 2 different phenotypes (i.e. paedomorphic and metamorphic) within the same population. Over the last 6 decades, this phenomenon was reported from only 5 populations of smooth newt *Lissotriton vulgaris* (Linnaeus, 1758) in Romania. In the spring of 2011, we found a new facultative paedomorphic population. The sample was female-biased, thus suggesting a sex-dependent expression of the paedomorphic phenotype. Most of the populations recorded in Romania were found in permanent water bodies with abundant vegetation.

Key words: Phenotype, larval traits, newts, sex ratio, trade-off, wetland

Paedomorphosis is an alternative ontogenetic pathway in which reproductive adults maintain larval traits. Sometimes both phenotypes (i.e. paedomorphic and metamorphic) can coexist within the same population and this phenomenon is referred to as facultative paedomorphosis. The mechanisms that trigger and maintain polymorphisms seem to be multiple, with both genetic and environmental components (Denoël et al., 2009), and they vary among species and populations (Semlitsch et al., 1990; Whiteman, 1994; Elinson and del Pino, 2012). Different environmental variables influence paedomorphosis and paedomorphic populations were reported from a diversity of habitats (Denoël et al., 2005b). Three main hypotheses were proposed to explain the maintenance of facultative paedomorphosis: "the paedomorph advantage", "the best of a bad lot", and "the dimorphic paedomorph" (Whiteman, 1994). Each of these hypotheses suggests different selection mechanisms and trade-offs that are closely correlated to environmental conditions and predict the fitness of the future morph.

Paedomorphosis was reported in all 9 families of newts and salamanders (class Amphibia; order Caudata) (Denoël et al., 2005b). Facultative paedomorphosis was observed in only 4 families: Salamandridae, Ambystomatidae, Hynobiidae, and some Plethodontidae (Denoël et al., 2005b). It is quite common among newts of the family Salamandridae, particularly among species of the former genera *Triturus*, now *Lissotriton* and *Ichtyosaura*, and *Notophthalmus* (Wells, 2007).

The smooth newt *Lissotriton vulgaris* (Linnaeus, 1758) is a widespread species in Europe, except for the Iberian Peninsula, from which it is absent (Arntzen et al., 2009). It is the most widespread newt species in Romania, where it occurs from sea level up to 1500 m in altitude (Cogălniceanu et al., 2000). Over the last 58 years, paedomorphosis in smooth newt populations was reported from only 5 locations, limited to western and southeastern Romania (Fuhn, 1963; Covaciu-Marcov and Cicort-Lucaciu, 2007; Gherghel et al., 2010; Covaciu-Marcov et al., 2011) (Table 1).

In the spring of 2011, we found a facultative paedomorphic smooth newt population in the southern part of the Danube Delta Biosphere Reserve (44°37′16.79″N, 28°48′16.89″E) (Figure). The area is part of the Sinoe-Zmeica lagoon system, a large wetland, mostly covered by common reed (*Phragmites australis*) and reed mace (*Typha* sp.) and with sparsely disseminated open shallow water bodies. The terrestrial habitats are represented by a natural levee (Grindul Lupilor), a flat sand dune with an altitudinal range of 0.5-1.5 m, covered by steppe vegetation, partly on salinized land. Both permanent and temporary aquatic habitats are present in the area. The climate is characterized by low annual precipitation (approaching 350 mm) with maximum of rainfall in June (45–55 mm) and minimum in February (18–35 mm) (Bogdan, 2008). We found 8 other amphibian species in this area: *Triturus dobrogicus*, *Pelophylax* kl. *esculentus*, *P. ridibundus*, *Pelobates syriacus*, *P. fuscus*, *Bombina bombina*, *Bufo viridis*, and *Hyla arborea*.

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Table 1. Past and recent records on paedomorphosis in *Lissotriton vulgaris* populations from Romania.

Collection date	Paedomorphs		Metamorphs		Collection site	Habitat description	Author, publication date
	female[s]	male[s]	female[s]	male[s]			
17 April 1953	1	-	12	-	Roșuleț Lake, Danube Delta	Not specified	Fuhn, 1963
April 1956	19		1	1	Caraorman, Danube Delta	The shore of a flooded area, rich in *Ceratophyllum* sp., muddy water	Fuhn, 1963
11 March 2007	1	-	Over 100		Prunișor, Arad	A system of large puddles, continued by a swampy area, near an oak forest; abundant aquatic vegetation and muddy bottom	Covaciu-Marcov and Cicort-Lucaciu, 2007
18 May 2007	1	-	Present, not specified		Murighiol, Danube Delta	Large pond with muddy bottom, covered by reed, with few open areas and a large fish population	Gherghel et al., 2010
2007	1	-	-	-	Scăpău, Mehedinți	An artificial ditch filled permanently with water; dense aquatic vegetation; at least 5 species of fish present	Covaciu-Marcov et al., 2011
April 2008	6	2	-	-			
2008	1	-	-	-			
16 March - 1April 2011	10	2	5	5	Sinoe, Constanța	Large wetland mostly covered by common reed and reed mace and with sparsely disseminated open shallow water bodies; predatory fish present	Present paper

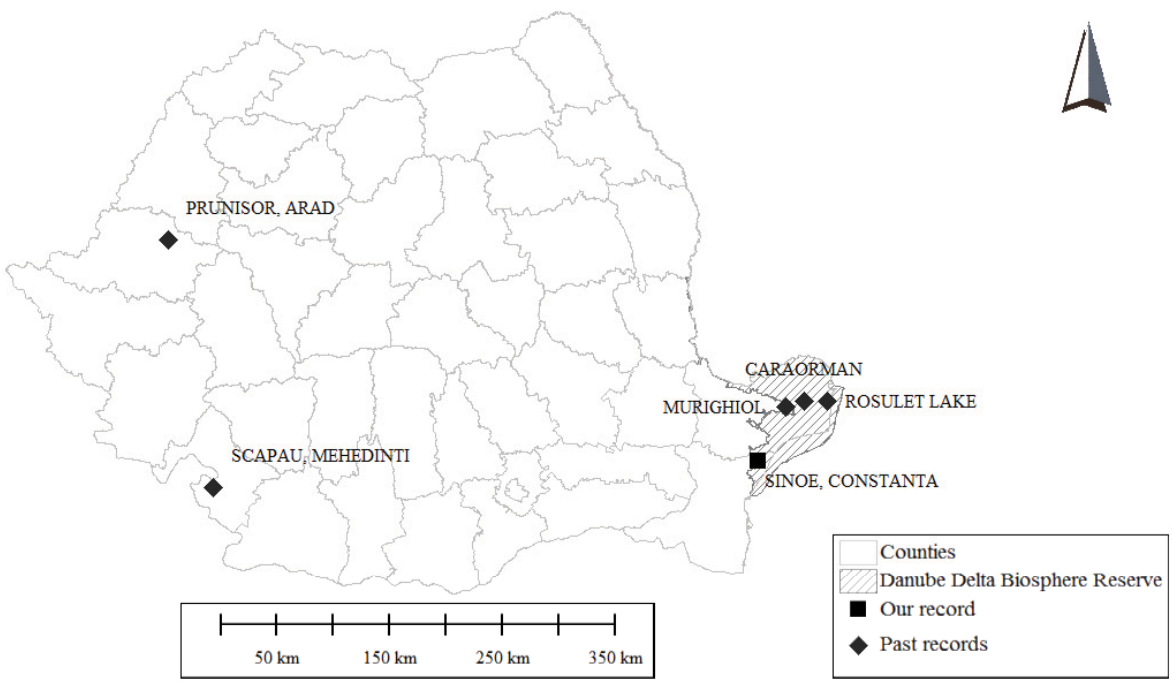

Figure. The occurrence of paedomorphosis in *Lissotriton vulgaris* populations within Romania: past records (filled diamonds), our record (filled square).

Predatory fish (e.g., *Esox lucius*, *Aspius aspius*, *Silurus glanis*, *Anguilla anguilla*, *Perca fluviatilis*, *Sander lucioperca*) (Oţel, 2007) and reptiles (e.g., *Natrix natrix*, *Natrix tessellata*, *Emys orbicularis*) are also present.

We performed the sampling during 5 fieldtrips (16 March to 1 April 2011) by night torch surveys, each lasting 2 to 5 h. The animals were captured in shallow waters, less than 0.5 m deep. We found 21 sexually mature smooth newt individuals consisting of 11 paedomorphs (10 females, 1 male) and 10 metamorphs (5 females, 5 males). We also found a dead paedomorphic male, which could not be measured. All captured males presented well-developed secondary sexual characters. We measured the snout-vent length (SVL) with dial calipers with a precision of 0.1 mm and body mass with a precision of 0.01 g on an electronic balance (Kern PCB) (Table 2). We brought the animals to the laboratory for measurements and released them afterwards at the capture site. In 2012, we caught no animals due to the extreme drought.

The body mass of females differed significantly between the 2 morphs (t-test, df = 13, P = 0.01), with paedomorphic females weighing more. The paedomorphic male had the highest body mass compared to the metamorphic males. SVL did not differ significantly between females of the 2 morphs (t-test, df = 13, P > 0.05).

We suggest that the trade-off faced by larvae between metamorphosing and having to cope with an arid terrestrial environment, or remaining in the water as paedomorphs and risking desiccation but having abundant food resources, has resulted in a rather balanced metamorph-to-paedomorph ratio. Although small, the paedomorphic sample was female-biased, suggesting that the response of the population to this trade-off may be sex-dependent. Higher body mass in paedomorphs could be explained by the higher water content of the individuals, since metamorphic newts had most probably hibernated on land and only recently reentered water; this may also indicate a higher fitness of paedomorphic individuals.

Facultative paedomorphosis was previously reported in Romania from smooth newt populations inhabiting both shallow temporary and permanent aquatic habitats with abundant vegetation (Table 1). Facultative paedomorphosis was expressed at different extents within each of these populations. Four of the records (66.6%) are from the Danube Delta, a 5500-km^2 wetland, while the other 2 are from low-altitude plains. Aquatic predators (mainly fish) were present in 5 sites (83.3%).

Although it has been proven that the presence of aquatic predators, mainly fish, negatively affects newt populations and implicitly paedomorphic individuals (Denoël et al., 2005a), the presence of dense vegetation cover seems to mitigate their impact by providing favorable microhabitats (Hartel et al., 2007). Unfavorable terrestrial conditions could explain why some of the individuals remained in the water, where food resources are abundant and vegetation provides shelter. This phenomenon was also observed in temporary aquatic habitats (e.g., flooded areas), and there is evidence that paedomorphic newts are able to cope with desiccation either by metamorphosis or by short migrations and seem to have adapted to this kind of extreme event (Denoël, 2003; Denoël et al., 2005a).

Facultative paedomorphosis was observed in a low number of populations and only in few areas in the country. Since long periods of selection against paedomorphosis might lead to the loss of this phenotype (Semlitsch and Wilbur, 1989; Denoël et al., 2005a), we emphasize the high importance of long-term monitoring and further research of their habitats in order to better understand and manage these populations.

Acknowledgments

Research in the area was possible thanks to a research permit issued by the Danube Delta Biosphere Reserve Administration, no. 24/01.04.2011, and it was partly supported by the Romanian National Authority for Scientific Research, grant PN-II-ID-PCE-2011-3-0173. Special thanks to Dr Mathieu Denöel for helpful comments on a previous version of the manuscript and for providing a bibliography; we also thank Daniela Iordache for help during fieldwork.

Table 2. Snout-vent length (SVL) and body mass of metamorphic and paedomorphic smooth newts: mean ± SD with range below (min–max).

Sex	Morph	Sample size	SVL (mm)	Body mass (g)
Females	Metamorph	5	32.0 ± 4.1 26.9–38.1	1.23 ± 0.23 1.07–1.64
	Paedomorph	10	32.7 ± 2.8 28.2–36.1	1.73 ± 0.22 1.28–2.01
Males	Metamorph	5	32.4 ± 2.9 29.1–36.5	1.17 ± 0.06 1.09–1.26
	Paedomorph	1	34.5	1.45

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