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Amphibian conservation, land-use changes and protected areas: A global overview

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ABSTRACT

Amphibians are undergoing a global conservation crisis, and they are one of the most underrepresented groups of vertebrates in the global network of protected areas (PAs). In this study, we evaluated the ability of the world's PAs to represent extant amphibian species. We also estimated the magnitude of the human footprint along the geographic distributions of gap species (i.e., those with distributions totally outside PAs). Twenty-four percent of species (n = 1535) are totally unrepresented, and another 18% (n = 1119) have less than 5% of their distribution inside PAs. Nearly half of all species with ranges under 1000 km^2 do not occur inside any PA. Furthermore, more than 65% of the distribution of gap species is in human-dominated landscapes. Although the Earth's PAs have greatly increased during the last ten years, the number of unprotected amphibians has also grown. Tropical countries in particular should strongly consider (1) the importance of using amphibians to drive conservation policies that eventually lead to the implementation and management of PAs, given amphibians' extinction risk and ability to act as bioindicators; (2) the effectiveness of national recovery plans for threatened amphibian species; and (3) the need for increased funding for scientific research to expand our knowledge of amphibian species. Meanwhile, data-deficient amphibian species should receive a higher priority than they usually receive in conservation planning, as a precautionary measure. Throughout this paper, we point out several challenges in creating more comprehensive amphibian conservation strategies and opportunities in the next decade.

1. Introduction

Amphibians are undergoing a global conservation crisis characterized by widespread species extinctions and population declines (Butchart et al., 2010; IUCN, 2013), with more than 41% of the living amphibian species currently considered to be threatened (Pimm et al., 2014). Although this is a difficult topic to address (Collins and Halliday, 2005; Scheffers et al., 2012), forecasts of extinction risks in the group are not optimistic (Hof et al., 2011; Sodhi et al., 2008; Wake and Vredenburg, 2008). Threats include the synergistic effect of many extinction drivers, such as habitat fragmentation and degradation, diseases and climate change (Stuart et al., 2004; Gardner et al., 2007; Becker and Zamudio, 2011; Hof et al., 2011). For all of these reasons, amphibians have become a high-priority group for which conservation efforts have become focused (Pous et al., 2010; Urbina-Cardona and Flores-Villela, 2010; Trindade-Filho et al., 2012; Nori et al., 2013; Nori and Loyola, 2015).

Protected areas (PAs) cover about 13% of the Earth's terrestrial surface (Bertzky et al., 2012), but several studies have revealed the relative inefficiency of PAs in representing biodiversity in general (Rodrigues et al., 2004a,b; Venter et al., 2014; Butchart et al., 2015; Nori and Loyola, 2015; Sánchez-Fernández and Abellán, 2015). Amphibians are the group with the most species whose geographic ranges are totally outside of the world's PAs. In particular, previous research revealed that 17% of these species live completely outside of PAs (Rodrigues et al., 2004b). Recent studies have further shown that most threatened amphibian species are inadequately represented in PAs worldwide (Venter et al., 2014). In Europe, PAs do not represent amphibian species significantly better than would be expected by chance (Sánchez-Fernández and Abellán, 2015). In addition, many amphibian species have restricted geographic ranges, highlighting the importance of choosing a scale that can be used to develop more accurate conservation strategies for this group (Cushman, 2006). Amphibians are rarely considered in conservation policy decisions (Rodrigues et al., 2004b), and in some regions, priority areas for amphibian conservation do not spatially match the priority areas for other vertebrate groups (Urbina-Cardona and Flores-Villela, 2010). Therefore, the underrepresentation of amphibians in conservation decisions involving PAs is much more problematic for range-restricted species that inhabit highly human-modified landscapes.

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Considering the global panorama of amphibian conservation, previous studies were undertaken over 10 years ago (Rodrigues et al., 2004a,b). However, these studies left out many details regarding amphibian conservation (e.g., the degree of protection at lower taxonomical levels within the group). Today, more information about the distribution of many amphibian species is currently available (including 862 additional species), and the area of the planet's PAs has greatly increased in the last ten years, from 11% to more than 13% of the world's surface (IUCN and UNEP-WCMC, 2013). Consequently, it is now possible to incorporate other useful information into analyses, such as the different types of land use within species' geographic ranges.

The overview presented above suggests that, currently, there is a gap in information regarding amphibian representation inside the global network of PAs and that, at the global scale, existing information is out-of-date and lacking useful, specific details to support conservation strategies. These reasons have motivated the present study, in which we provide both a new and comprehensive overview of the global PA network's ability to protect amphibian species and new information about the overlap of amphibian geographic distributions with different types of human land use. Additionally, we consider different taxa, conservation statuses and geographic regions, making special distinctions for gap species and range-restricted species.

In particular, we aim to: (1) determine the proportion of represented amphibian species inside the world's PAs in different management categories (according to the IUCN) for each taxonomic family by separately evaluating all species and range-restricted species; (2) assess the number of species unrepresented or poorly represented in PAs and those species' locations; (3) assess the proportion of each amphibian species' total distribution represented in PAs; (4) estimate the number of gap species per unit area for each continent and country; (5) estimate the magnitude of human-modified landscapes inside the geographic ranges of gap species; and, finally, (6) evaluate the conservation status of gap species, especially the status of range-restricted species that inhabit human-modified environments.

2. Methods

2.1. Data

We obtained shape files for terrestrial PAs around the globe from the World Database of Protected Areas website (IUCN and UNEP-WCMC, 2013). We selected only those PAs with "designated" status (i.e., we did not consider "inscribed," "non-reported," or "proposed" PAs) from all six management categories defined by the IUCN (I to VI), totaling 126,280 PAs. Some PAs are not represented in the WDPA database, including subregional and private PAs; we did not include these areas in our study. It would be important to include these PAs in future studies with similar analyses at regional scales.

To build the amphibian dataset, we downloaded vector files of range maps for the 6316 species available in the IUCN database (IUCN, 2013), which includes 86.5% of all extant amphibian species, according to Frost (2014). These vector maps were generated and/or validated by experts in each taxonomic group. They are available in the shapefile format and contain the known range of each species, depicted as polygons. Our results did not include taxonomic changes arising from the inclusive phylogenetic analysis of Brachycephaloidea (=Terrarana) undertaken by Padial et al. (2014). Overall, the range maps accurately represent the known distribution of most of the species included (Ficetola et al., 2013), and they are useful and appropriate for global extent analyses. However, their use implies the need to assume commission and omission errors (mainly the former) in species distributions, especially in the tropical areas of South America and Asia (Ficetola et al., 2013).

We also compiled data on each species' current conservation status (IUCN, 2013) and its taxonomic order and family (Frost, 2013; downloaded from Amphibian Species of the World 5.6, available at http://research.amnh.org/vz/herpetology/amphibia/). Using ArcGis 10.2, we joined this information with the range map of each species. We obtained information about human impact on natural environments from the "Anthropogenic Biomes of the World (v. 1)" website (http://ecotope.org/anthromes/v1/guide/). Ellis and Ramankutty (2008) proposed these biomes using different sources of information, such as land use and human population density. The database offers 21 different categories of anthropogenic biomes in raster files. For this study, using a reclassification tool in ArcGis 10.2, we regrouped those 21 categories into four. Our categories have a decreasing order of human population density: (a) highly urbanized areas with up to 440 persons/km^2, (b) rural villages and sparsely urbanized areas with up to 210 persons/km^2, (c) crop areas with up to 6 persons/km^2 and (d) wild areas with no persons/km^2. These categories were modified from Brum et al. (2013), where more details can be found. For another source of human influence on the landscape, we extracted information on deforestation between 2000 and 2012 for each country from Hansen et al. (2013).

2.2. Analyses

For each amphibian family, we calculated the percentage of species (a) unrepresented in PAs (i.e., gap species), (b) only represented in PAs under categories I to IV, which have specific conservation objectives, and (c) represented in PAs under categories V and VI, which have no strict biological conservation goals. We replicated these analyses considering only species with geographic ranges smaller than 1000 km^2 (i.e., range-restricted species; see Rodrigues et al., 2004a). There were 2323 total range-restricted species, nearly 37% of our database.

We have calculated, shown and discussed the percentage of overlap between each species distribution and PAs. Hereafter, we refer to those species whose ranges fall totally outside of PAs as "unrepresented" or "gap" species. Following our reasoning, "represented" species are those whose geographic distribution overlaps with PAs. To determine both the number and location of gap species, we superimposed the PA range polygons onto the geographic range map for each species, and by implementing the "select by location tool" in ArcGis 10.2, we selected those species that overlapped with at least one PA. Then, we inverted this selection in order to select from all the gap species. The location of each species was graphically represented as the centroid of their distribution.

Then, using ArcGis 10.2, we overlaid the polygons of gap species with the political boundaries of countries and quantified the number of species occurring in each country. Using this information, we were able to calculate the number of gap species per unit area for each country. In order to determine the percentage of representation per species, first we calculated the area of each species' range and the area of that range that overlaps with PAs. Finally, we calculated the proportion of each species' range that is protected.

Finally, to determine the magnitude of human influence for each gap species' range, we calculated the percentage of each range occupied by each of our four anthropogenic biome categories. We did this by implementing the zonal statistic tool of ArcGis 10.2. In addition, we retrieved each gap species' IUCN threat status. We also investigated the criteria IUCN used to classify these species under a given threat category: critically endangered (CR), endangered (EN) and vulnerable (VU). We calculated the percentage of species assigned to each threat category and mapped them worldwide; we also replicated this analysis both for gap species having more than 50% of their distribution ranges overlapping human-modified environments and for species with very restricted ranges (i.e., smaller than 1000 km^2).

3. Results

The majority of described amphibian species are indeed represented in PAs: 4781 species (75.69%). Furthermore, we found that 64% of