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Living on the EDGE: From the evolutionary uniqueness to the conservation status of the Colombian elapids and viperids

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Phylogenetics applied to conservation provides a comprehensive and alternative approach that contributes to prioritising species and areas for conservation, even if the species have significant information gaps concerning their ecology. Using a distribution of 10,000 phylogenetic trees of the 30 elapid and 21 viperid snakes in Colombia, we calculated the species evolutionary distinctiveness (ED) scores. Then, based on the ED median values reported from previously fully-sampled phylogenies of squamates, we quantified evolutionarily distinct and globally endangered (EDGE) scores and, with updated distribution maps of the species, we computed and plotted biogeographically weighted evolutionary distinctiveness (BED) scores. Among threatened species, *Bothrocophias campbelli* reached the highest ED score. This species, together with *Micrurus medemi*, are the top EDGE species, and with *Micrurus renjifoi* achieved the highest BED scores. The spatial patterns of richness and BED values highlight the Andean, Amazonian and Pacific regions as biodiversity hotspots. Although some areas are under some protection status, anthropic pressures, such as deforestation, along with the lack of knowledge about these snakes, exhibit a worrisome panorama. Thus, it is imperative to implement conservation measures focused on areas where species with both ecological and evolutionary value are concentrated.

Keywords: Coral snakes, Elapidae, evolutionary distinctiveness, global endangerment, phylogenetic diversity, Viperidae, vipers

INTRODUCTION

Diverse strategies have been developed to adequately allocate limited resources for conservation and reduce the impact of global biodiversity loss (Possingham & Wilson, 2005). The main conservation strategies have focused on prioritising species based on their degree of endemism and threat status, as well as on species that fall within the concept of charismatic, flagship, indicator, keystone, rare and umbrella, among others (Joseph et al., 2009; Li & Pimm, 2016; IUCN, 2022). However, these approaches may leave out important aspects, like the evolutionary history of species (Mace et al., 2003; Pellens & Grandcolas, 2016), leading to gaps concerning the protection of ecological, genetic and morphological diversity (Mace & Purvis, 2008; Magnuson et al., 2010; Collen et al., 2011). Therefore, it is necessary to implement methodological perspectives conducting more effective conservation, taking into account aspects such as phylogenetic diversity (Redding et al., 2010; Safi et al., 2013; Winter et al., 2013; Redding & Moers, 2015; Mazel et al., 2018). In this sense, the 'EDGE of Existence programme' is an initiative focused on the conservation of species that represent a high level of phylogenetic uniqueness or evolutionary distinctiveness (ED) that measures the contribution of each species to the phylogenetic diversity (PD) of a given clade (sensu Faith, 1992), and that are also threatened and globally endangered (GE) (Isaac et al., 2007).

Phylogenetic metrics applied to conservation are a particularly helpful approach when applied to clades with significant information gaps, like reptiles (Fenker et al., 2014; Forest et al., 2015; Pellens & Grandcolas, 2016; Tingley et al., 2016). These vertebrates are being explored with the ED and EDGE scores at several geographical scales (Boland & Burwell, 2020; Colston et al., 2020;

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Chan & Grismer, 2021). Because many conservation actions are implemented at local or regional scale, and threats and vulnerability of species tends to vary from one country to another (Moilanen & Arponen, 2011; Dallimer & Strange, 2015), it is necessary to integrate conservation and evolutionary history in the context of political administrative boundaries. Analyses at this scale can contribute to overcoming the lack of knowledge that often restricts the scope of large-scale conservation actions. Assessing how much of the evolutionary history of a clade is represented by the species subset found in each area, such as a country, could be a useful tool to lead a comprehensive prioritisation of species and areas for conservation.

In recent years, indexes have emerged that combine aspects of the evolutionary history and the distribution pattern of species (Murali et al., 2021; Gumbs et al., 2020; Jetz et al., 2014). One of these indexes is the biogeographically weighted evolutionary distinctiveness (BED) index (Cadotte & Davies, 2010) which focuses on the evolutionary uniqueness and the extent of a species' distribution range within a given area. The distribution of a species may cover a significantly large proportion of one region and may cover a tiny portion of another one; the BED allows a detailed assessment of the spatial patterns of phylogenetic diversity, given that it allows a higher value to be assigned to species that are evolutionarily distinctive and spatially restricted. However, the calculation of biogeographically BED has been scarcely applied in vertebrates, including reptiles (Quan et al., 2018), and still no studies have focused on any country in the neotropics, one of the most diverse regions in the planet (Rosenzweig, 1995).

Among reptiles, snakes have been exhibiting dramatic declines in their population size because of anthropogenic activities, mainly deforestation for agriculture and cattle-raising (Reading et al., 2010; Morales-Betancourt et al., 2015). Many snakes are wrongly considered to have a low aesthetic value and are the source of a widespread phobia and innumerable myths, which reduces willingness to protect them (Prokop & Randler, 2018). Despite this, snakes are particularly important for human well-being, in as much as they act as biological control agents of species that otherwise could be potential pests and reservoirs of infectious diseases (Cortés-Gomez et al., 2015; Valencia-Aguilar et al., 2013; Beaupre & Douglas, 2011). Further, venomous snakes are also a valuable resource for medicine, to the extent that some active substances of their toxins are used in the development of drugs for the treatment of several diseases (Galvis, 2007). This is the particular case of venomous snakes of the Elapidae (coral snakes, mambas) and Viperidae (rattlesnakes, vipers) families (McDiarmid, 2012; Vitt & Caldwell, 2014).

About 8 % (272 spp.) of the world's snake species are found in Colombia, where they are threatened by deforestation, expansion of the agricultural frontier, mining, leaf litter removal and human aversion (Campbell & Lamar, 2004; Morales-Betancourt et al., 2015); 19 % (53 spp.) of these species belong to Elapidae and Viperidae families. Elapids comprise 30 species of fossorial snakes that tend to exhibit low population densities. They are distributed from sea level, as is the case of *Hydrophis platurus* that inhabits the Pacific Ocean, to the Andean ecosystems at 2,000 meters of elevation (Lynch, 2012; Lynch et al., 2014). Viperids are represented in Colombia by about 23 species ranging from sea level to 2,600 meters of elevation (Angarita-Sierra et al., 2022). They are restricted to humid forests with little intervention, although there are species, such as *Bothrops asper* and *Bothrops atrox*, that quickly adapt to disturbed habitats and transformed landscapes (Lynch et al., 2014).

Regrettably, the study of snakes in Colombia has not been a priority (Lynch, 2012) and few initiatives have been undertaken to protect them (Lynch et al., 2014). In the case of elapids and viperids, none of the species have population studies and only 6 % of them are ranked under some degree of local threat (Morales-Betancourt et al., 2015). Studies of these snake groups focus on the description of new species, diet, distribution and snake bite cases (Silva, 1989; Renjifo & Lundberg, 2003; Castro et al., 2005; Ayerbe & López, 2005; Folleco Fernández, 2010; Pitalua-L et al., 2018; Pérez et al., 2019; Peláez & Perlaza, 2020; Pereañez et al., 2020; Cañas et al., 2021; Angarita-Sierra et al., 2022), but compared to other animal groups, the information available about them is scarce and isolated.

Despite the remarkable diversity of Colombian elapids and viperids and their socio-ecological importance, the widespread lack of knowledge about aspects of their natural history negatively affects our ability to prioritise and protect them. To shed light on the knowledge gaps and contribute to the conservation of elapids and viperids in Colombia, our aims in this study were:

i) to review the conservation status of Colombian elapids and viperids;
ii) to rank the species according to the ED, EDGE, and BED scores;
iii) to identify the distribution patterns of the richness and the BED scores of these snakes in the country.

We hope to offer baseline information to identify snake species and lineages, and geographic areas in Colombia to be prioritised in future conservation and management plans.

METHODS

Species lists

We compiled an updated list of elapid and viperid species occurring in Colombia from bibliographic sources (Ayerbe & López, 2005; Folleco Fernández, 2010; Lynch et al., 2014; Morales-Betancourt et al., 2015; Ospina-L, 2017; Díaz-Ricaurte et al., 2017; 2018; Quiñones-Betancourt et al., 2018; Pitalua-L et al., 2018; Díaz-Ricaurte & Ferreto Fiorillo, 2019a; 2019b; Angarita-Sierra et al., 2022).

ED and EDGE scores

For a given community, the sum of the ED of species, measured by "fair proportions" (Isaac , 2007), will equal phylogenetic diversity (Faith, 1992). Thus, this study considers both the contribution of each species of elapids and viperids to the local community's phylogenetic diversity (i.e. to the subset of species occurring in Colombia; hereinafter ED_{local}), and the contribution of each species to the global phylogenetic diversity (i.e. to the overall squamate clade; hereinafter ED_{global}). Because most species do not have a threat category for Colombia, we do not have a national equivalent to the GE that can be weighted with the ED of the species at the local level. Therefore, EDGE scores were calculated with the ED_{global} and GE, following International Union of Conservation of Nature (IUCN) categories.

For the ED_{global} scores approach, we used median ED values of target species calculated by Tonini et al. (2016) over fully sampled phylogenies of Squamata. For the ED_{local} scores approach, we used the median ED values of target species calculated over 10,000 phylogenetic trees pruned to just the Colombia species from the distribution provided by Tonini et al. (2016) and available at VertLife project (http://vertlife.org). For this, we calculated the ED scores with the evol.distinct function implemented in the picante R package (Kembel et al., 2010). Then, we calculated their respective median value with an R base function. The median and variance of these ED scores were visualised as a boxplot chart made in the ggplot2 R package. It should be noted that the subsequent analyses were performed on the basis of the ED_{global} scores.

In order to get EDGE scores, we compiled the species conservation status from the IUCN Red List of Threatened Species (www.iucnredlist.org) as a measure of Global Endangerment (GE), and assigned numerical scores to these categories in the following manner: Least Concern (LC) = 0, Near Threatened (NT) and Conservation Dependent (LR/cd) = 1, Vulnerable (VU) = 2, Endangered (EN) = 3 and Critically Endangered (CR) = 4. Thereafter, we compiled and applied the formula EDGE= ln(1+ED)+GE*ln(2) in a custom R function edge.species (Supplementary material 1) to obtain the EDGE score of each species. For the above, we followed both the numerical equivalent of the IUCN Red List categories, as well as the EDGE formula proposed by Isaac et al. (2007).

Distribution maps and BED scores

We used the distribution map polygons for 47 of the 51 species (94 %) from Roll et al. (2017) available as supplementary material in the Data Dryad repository (https://datadryad.org/stash/dataset/doi:10.5061/dryad.83s7k). For the remaining four species (*Hydrophis platurus*, *Micrurus multifasciatus*, *Bothrocophias campbelli* and *Bothrops venezuelensis*), we used the distribution map polygons from the IUCN Red List of Threatened Species database (https://www.iucnredlist.org/). All polygons were cut to define the distribution area of the species in Colombia.

To quantify the proportion of the Colombian territory that overlaps with the distribution of each elapid and viperid species, we set a map of Colombian geopolitical land boundaries with a 1 x 1 degree grid (totaling 129 cells covered by the Colombian land territory). Then, we counted the number of cells occupied by the distribution of each species. For the marine species *H. platurus* we set up a map of Colombian geopolitical maritime boundaries grid with the same parameters (totaling 95 cells covered by the Colombian maritime territory); thereafter, we performed the same procedure as mentioned above. Subsequently, to calculate the BED scores of each species, we used the formula proposed by Cadotte & Davies (2010), where the ED score of each species was divided by the proportion of Colombian territory the species occupies.

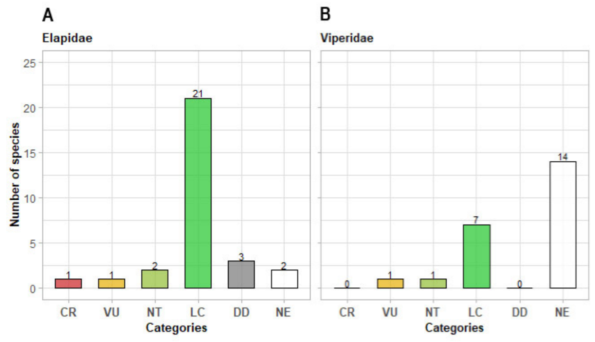

Figure 1. Number of Colombian elapid and viperid species in each category of the IUCN Red List

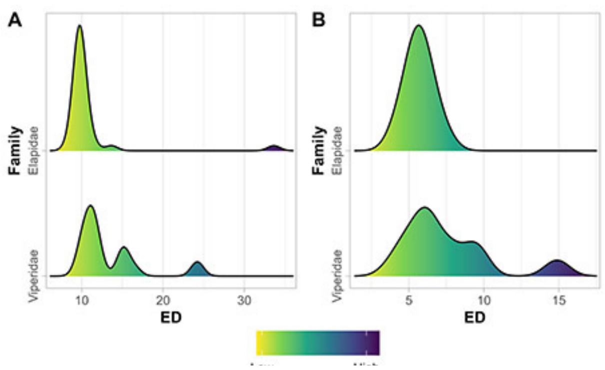

Figure 2. Distribution of **(A)** the median ED_{local} scores and **(B)** ED_{global} scores of Colombian elapids and viperids

Species richness and BED score maps

We elaborated maps of species richness and BED scores for elapids and viperids using QGIS 3.28 (QGIS.org, 2022). We rasterised values of species richness and BED scores for each species in the target groups. We used the r.series function to summarise the values. Then, we performed a neighbourhood analysis (r.neighboor function) with a window size of 10 km and a sigma value for a gaussian filter of 2 to avoid a discrete border effect (Jackisch, 2007).

RESULTS

Species lists

In Colombia, the family Elapidae is represented by 29 species of the genus *Micrurus* and one species of *Hydrophis*, while Viperidae is represented by ten species of the genus *Bothrops*, seven of *Bothrocophias*, two of *Porthidium*, two of *Lachesis*, one of *Bothriechis* and one of *Crotalus*. 64.2 % of elapids and viperids in Colombia have been categorised by the IUCN in some extinction

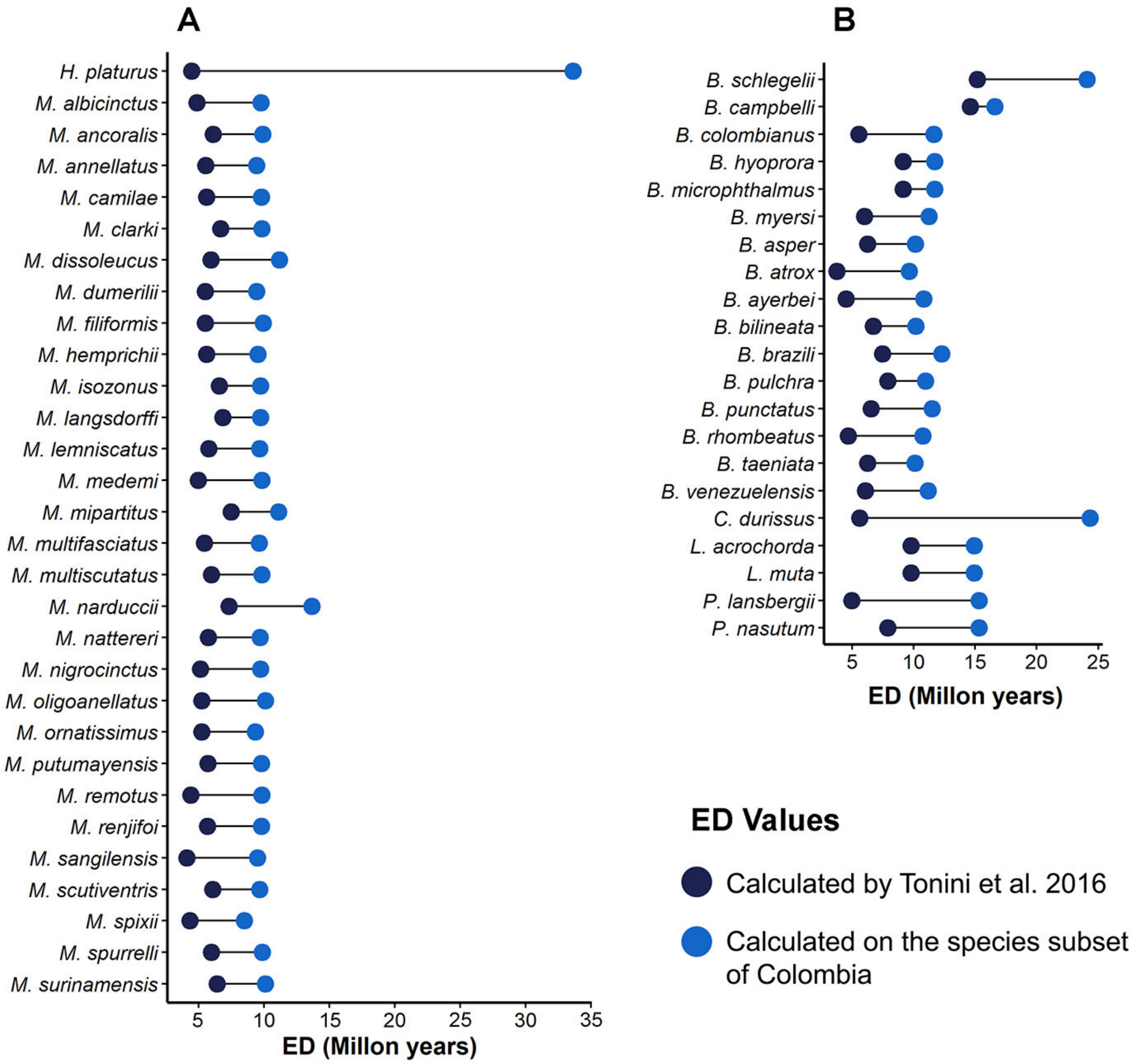

Figure 3. Comparison of ED_{local} scores and ED_{global} scores of Colombian elapids **(A)** and viperids **(B)**

risk category; 52.8 % of the species are classified as Least Concern (LC), 3.8 % as Vulnerable (VU), 5.7 % as Near Threatened (NT), and one species (*Micrurus medemi*) as Critically Endangered (CR). In all, 35.8 % of species (9.4 % of elapids and 26.4 % of viperids) have not been evaluated (NE) or are Data Deficient (DD) (Fig. 1), so we did not include them in the quantification of EDGE scores.

ED and EDGE scores

Regarding elapids, the mean ED_{local} score was 10.72 ma (Fig. 2a), with *H. platurus* (ED_{local} = 33.62 ma) reaching the highest ED_{local} scores (Fig. 3a and Fig. S1a). Whereas, accounting for the ED_{global} scores, the mean ED_{global} value was 5.68 ma (Fig. 2b), and the species with the highest ED_{global} scores were *Micrurus mipartitus* (ED_{global} = 7.48 ma) and *Micrurus narduccii* (ED_{global} = 7.32 ma) (Fig. 3a). According to the IUCN, the species with the highest risk of extinction are *M. medemi* (CR) and *Micrurus sangilensis* (VU); consequently, they exhibit the highest EDGE scores among elapids (EDGE = 4.56 and 3.01 respectively) (Fig. 4a).

For viperids, the mean ED_{local} score value was 13.30 (Fig. 2a). The species *Crotalus durissus* (ED_{local} = 24.33 ma) and *Bothriechis schlegelii* (ED_{local} = 24.09 ma) (Fig. 3b and Fig. S1b) reached the highest scores. Regarding the ED_{global} scores, the mean ED value was 7.51 ma (Fig. 2b); the highest scores were for *B. schlegelii* (ED_{global} = 15.16 ma) and *B. campbelli* (ED_{global} = 14.60 ma) (Fig. 3b). When linking the ED scores of species with their extinction risk, *B. campbelli* (VU) and *B. schlegelii* (LC) show the highest EDGE scores among the viperids (EDGE = 4.13 and 2.78 respectively) (Fig. 4b).

When looking at the species classified into threat categories, the viperid *B. campbelli* (VU) obtained the highest scores (ED_{global} = 14.60; ED_{local} = 16.59). While the elapids *M. medemi* (CR) (ED_{global} = 4.97; ED_{local} = 9.81) and *M. sangilensis* (VU) (ED_{global} = 4.09; ED_{local} = 9.5) obtained lower scores, but very similar to each other. Notably, *B. campbelli* (VU) together with *Bothrocophias myersi* (NT) are the only viperid species evaluated that are not at low risk (LC) (Supplementary material 2).

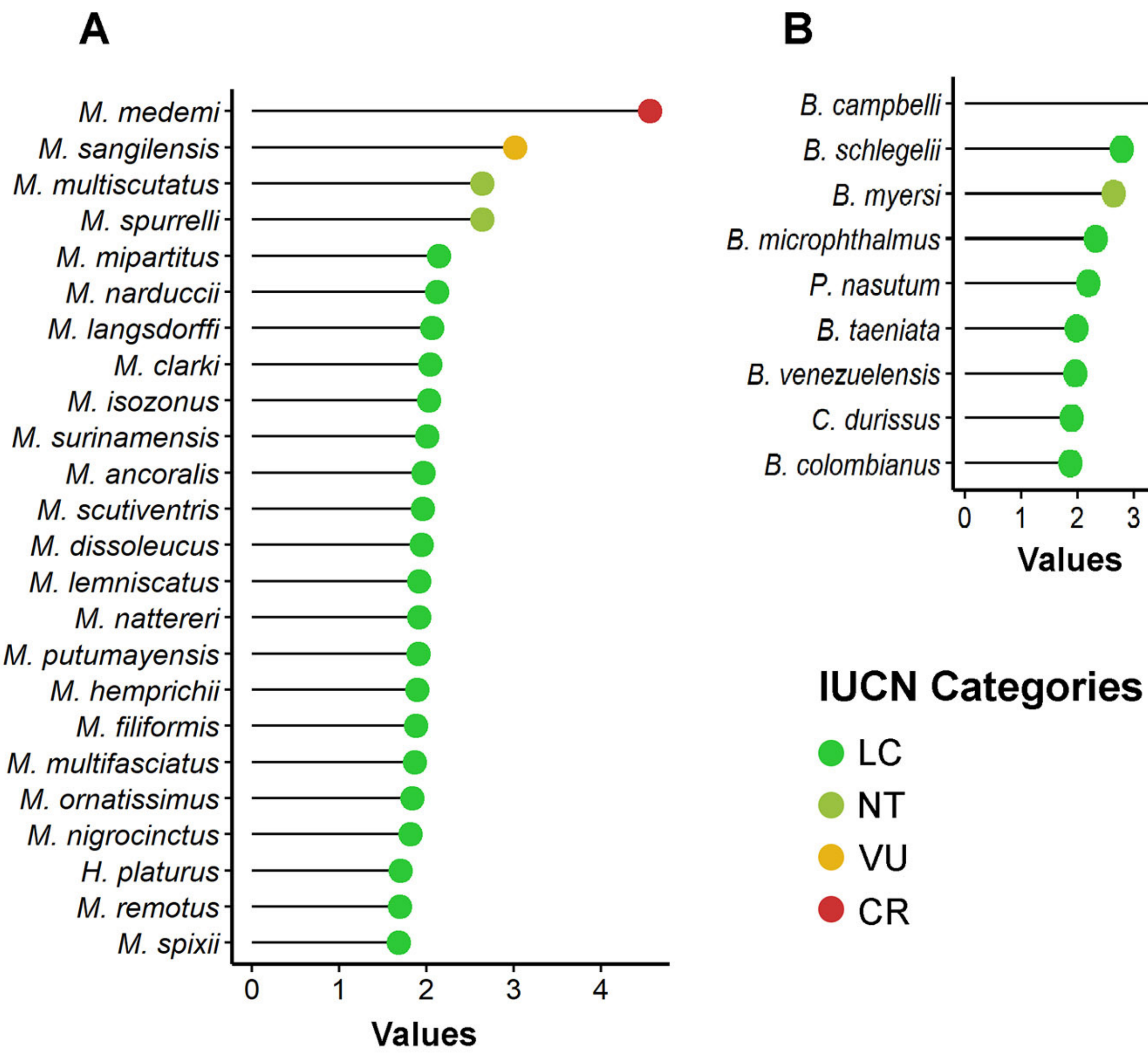

Figure 4. EDGE scores of Colombian elapids **(A)** and viperids **(B)**

Distribution maps and BED scores

Among the elapids, *Micrurus lemniscatus* was the species present in the largest number of cells, 88 out of 129 (BED = 0.065), while *Micrurus renjifoi* and *M. multifasciatus* were the most restricted, each occurring in only one cell, and those with the highest BED scores (5.688 and 5.446 respectively) (Fig. S2a). In viperids, *B. atrox* was the species present in the largest number of cells, 119 out of 129 (BED = 0.031), whereas the species *Bothrops pulchra* was present in the lowest number of cells, only 2 of 129, achieving the highest BED score (3.936) (Fig. S2b) (Supplementary material 2).

Species richness and BED score maps

Spatial patterns of species richness and BED scores showed considerable variation within and between Elapidae and Viperidae. The Amazon was the region where species richness was commonly high for both families; however, viperids were more represented than elapids in the Andean, Caribbean and Pacific regions. Regarding the pattern of BED scores, there are several specific areas within Colombian regions that exhibit the highest values; for elapids, the highest BED values were in some portions of the Caribbean region including the area of the Darién strains towards the Caribbean Sea, the Pacific region and the Amazon region. In contrast, the highest BED scores for viperids are found in the south and middle part of the Pacific region, and in the north-eastern Andes, on the border with Venezuela. A more detailed description of localities and areas where highest species richness and BED scores were found is provided in Supplementary material 3.

DISCUSSION

A widespread lack of knowledge exists about the conservation status of elapids and viperids in Colombia, which is reflected by five species of elapids and 12 species of viperids without adequate data (DD and NE) (Fig. 1). Among them, species like *Micrurus camilae*, *Micrurus oligoanellatus* and *M. renjifoi* were described over 15 years ago but have been poorly studied (in DD according to IUCN); therefore, their extinction risk is unknown and likely remains underestimated (Lamar, 2003; Renjifo & Lundberg, 2003; Ayerbe & López, 2005; Peláez & Perlaza-Berrío, 2020). This is concerning given that reptiles

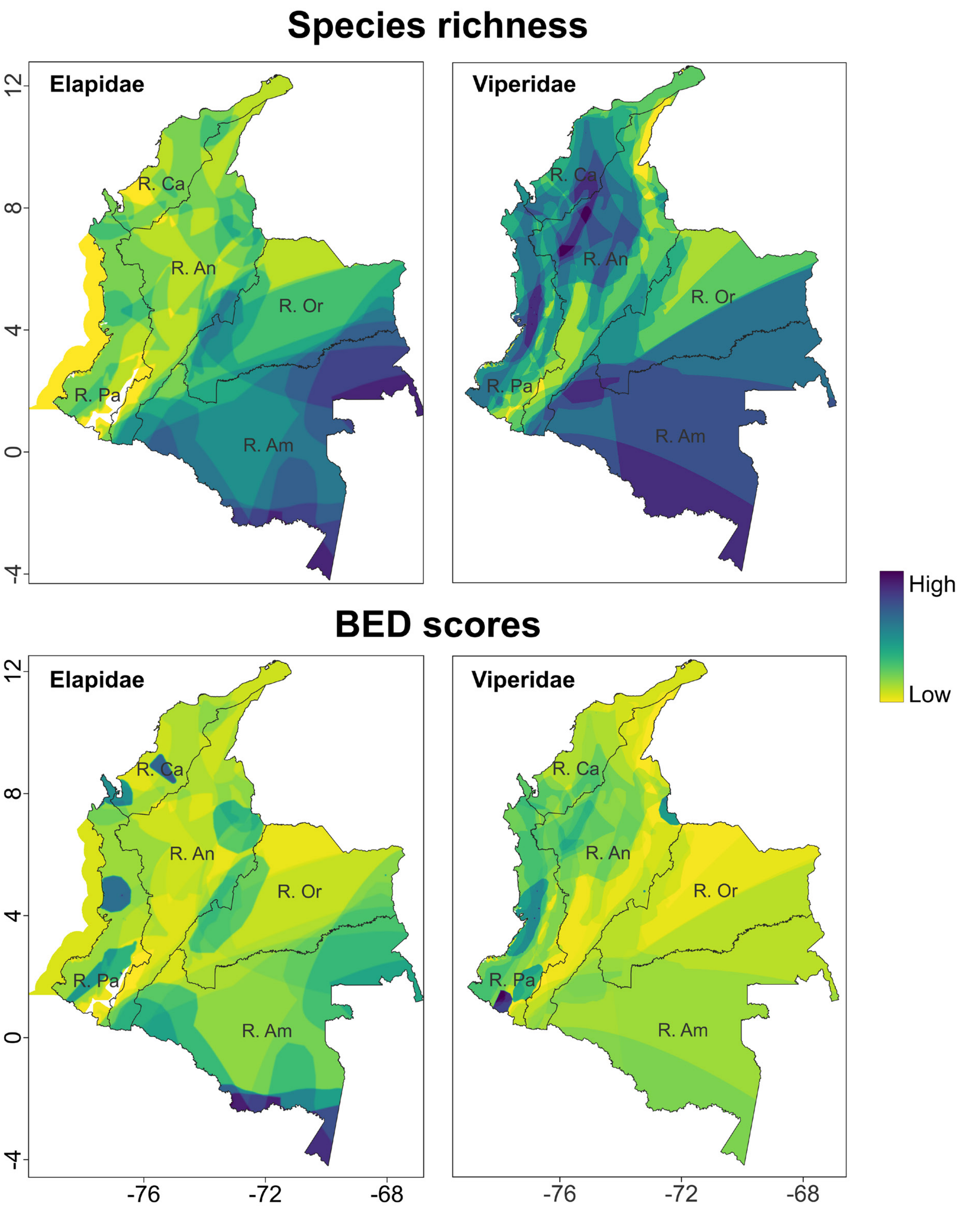

Figure 5. Spatial patterns of species richness (upper maps) and BED scores (bottom maps) of Colombian elapids (left maps) and viperids (right maps). The map shows the boundaries of the main regions of Colombia as follows: R. Am: Amazonian region; R. An; Andean region, R. Ca: Caribbean region; R. Or: Orinoco region; and R. Pa: Pacific region. Note that maps for elapids include a sea species (*H. platurus*) in the Pacific Ocean.

comprise about 30 % of vertebrate species on the planet (Böhm et al., 2013; Bland & Böhm, 2016; Maritz et al., 2016; Tingley et al., 2016), and in the last decades global average declines in reptile populations of more than 50 % have been estimated using approaches such as the Living Planet Index (LPI) (Saha et al., 2018). Other neotropical countries also have made efforts to locally assess the conservation status of their elapids and viperids. In Ecuador, for example, a relatively large number of species have been locally categorised, including *Lachesis acrochorda* and *Lachesis muta* as VU; *B. pulchra* and *Bothrops punctatus* as NT; *Bothrocophias hyoprora*, *B. asper*, *B. atrox*, *Bothrops bilineata* and *Bothrops brazilias as* LC; and *Micrurus annellatus* as DD (Carrillo et al., 2005).

According to these authors, most of the species under LC category are distributed in the Ecuadorian Amazon. However, at the time they were evaluated, this region was not so fragmented, a situation that has undoubtedly changed in recent years (Castro, 2022; Campos & de Melo Faria, 2022). In Brazil, some categorisation schemes have classified the species *B. bilineatus* and *L. muta* as VU. However, such a large country has both national and state classifications, making it possible for a species to be in more than one category. For example, in the state of Rio de Janeiro *L. muta* is endangered (EN) while *B. bilineatus* is probably extinct (Decreto 1499-R/2005; Decreto 51.797/2014; PORTARIA 37/2017; Resolução SEMAS 1/2017; SEMA, 2018).

The ED_{local} scores distribution of Elapidae and Viperidae seems to have their most distinctive species with typically high values (Fig. 3); Elapidae: *H. platurus* (ED = 33.62), Viperidae: *C. durissus* (ED = 24.33) and *B. schlegelii* (ED = 24.09). Although *Hydrophis* is one of the clades with the highest rates of diversification within Elapidae (Lee et al., 2016), *H. platurus* reached the highest value of local ED due to it being the only species of the genus distributed in Colombia. Moreover, *Hydrophis* diverged >30 Mya from *Micrurus*, the genus that includes all other Colombian elapid species (Tonini et al., 2016). Regarding viperids, *B. schlegelii* is the only species of a clade of Central American origin with a distribution that comprises areas in north-western South America (Fenker et al., 2014; Mason et al., 2019). Similarly, *C. durissus* is the only species of a well-diversified clade that arrived in South America via the Panama isthmus and achieved widespread disjunct distribution (Wüster et al., 2002; Alencar et al., 2016). Both species belong to clades that diverged >20 Mya from the remaining Colombian viperid species (Tonini et al., 2016) (Fig. 3b). When analysed within a geographical delimitation, distinctive species constitute rare or unique samples of lineages that, even if highly diversified or widely distributed, display reduced richness and have few or no related taxa in a given area (e.g. country).

As expected, higher EDGE scores correspond to species included in threatened categories. This is the case of the Critically Endangered *M. medemi* and the Vulnerable species *B. campbelli* and *M. sangilensis* (Fig. 4). At a global scale, the EDGE species list comprises 607 species of reptiles, including two elapids: *Bungarus slowinskii* (EN) distributed in south-east Asia, *Hemiaspis damelii* (VU) distributed in Australia, and four viperids: *Protobothrops mangshanensis* (EN) distributed in China, *Mixcoatlus barbouri* (EN), *Mixcoatlus melanurus* (EN) and *Ophryacus undulatus* (VU) distributed in Mexico. It should be noted that none of the South American species of Elapidae and Viperidae are included in this global EDGE list. In this sense, it is essential to take into account the spatial scale in which the prioritisations are made, to not underestimate the risk of extinction of species that may not be considered threatened or have a low risk of extinction at the global level but may be the most critical at the local level. For this reason, it is essential to update local red lists, such as Morales-Betancourt et al. (2015) that, despite being less than a decade old, has a very limited species coverage, resulting in large gaps in information on groups like viperids and elapids.

In Colombia, some areas with a high diversity of elapids and viperids overlap with protected areas. In the case of Elapidae, the areas within the Amazon region where the greatest number of species is concentrated includes the Amacayacu National Natural Park and the Puinawai National Natural Reserve. The Amacayacu National Natural Park also would play an important conservation role from the BED perspective, as well as Los Katios and Munchique National Natural Park in the Pacific region. However, there are other areas without any special protection, such as those in the south-central Amazon, and the Caribbean and Pacific Regions. With respect to Viperidae, the areas identified as richness hotspots include the Natural Parks of Amacayacu, Río Puré and Cahuinarí in the Amazon region, and the Farallones National Park in the Pacific region. Meanwhile, the areas with the highest BED values for Viperidae suggest that the Farallones National Park is also highly important, as well as the Natural Parks Doña Juana-Cascabel Volcanic Complex (between the Andean and Pacific regions) and Tamá (Andean region), the Galeras Flora and Fauna Sanctuary in the Andean region. There are areas of equal importance that have no protection status, such as south of the Amazonian region, eastern Orinoco region, central west and south of the Pacific region, central Antioquia, and south-central Pasto (Andean Region) (Fig. 5c). Here, it can be noted that the most important protected areas for the conservation of elapids and viperids are the National Natural Parks of Amacayácu and Farallones respectively. Therefore, these Natural Parks and their areas of influence should be recognised as priority areas to implement strategies that involve research projects and work with local communities to increase the protection of those vertebrates (Caten et al., 2020).

Metrics such as ED, EDGE, and BED, which consider the evolutionary history and geographic patterns of species, can be useful tools to identify areas, in a local or regional context, as priority for conservation. This approach can harbour species that are both distinct and rare and are not considered in traditional diversity analyses based on species richness (Polasky et al., 2001; Forest et al., 2015; Tucker et al., 2012). For example, the present study identified areas, such as north-eastern Colombia, on the border with Venezuela, and the centre of the Pacific region harbouring elapid and viperid species that are evolutionarily distinctive and geographically restricted (Figs. 5, S5 & S6). In other words, areas like these, with high BED scores, should be considered when planning the establishment of natural reserves or educational plans when seeking to optimise the conservation of elapids and viperids and their evolutionary history in Colombia. It should be clarified that not all species with high BED scores in this study are endemic to Colombia; actually, some of them have a wide distribution spanning two or more countries, but within Colombia they are distributed in a restricted area (Fig. S2b). For instance, elapids *Micrurus albicinctus* and *M. annellatus* are widely distributed in the Amazon rainforest of several countries but are only found within a small area in the Colombian Amazon region. Then, when calculating the BED scores of these species, considering only their distribution area in Colombia, these scores increase considerably, and consequently, the BED scores of those areas in Colombia increase as well (Fig. 5b). If conservation of elapids and viperids is planned at regional (international) scale, said aspect should be considered with priority assigned to areas with species that are equally important, according to ED, EDGE, and BED scores; for example, *B. campbelli*. Determining priority areas for conservation using an evolutionary history perspective at regional scale is beyond the scope of this study, but studies in this regard are necessary (see examples by Isaac et al., 2007; Fenker et al., 2014).

Overall, when testing spatial diversity patterns through species richness and BED scores approach, there is an important mismatch, but there are some localities in the Andes, Amazon and Pacific regions that are priority from both perspectives (Figs. 5, S3–S6). The situation in the Andean and Pacific regions, home of ten and seven endemic species respectively, is particularly worrisome, as they contain some of the least protected in the country (Forero-Medina & Joppa, 2010) and their protected areas are threatened by a critical increase in deforestation levels in the post-conflict years (Clerici et al., 2020). This scenario is even more concerning under climate change scenarios performed by Velásquez-Tibatá (2014) who highlight that the Andean region has the most alarming panorama for diversity. Taking into account the previous problematic and the results in this study, we suggest incorporating within the conservation plans the prioritisation of areas with a high BED scores. This perspective makes it possible to include aspects related with the evolutionary history of lineages and their restricted range of distribution in a specific country or region and, therefore, their level of risk and eventual adaptability to local and global changes in the environment.

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