Changes in dorsal spot pattern in adult *Salamandra salamandra* (LINNAEUS, 1758)

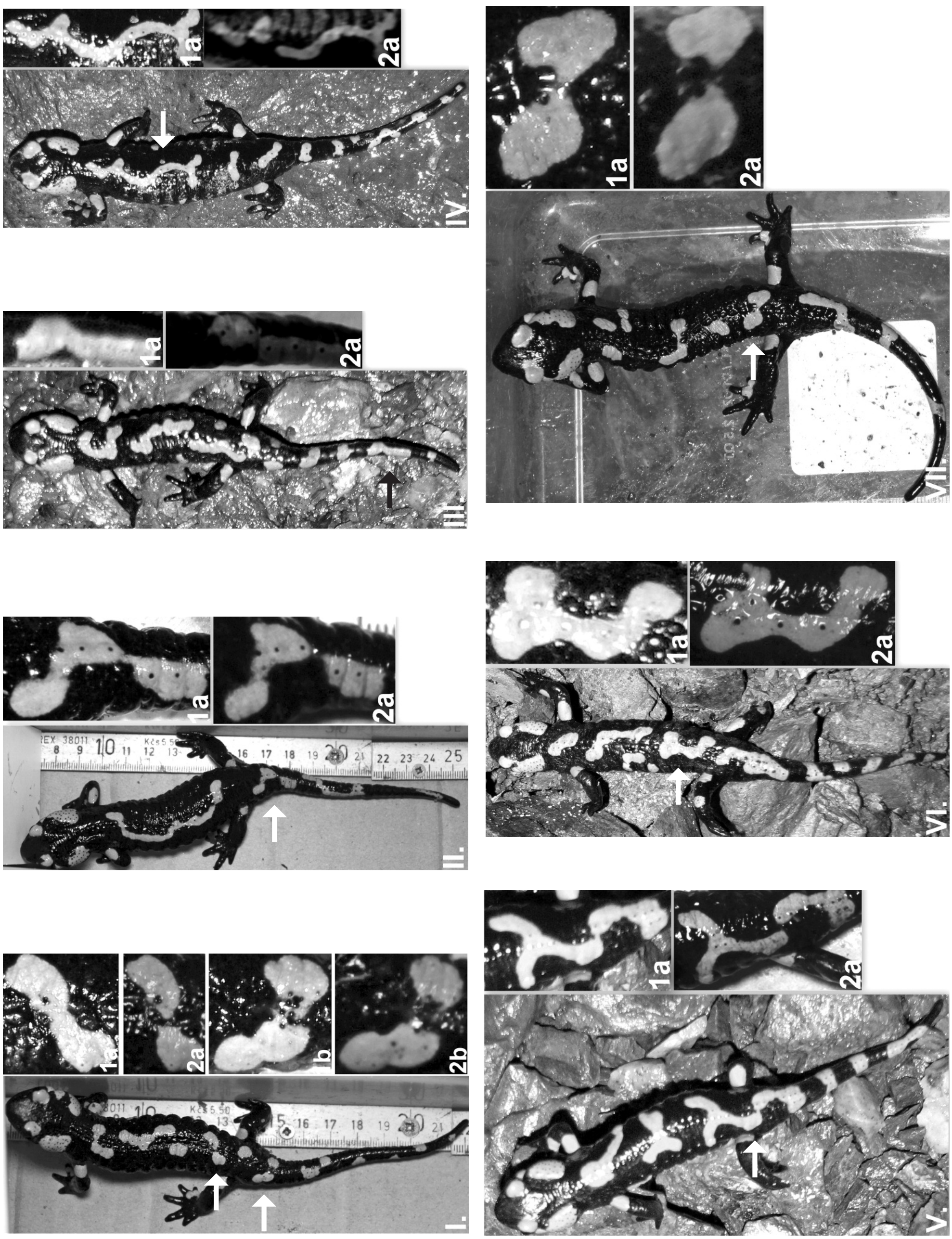
Mark-recapture techniques for the individual recognition of animals are commonly used in population studies of amphibians. The supposed longer-term constancy of the individual colorpattern represents the basis for a widely accepted non-invasive technique for individual recognition in amphibian species in which the dorsal or ventral pattern varies among individuals (DONELLY et al. 1994; CARAFA & BIONDI 2004; PLĂIAȘU et al. 2005; BIANCARDI & DICERBO 2010; GOLLMANN & GOLLMANN 2011; COURTOIS et al. 2013; LEEB et al. 2013). Thus, the conspicuous dorsal pattern of yellow to orange spots on black background of Fire Salamanders, *Salamandra salamandra* (LINNAEUS, 1758), is considered a suitable identification tool in mark-recapture studies (e.g., CARAFA & BIONDI 2004; BAR-DAVID et al. 2007; SCHMIDT et al. 2014). The authors of the present note used this approach in their research on hibernation and sexual dimorphism in the colorpattern of Fire Salamanders in Slovakia (BALOGOVÁ & UHRIN 2014, 2015). In the present study, minor, however unexpected, changes in the shape of spots of adult *S. salamandra salamandra* observed during their ontogeny are reported.

Salamanders were repeatedly captured from November 2011 to March 2014 in an artificial damp gallery near the village of Tichá Voda (eastern Slovakia; 48°46.2'N, 20°36.3'E; 855 m a. s. l.; 49 individually recognized specimens, 24 males, 15 females, 10 juveniles) and from December 2011 to April 2014 in Bobačka Cave (eastern Slovakia; 48°46.9' N, 20°06.3'E; 811 m a. s. l.; 106 individually recognized specimens, 47 males, 51 females, 8 juveniles). Each individual's dorsal side was photographed and coded according to a method based on unique spot markings (OPATRNÝ 1983).

From 49 identified individuals in the gallery near the village of Tichá Voda, 37 (75.5 %) were recaptured [number of recaptures > 0] and 27 (55.1 %) more than once [number of recaptures > 1]. In seven salamanders (14.3 %), individual changes in dorsal coloration were recorded, with 301 days (3 March to 28 December, 2012) representing the shortest interval leading to the observed modification. In Bobačka Cave, from 106 identified individuals 42 (39.6 %) were recaptured [number of recaptures > 0], 23 (21.7 %) more than once [number of recaptures > 1]. In three salamanders (2.8 %), dorsal pattern changes were detected, with 307 days (9 March, 2012 to 9 January, 2013) representing the shortest interval leading to the observed modification. The gradual alteration of a complex circular spot (Fig. 1, individual no. VIII) was recorded during two years (639 days). Generally, two types of changes were observed: (1) reduction of the spot area, and (2) spot splitting (Fig. 1).

Recognition of individual animals using photo documentation has great advantages; e. g., it does not involve stress and risk of infection as do invasive techniques, such as applying PIT (Passive Integrated Transponder) tags, toe clipping or branding (PLĂIAȘU et al. 2005; WAYE 2013). In the present study, minor changes in the dorsal pattern were seen already as early as at the age of about ten months when compared to earlier developmental stages.

The growth velocity of Fire Salamanders decreases at about the age of two years and varies between individuals depending on external ecological factors (BARUŠ & OLIVA 1992). For instance, in one salamander, an increase by 19.0 mm in total length over five years was observed, whereas another one gained just 3.0 mm over five years and three months. The authors assume that the velocity of dorsal pattern alteration is correlated with individual growth velocity. Thus, future studies should try to find out whether or not changes in dorsal spots are more rapid and pronounced in juvenile individuals than in adults because of the faster growth rate of the former. Several observations raised doubts regarding pattern constancy. BOGAERTS (2002) reported colorpattern modifications during ontogenesis in *S. salamandra* which were however, declared to be of minor significance in sexually mature adults and would not impede individual identification (THIESMEIER 2004). BEUKEMA (2011) provided evidence on the ontogenetic development of the dorsal pattern in *Salamandra corsica* SAVI, 1838,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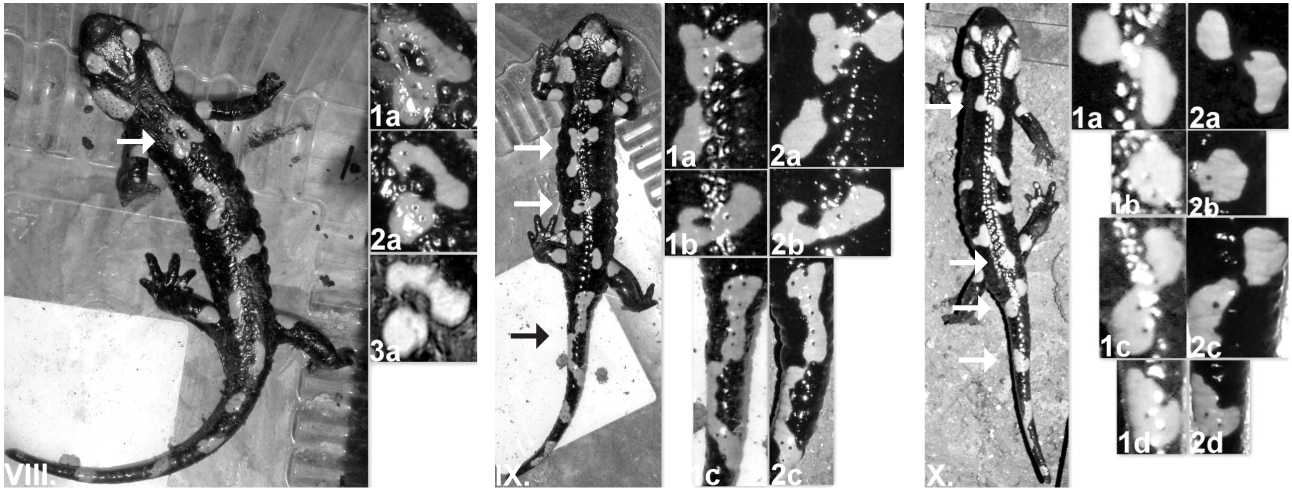

Fig. 1 (this and opposite page): Ontogenetic changes in the shape of yellow dorsal spots of recaptured individuals of *Salamandra salamandra* (LINNAEUS, 1758).
Brightness differences between identical spots photographed at different dates are caused by different light conditions in the field.

Individuals I – VII from Tichá Voda artificial damp gallery, VIII – X from Bobačka Cave.

I.1a,1b – 3 March, 2012; 2a,2b – 1 March, 2013 (364 days).
II.1a – 3 March, 2012; 2a – 28 December, 2012 (301 days).
III.1a – 14 November, 2011; 2a – 30 December, 2013 (778 days).
IV.1a – 14 November, 2011; 2a – 30 December, 2013 (778 days).
V.1a – 14 November, 2011; 2a – 28 December, 2012 (411 days).
VI.1a – 14 November, 2011; 2a – 1 March 2013 (474 days).
VII.1a – 20 December, 2011; 2a – 30 December, 2013 (742 days).

VIII.1a – 9 March, 2012; 2a – 9 January, 2013 (307 days); 3a – 7 December, 2013 (333 days).
IX.1a, 1b, 1c – 4 January, 2012; 2a, 2b, 2c – 21 December, 2013 (718 days).
X.1a, 1b, 1c, 1d – 4 January, 2012; 2a, 2b, 2c, 2d – 21 December, 2013 (718 days).

recording a significant increase in the number of spots, which changed from a more rounded to irregular shape with increasing snout vent length. This could have been caused by the splitting of coherent larger spots into smaller spots, as was recorded in the present study. BEUKEMA (2011) furthermore drew attention to long-term studies and possible identification errors that may arise from his observation. WAYE (2013) observed marked ontogenetic alterations in the colorpattern of *Ambystoma tigrinum* (GREEN, 1825) which may complicate not only individual identification but also subspecific classification of Tiger Salamanders. Furthermore, the reliability of photo documentation for individual identification was critically reviewed in some frog species, e. g., *Litoria genimaculata* (HORST, 1883) and *Bombina variegata* (LINNAEUS, 1758) (KENYON et al. 2009; GOLLMANN & GOLLMANN 2011).

In conclusion, the authors suggest that in long-term studies of *Salamandra salamandra* photo documentation should be combined with another method of individual recognition. The non-invasive method proposed for *S. salamandra* by ŠUKALO et al. (2013) could be suitable. In a modified approach, the unique individual alphanumeric code would be formed by the number of openings on the yellow surface of the parotid glands only, exclusive of the openings on the potentially unstable yellow areas along the dorsum and tail.

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