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# Biogeography and conservation of viperids from North-West Africa: An application of ecological niche-based models and GIS

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ABSTRACT

North-West Africa is an outstanding region to study biogeographic patterns in biodiversity distribution. This study identifies biogeographic affinities and areas of probable occurrence for seven viperid snakes through the combination of high resolution presence data and environmental factors. Vipers exhibited distinct biogeographical affinities: *Bitis arietans* was mostly found along savannahs, *Echis leucogaster* along the Sahel/savannahs, *Cerastes cerastes* and *C. vipera* throughout most desertic areas, *Daboia mauritanica* in coastal and hilly regions and *Vipera latastei* and *V. monticola* in almost only mountains. Suitable habitats were predicted for *B. arietans* in southern Senegal and Mali, and coastal southern Morocco, for *E. leucogaster* in southern Mauritania, Senegal, Mali, and fragmented habitats in Saharan mountains and south-western Morocco, for *C. cerastes* from the Atlantic coast to northern Algeria, for *C. vipera* in the central region, for *D. mauritanica* in northern-western Morocco and northern Algeria, for *V. latastei* in the Rif, Middle Atlas and coastal Morocco, and for *V. monticola* in the High Atlas. In potential sympatric areas, competition is probably limiting distribution, resulting in parapatric ranges. Northern Saharan populations of *B. arietans* and *E. leucogaster* are isolated. Saharan mountains and coastal south-western Morocco constitute isolated suitable areas for sub-Saharan relicts.



## 1. Introduction

North-West Africa is an outstanding region to study biogeographic patterns in the distribution of biodiversity. The complex geographic shifts around the Strait of Gibraltar over the past 14 million years (De Jong, 1998) resulted in high percentages of European and African-originated species found in Morocco and Iberian Peninsula, respectively (Bons and Geniez, 1996; Sindaco and Jeremčenko, 2008). The climatic oscillations of the Late Quaternary (Gasse, 2006) have also prompted shifts in species distributions, with range expansions of Palaearctic and Afro-Tropical species and range contractions of Saharo-Sindian species during cold or humid periods, and opposite patterns occurring during arid periods (Le Houérou, 1997; Quézel, 1978). After the mild mid-Holocene, the transition of most of North Africa to the Sahara desert climate, with gradual drying of the savannah-like ecosystem and progressive setting of arider conditions (Drake et al., 2008; Kröpelin et al., 2008), induced expansion of aridity-related species and vicariant effects (along a northern–southern axis) in humidity-related species. Currently, several species with continuous range north or south of the Sahara present isolated populations on the other side of the desert, and, in some cases, relict populations may be found in suitable habitat patches in Saharan mountains (Le Houérou, 1997). In many cases, ancient population isolation has induced diversification mechanisms (Carranza et al., 2008; Douady et al., 2003; Fonseca et al., 2009).

Presently, there are seven viper species (Serpentes, Viperidae) in North-West Africa (west of Greenwich's longitude 0) with diversified ranges (Fig. 1): 1) the Puff adder, *Bitis arietans* (Merrem, 1820), which is widespread south of the Sahara (only absent from tropical rainforests) and presents isolated populations in south-western Morocco; 2) the Carpet viper, *Echis leucogaster* Roman 1972, which is widespread in the Sahelian band from the Atlantic Ocean to Niger, and occurs in isolated populations in central and north of the Sahara; 3) the Horned viper, *Cerastes cerastes* (Linnaeus 1758), which is widespread throughout arid areas but appears to select rocky over

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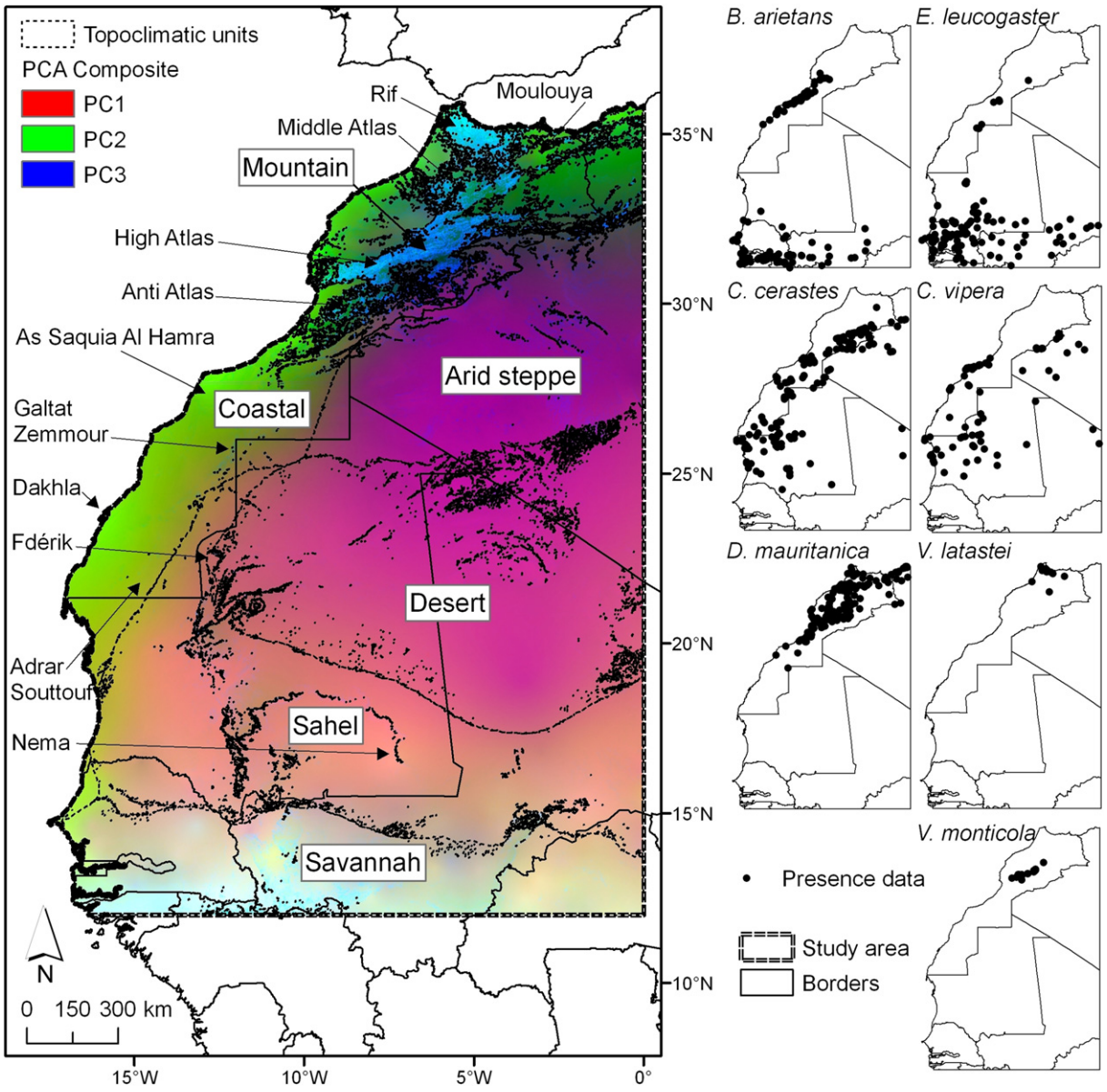


**Fig. 1.** Location of the study area, toponomies used in text, and distribution of presence data used for developing the ecological models. Composite image from a Principal Components Analysis of six topoclimatic variables identifies major topoclimatic units in the study area (names in boxes).

sandy habitats; 4) the Sand viper, *Cerastes vipera* (Linnaeus 1758), which is restricted to the sandy habitats of desert areas; 5) the Maghrebian viper, *Daboia mauritanica* (Grey, 1849), which is widespread north of the Sahara, from Morocco to eastern Algeria, with isolated populations in arid areas; 6) the Lataste's viper, *Vipera latastei* Boscá 1878, which occurs from the Rif and Middle Atlas mountains of Morocco to western Tunisia; and 7) the Atlas dwarf viper, *Vipera monticola* Saint-Girons 1954, which is restricted to the High Atlas mountains of Morocco (Bons and Geniez, 1996; Dobiey and Vogel, 2007; Geniez et al., 2004; Trape and Mané, 2006).

Although the global range of these vipers is relatively well known, there are many knowledge gaps concerning local distribution, occupied habitats, contribution of environmental factors to range configuration, and fragmentation levels in North-West Africa. For instance, *B. arietans* has been suggested to occur around Dakhla peninsula (Geniez et al., 2004), about 300 km south of the meridional limit of the known distribution of isolated populations in Morocco, but it is unknown if the species is actually present there. The quantification of suitable areas for isolated populations of *E. leucogaster* and *D. mauritanica* in Saharan mountains is especially important for conservation purposes (Aymerich et al., 2004; de Pous et al., 2010; Geniez et al., 2004), but logistic and accessibility difficulties hamper fieldwork and the detection of other presumably isolated populations. Distinct niche selection in contact zones has been suggested to be related to local parapatric ranges in vipers (Brito and Crespo, 2002; Brito et al., 2008; Martínez-Freiría et al., 2008; Tomović et al., 2010), and this seems to be the case of both *Cerastes*, since *C. cerastes* occurs mostly in rocky habitats while *C. vipera* selects sandy areas (Geniez et al., 2004; Trape and Mané, 2006). Nevertheless, the contribution of climatic and other habitat factors to shape species ranges remains largely unknown. This is also the case of *E. leucogaster* and both *Vipera*, where recent studies have suggested the importance of topographical and climatic factors (Brito et al., 2008; Escoriza et al., 2009), but the contribution of land-cover factors to the ecological niches of the species here considered remains unexplored. Finally, the range of