The distribution of the crested and marbled newt species (Amphibia: Salamandridae: Triturus) an addition to the New Atlas of Amphibians and Reptiles of Europe

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The distribution of the crested and marbled newt species (Amphibia: Salamandridae: *Triturus*) – an addition to the New Atlas of Amphibians and Reptiles of Europe

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Abstract. In the recently published New Atlas of Amphibians and Reptiles of Europe (Sillero et al., 2014a), the distribution of the newt genus *Triturus* was not resolved at the level of the species. The main reason for this was the lack of high quality distribution data from in and around the parapatric contact zones between species, where interspecific hybridization occurs. We are working extensively on *Triturus* and the (particularly genetic) data we have accumulated allow us to map the individual *Triturus* species at the appropriate scale. We here provide a database composed of distribution data for the individual species, at generally high resolution, particularly from in and around contact zones. Based on this database we produce maps at the 50 × 50 km UTM grid resolution as used in the new atlas and highlight those grid cells in which more than one *Triturus* species occurs.

Keywords: contact zone, herpetofauna, hybrid zone, *Triturus ivanbureschi*.

Recently, the New Atlas of Amphibians and Reptiles of Europe was published (Sillero et al., 2014a). We refer to this publication as 'the new atlas' throughout this paper. One of the aims of the new atlas was to identify gaps in the currently available knowledge on species distributions. Such knowledge gaps were particularly prevalent where, in the light of taxonomic progress, the recognition of new species has resulted in poorly understood range boundaries. One of the genera highlighted as troublesome to map was *Triturus*. Only the two main groups encompassing this genus, namely the marbled and crested newts, were represented in the new atlas, rather than the individual species that constitute these two groups (Supplementary Atlas S1 Distribution Amphibians in Sillero et al., 2014a). For the two species of marbled newts, species identification of larvae for numerous records was uncertain, especially for Portugal (footnote 4 to table 3 in Sillero et al., 2014a). For the six species of crested newts (referred to as a 'complex', although in our opinion the term 'superspecies' as used by Wallis and Arntzen, 1989 is more appropriate), species were not unambiguously distinguished in the available databases (footnote 20 to table 3 in Sillero et al., 2014a). We here supplement the new atlas by mapping the different European *Triturus* species.

The taxonomy of *Triturus* has been regularly revised (Wolterstorff, 1923; Bucci-Innocenti et al., 1983; Garcia-Paris et al., 1993; Arntzen et al., 2007; Espregueira Themudo and Arntzen, 2007a; Arntzen and Wielstra, 2010; Wielstra et al., 2013c). As a consequence, the number of recognized species and, indeed, parapatric contact zones has increased. Although the geographical distribution of *Triturus* species is well understood in a broad sense (Arntzen, 2003; Herrero et al., 2003a, 2003b), documentation of the contact zones between species constitutes an ongoing effort (Arntzen and Espregueira The-

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mudo, 2008; Wielstra et al., 2013b). Where species meet, hybridization occurs to a smaller or greater extent (Arntzen, 2003; Arntzen et al., in press). This means that *Triturus* populations can in general be assigned to species unambiguously, except those that are positioned in or near to contact zones. Considering our interest in interspecific hybridization, our research effort has particularly focussed on documenting the position of *Triturus* hybrid zones (Espregueira Themudo and Arntzen, 2007b; Wielstra and Arntzen, 2012; Arntzen et al., in press).

Although morphological criteria provide a reasonable estimation of species identity for *Triturus*, the diagnostic value of these criteria breaks down near hybrid zones (Arntzen and Wallis, 1999; Arntzen, 2003; Arntzen et al., in press). Furthermore, for the group of species previously treated as *T. karelinii*, no species specific morphological character states are as yet known (Ivanović et al., 2013). Genetic data, on the other hand, provide an objective measure of species identity. For species assignment and hybrid zone analysis we have previously used mitochondrial DNA restriction fragment length polymorphism (Wallis and Arntzen, 1989; Arntzen and Wallis, 1991), allozymes (Arntzen and Wallis, 1991; Espregueira Themudo and Arntzen, 2007a; Vörös and Arntzen, 2010; Arntzen et al., in press), microsatellites (Jehle et al., 2005; Arntzen et al., 2009, 2010) and sequence data for mitochondrial DNA (Wielstra et al., 2010, 2013b; Wielstra and Arntzen, 2011) and up to five nuclear DNA markers (Espregueira Themudo et al., 2009, 2012; Wielstra et al., 2013a). We have recently developed an Ion Torrent next-generation sequencing protocol targeting 52 nuclear DNA markers (Wielstra et al., 2014; Wielstra and Arntzen, unpublished) and in the context of our ongoing hybrid zone research we are genotyping a large number of *Triturus* newts held in the collection of Naturalis Biodiversity Center (e.g. Wielstra and Arntzen, 2014a).

With the above marker systems we have greatly increased our understanding of the *Triturus* distribution in and around the contact zones. Localities from the Naturalis Biodiversity Center collection form the core of our database of *Triturus* distribution data (579 data points). Additional distribution data were taken from the literature (e.g. Tarkhnishvili and Gokhelashvili, 1999; Tzankov and Stoyanov, 2008; Litvinchuk and Borkin, 2009; Canestrelli et al., 2012; Mikulíček et al., 2012; 1469 data points), from an atlas (Loureiro et al., 2010; 375 data points), from natural history collections (71 data points) and from the national database for Hungary (not yet included in the new atlas upon its publication; 60 data points) or were communicated to us by colleagues (88 data points). Furthermore, digitized atlas, survey and museum data were taken from the Global Biodiversity Information Facility (accessible via www.gbif.org; 2526 data points). A map showing the *Triturus* distribution data is provided in fig. 1. The underlying database (5168 data points in total), including a complete list of references, is available online as Supplementary Material S1. We updated an earlier version of this database (Wielstra et al., 2012, 2013b), with the most notable changes being that we incorporated field data up to and including 2014, digitized museum data for Hungary and recently published distribution data for Romania (Cogălniceanu et al., 2013).

We converted the data following Sillero et al. (2014a) to map the individual *Triturus* species at a 50 × 50 km UTM grid resolution. Not considered for these maps were distribution data falling outside of the area covered by the new atlas or from around contact zones for which either no genetic data could be consulted or for which genetic admixture was detected (but for the sake of completeness these distribution data are included in fig. 1 and Supplementary Material S1). Because our database particularly focusses on the contact zones between the *Triturus* species, it is less complete away from contact zones, particularly in the core of the range of *T. cristatus* (although our database does manage to fill a considerable

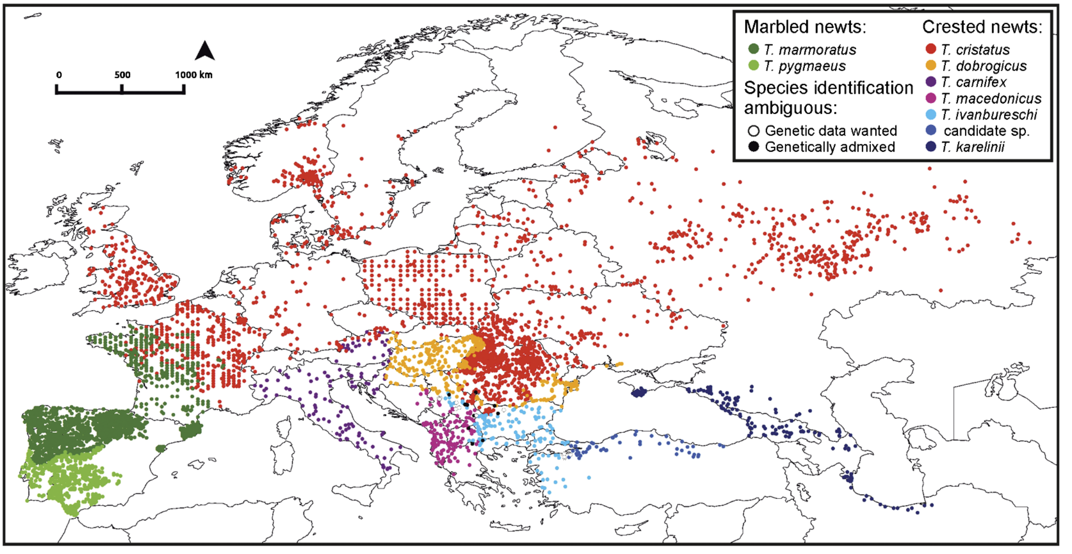

Figure 1. The *Triturus* distribution database presented in this paper, plotted on a map. Raw data and references are provided as Supplementary Material S1. Data points are colour coded according to species identity and we distinguish one more candidate species. Genetically admixed populations or populations for which genetic data is required to establish identity are noted as such. Ranges are mostly parapatric but those of the marbled newt *T. marmoratus* and the crested newt *T. cristatus* overlap in western France. This figure is published in colour in the online version.

number of additional grid cells in Central Europe and on the Balkan Peninsula compared to the new atlas). Fortunately, in the new atlas a large number of additional 50 × 50 km UTM grid cells containing *Triturus* records positioned away from the contact zones were presented. Guided by the database in the Supplementary Material S1, these grid cells were allocated to species when this could be done unambiguously, i.e. when they were positioned away from contact zones, and incorporated on the species maps. An overview of the maps is provided in fig. 2 and detailed maps can be found as online Supplementary fig. S1. Shape files are available under Supplementary Material S1. The new distribution data for the individual *Triturus* species can now be integrated in 'NA2RE', the web-based spatial data infrastructure underpinning the new atlas (Sillero et al., 2014b; http://na2re.ismai.pt).

The new atlas used the name *T. arntzeni* for the Balkan representative of the group of species traditionally referred to as *T. karelinii* (hereafter *T. karelinii sensu lato*). We have recently shown that the name *T. arntzeni* is not valid, as newts from the type locality are genetically admixed, containing genetic material of (mostly) *T. macedonicus* and *T. karelinii sensu lato* (Wielstra et al., 2013c; Wielstra and Arntzen, 2014a) and we have introduced the name *T. ivanbureschi* instead (Wielstra et al., 2013c). A distinct genetic group currently subsumed in *T. ivanbureschi*, distributed in Asiatic Turkey and hence outside of the region covered by the new atlas, may represent an as yet undescribed crested newt species (Wielstra et al., 2013a, 2013c).

Mapping of interspecific *Triturus* hybrids was beyond the purpose of the new atlas, but we provide some general insight on the distribution of hybrids. F1 hybrids of the marbled newt *T. marmoratus* and the crested newt *T. cristatus* can be expected to occur throughout the area where the two parent species are in sympatry in western France. These hybrids represent an 'evolutionary dead end' with the frequency of backcrossing being negligible (Wolterstorff, 1904; Arntzen and Wallis, 1991; Arntzen et al., 2009). Backcrossing is possible with hybrids between marbled newt species or hy-

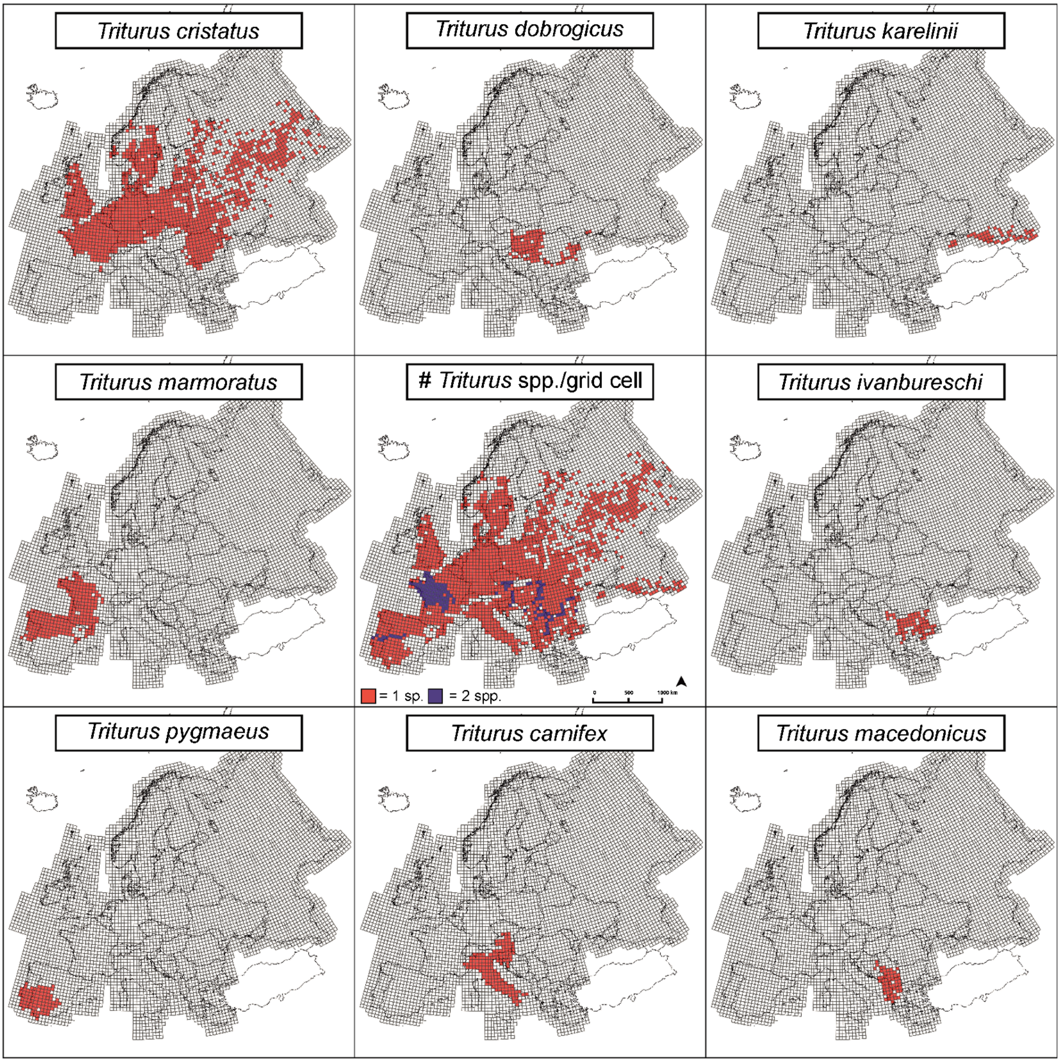

Figure 2. Distribution maps for European *Triturus* newts. Maps are in the format of the New Atlas of Amphibians and Reptiles of Europe, at a 50 × 50 km UTM grid resolution and restricted to Europe. The composite map in the centre shows the number of *Triturus* species per grid cell (red grid cells reflecting the presence of a single and blue ones the presence of two species) and the surrounding maps (arranged in line with geography) show the individual species. This figure is published in colour in the online version. Higher resolution versions of the individual maps can be found online in Supplementary fig. S1.

brids between crested newt species, as is reflected by asymmetric mtDNA introgression (Espregueira Themudo and Arntzen, 2007b; Espregueira Themudo et al., 2012; Wielstra and Arntzen, 2012, 2014b). However, the narrowness of the hybrid zones suggests the prevalence of reproductive isolating mechanisms, limiting gene flow and allowing species to maintain their genetic integrity (Arntzen, 2003; Arntzen et al., in press). Grid cells where multiple *Triturus* species co-occur and where interspecific hybridization could be expected are presented in fig. 2 and Supplementary fig. S1.

We here improved on the New Atlas of Amphibians and Reptiles of Europe (Sillero et al., 2014a) by providing distribution data for the individual species comprising the marbled and crested newts, particularly from in and around the parapatric contact zones between species (fig. 2, fig. S1). As stated in the new atlas, "a precise knowledge of the spatial distribution of taxa is essential for decision-making processes in land management and biodiversity conservation, both for present and under future global change scenarios". Additionally, *Triturus* provides a suitable system for hybrid zone study and for this aim a clear distribution picture for the different *Triturus* species is essential. The new atlas highlighted additional taxa for which detailed studies of the contact zones between constituent species, such as provided here for *Triturus*, are warranted. We hope this paper would stimulate researchers working on such taxa to publish up-to-date distribution maps.

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