

Ontogenetic change of colour pattern in *Bombina variegata*: implications for individual identification

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Abstract. Ontogenetic changes in colour patterns pose problems for recognition of individuals. We illustrate such changes with examples from a long-term study of yellow-bellied toads, *Bombina variegata*. Most changes take place in the weeks after metamorphosis, but subsequent identification of toads registered at metamorphosis is usually possible through comparisons of the throat pattern.

Keywords. Anura; development; identification; pattern mapping

Introduction

Pattern mapping, the photographic recording of colour patterns, is the preferred method for individual registration of amphibians (Donnelly et al., 1994). This approach has been successfully used in ecological studies of fire-bellied toads (genus *Bombina*) for many decades (Nilsson, 1954; Seidel, 1993). The ventral colour pattern is stable in subadult and adult *Bombina*, except for small changes that do not interfere with identification. At metamorphosis, however, the colour pattern is not yet complete. To illustrate the potential of using photographs of newly metamorphosed toadlets for later identification, we present examples of ontogenetic change observed during a long-term study on the

yellow-bellied toad, *Bombina variegata* (Gollmann and Gollmann, 2002, 2005).

Material and methods

Colour photographs of the ventral side of *B. variegata* individuals from Lainzer Tiergarten, a large nature reserve in Vienna, Austria, were made in the field, holding the toad in a hand immediately after capture. No additional marking method was used, except for noting injuries such as missing toes or limbs. For identification of toads, photographs were compared with older photos from this study area.

Results

From 1996 to 2007, we photographed a total of 4037 toadlets shortly after metamorphosis, and recaptured many of them. For example, out of 196 metamorphs photographed in 2006, we recaptured and identified 104 individuals in the same year and 38 more in 2007. At metamorphosis, the degree of pattern development was variable: Sometimes the pattern was nearly fully developed whereas sometimes the bellies were very pale.

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Figure 1. Ventral pattern of toad nr. 2769, on 11 July 2001 immediately after metamorphosis, on 2 August 2001 and on 8 May 2002 (left to right).



Figure 2. Ventral pattern of toad nr. 5647, on 9 September 2006 (left) and 3 July 2007 (right).

In many cases, the pattern was incomplete, especially in the breast region, but the throat pattern allowed unambiguous subsequent identification of metamorphs (Figs 1-3). A few weeks after metamorphosis, the pattern was usually completely developed, as dark markings appeared on the pale background (Fig. 1). Over the next years, the extent of the dark spots often increased, but the topology of the pattern remained unchanged (Figs 4-6). Most identifications of metamorphs were made within two years of first capture, but identification was possible also after longer intervals (up to 11 years). In addition to the colour pattern itself, the position of keratinized black warts on the belly can aid in identification.

Discussion

Colour pattern allows reliable individual identification of yellow-bellied toads; in most cases this holds also for toads photographed immediately after metamorphosis. For this presentation, we selected mainly difficult cases (Figs 2-4), which illustrate both the problems of comparing pictures of metamorphs and their potential for subsequent identification of toads. Because the complexity of the patterns allows many independent comparisons, such as throat against belly, or colour spots against keratinized warts, we are confident that we did not make any incorrect identification. We may have failed to recognize a few toadlets after recapture;



Figure 3. Ventral pattern of toad nr. 5620, on 24 June 2006 (left) and 9 June 2007 (right).



Figure 4. Ventral pattern of toad nr. 5571, on 11 July 2002 (left) and 2 June 2007 (right).

the high number of successful identifications, however, suggests that this kind of error was rare. For efficient comparison of pictures by eye, it is advantageous not to look for overall similarity, but to form a search image for a particular element. In the case of comparisons with photos of metamorphs, this search image should focus on the throat pattern, which usually is present already at metamorphosis.

Ontogenetic variation of colour pattern in *B. variegata* poses two problems for comparisons of pictures, that will also be relevant for automated comparisons with image recognition software (in addition to difficulties caused by the quality of photographs, such as highlights): allometry and increase of dark elements. As the toads grow, the belly increases more in area than the throat, which leads to a change in the overall pattern, although the topology of its elements remains unchanged (in the examples provided in figures 4 to 6, the median ratio of throat area / belly area diminishes from 0.41 to 0.26).

In many toads, the dark grey or black parts of the pattern increase with age. At metamorphosis, some of these dark elements may not yet be visible, especially in the breast region; in later life these elements often expand in area. These changes may pose problems for classification schemes developed to sort photographs by similarity of patterns, using connections between defined colour spots (e.g. Gollmann and Gollmann, 2002, p. 119f; Plăiașu et al., 2005). For example, the



Figure 5. Ventral pattern of toad nr. 278, on 18 August 1996 (left) and 9 June 2004 (right).



Figure 6. Ventral pattern of toad nr. 6079, on 27 August 2008 (left) and 5 June 2011 (right).

connection between the two yellow breast patches may be present early in life, but become interrupted by dark pigment later (Fig. 6).

Finally, we want to point to the possibility of using the back pattern for individual identification. The dorsal colour pattern is usually less distinct in *B. variegata* than in *Bombina bombina* or *Bombina orientalis*, but the arrangement of warts is probably constant, though this matter has not yet been systematically studied. We suggest that high-resolution photography of the dorsal side, or a part of it, can be particularly useful for identification in two situations: metamorphlings with a pale ventral side without distinct pattern, or behavioural studies where the capture of toads necessary for examining their undersides would be disruptive for the aims of the investigation.

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