Patterns of amphibian diversity in the Western Palearctic

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ABSTRACT - The discovery of cryptic species by molecular tools is leading us to revisit our perception of amphibian diversity and distribution. Here an analysis is presented of amphibian diversity across the Western Palearctic based on an up-to-date taxonomic list accounting for recently discovered taxa. While glacial refugia locally host many species, the most diverse regions are found at intermediate latitudes, where amphibians colonising from different refugia coexist. At least eight major diversity hotspots are identified. This data will be useful for future biogeographic and conservation assessments.

INTRODUCTION

Understanding patterns of amphibian diversity is instrumental to prioritise conservation efforts towards hotspots of endemism and species richness. An up-to-date spatial diversity framework is also fundamental to implement ecological, biogeographic and evolutionary research. In the Western Palearctic, i.e. Europe, North-Africa and the Middle East, the current distribution ranges of species, especially ectotherms, were mainly shaped by the Quaternary ice ages (Schmitt, 2007). In particular, the mild conditions, ecological stability and complex topography of southern regions have promoted the persistence and diversification of many radiations (Schmitt, 2007). Two decades of phylogeographic work have lifted the veil on this cryptic diversity, ultimately leading to the description of new species. However, this diversity is rarely taken into account in spatial assessments, because the legitimacy of cryptic species is debated, assessing their distribution requires molecular tools, and their discovery and/or specific assessment is often very recent (e.g. *Lissotriton*, Pabijan et al., 2017; *Pelodytes*, Díaz-Rodrígues et al., 2017; *Ommatotriton*, van Riemsdijk et al., 2017; *Hyla*, Dufresnes et al., 2018b). As a result, only 114 native Western Palearctic amphibians appear on the IUCN red list database (IUCN 2018), while about 20% more (137) could now be considered combining recent research (Dufresnes, 2019). Similarly, the 2014 European atlas for amphibians includes 73 native species (Sillero et al., 2014), instead of the 91 now known from Europe.

Here I have compiled distribution data from Western Palearctic species, including newly discovered cryptic species, to get an up-to-date picture of the global patterns of amphibian diversity.

MATERIALS AND METHODS

All analyses were conducted in QGIS 2.18.4 (QGIS Development Team 2018). Distribution data was gathered from the IUCN red list (IUCN 2018) and updated according to recent phylogeographic work. This included species splits for *Bufo spinosus*, *Bufo eichwaldi* (Recuero et al., 2012), *Bufotes* cf. *turanensis* (G. Mazepa, unpublished data), *Hyla* cf. *intermedia* (Dufresnes et al., 2018b), *Hyla molleri*, *Hyla orientalis* (Stöck et al., 2012), *Hyla felixarabica* (Gvoždík et al., 2010), *Pelobates vespertinus*, *Pelobates balcanicus* (CD unpublished data), *Pelodytes atlanticus*, *Pelodytes hespericus* (Díaz-Rodrígues et al., 2017), *Pelophylax cypriensis* (Plötner et al., 2012), *Lissotriton graecus*, *Lissotriton kosswigi*, *Lissotriton lantzi*, *Lissotriton schmidtleri* (Pabijan et al., 2017), *Triturus macedonicus*, *Triturus ivanbureschi*, *Triturus anatolicus* (Wielstra et al., 2013), *Ommatotriton nesterovi* (van Riemsdijk et al., 2017), *Salamandrina perspicillata* (Canestrelli et al., 2006), *Lyciasalamandra billae* (Veith et al., 2016); merging between *Bufotes viridis* and *Bufotes variabilis* (Dufresnes et al., 2018a); and fine-tuning of distributions, prepared for a new field-guide of Western-Palearctic amphibians soon to be published (Dufresnes, 2019). In total, individual distribution layers were produced for 137 native species (full list in Table S1).

A grid of 20×20 km was generated the region of interest using the MMQGIS plugin (http://michaelminn.com), drawn along the Arctic ice cap in the north, the Atlantic Ocean in the west, the Saharan and Middle Eastern deserts in the south and south-east, and the Ural Mountains in the north-east. Distribution shapefiles were then matched against the grid to count the number of species present in each quadrat using the Join Attributes By Location feature.

RESULTS AND DISCUSSION

Amphibian diversity in the Western Palearctic is maximal at intermediate latitudes across western and central Europe (Fig. 1), where different species originating from separate glacial refugia (Iberia, Balkans, Black Sea area) meet

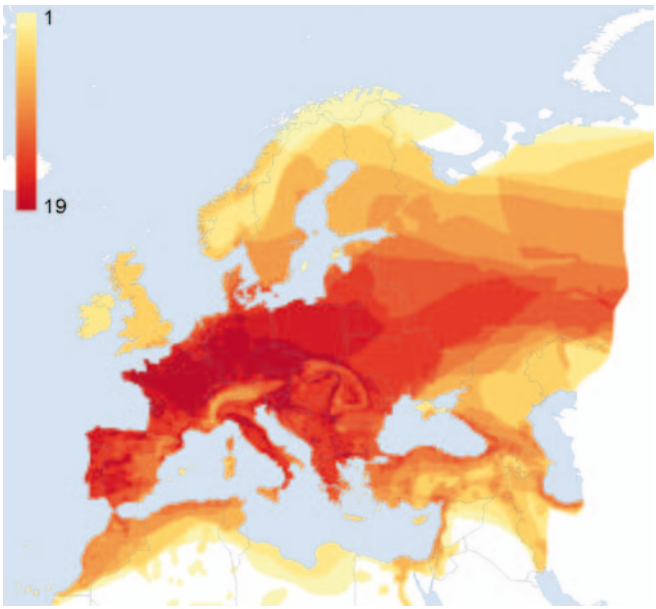

Figure 1. Diversity of Western Palearctic amphibians, based on 20×20 km grids, and accounting for the 137 native species present in the region

in so called "melting pots" of diversity. This pattern is paradigmatic of European biogeography (Hewitt, 2011), and matches the results of previous comparative studies of European amphibians and reptiles, although not accounting for recent species split (Meliadou & Troumbis, 1997; Sillero et al., 2014). In addition to this key area, I identified seven localised hotspots of diversity (i.e. with more than ten co-occurring taxa), mostly driven by regional endemism and long-term persistence of species due to ecological stability throughout the Quaternary: (1) the north-western African coast; (2) the central and northern Iberian Peninsula; (3) the Apennine belt in Italy; (4) the Balkan Peninsula, especially the foothills of the Carpathians; (5) the Anatolian and Caucasian Black Sea coasts; (6) The Levant region (eastern Mediterranean coast); (7) the Hyrcanian region (southern shores of the Caspian Sea). In contrast, islands and deserts expectedly bear low species richness (Fig. 1).

These patterns summarised well two decades of amphibian phylogeography. The diversity of the Palearctic seems mainly shaped by diversifications between and within regional hotspots, acting both as shelter and active promoters of diversity. A similar picture holds at the intra-specific level (e.g. Dufresnes et al., 2016). It is quite fascinating to notice that the richest areas in terms of specific richness (Western and Central Europe) are also the poorest in terms of intra-specific diversity. Indeed, most of the many amphibians found in France, German, Belgium, Switzerland and adjacent countries have little genetic variation, due to post-glacial expansions (as shown in *Hyla arborea*, Dufresnes et al., 2013). This lack of adaptive potential likely contributes to their generally poor conservation situation in these areas (Dufresnes & Perrin, 2015). Hence, the high yet vulnerable diversity of amphibians in Western and Central Europe is particularly of concern in these heavily impacted regions. This data will be useful in future research and conservation efforts.

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