

EVALUATING GLOBAL BIODIVERSITY HOTSPOTS – VERY RICH AND EVEN MORE ENDANGERED

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ABSTRACT

Species on the Earth are under increasing human pressure, according to some authors, the current rate of extinction occurred only a few times in the past, for the last time in the Cretaceous Period in the Mesozoic Era. The main goal of current nature conservation is to maintain the highest native biological diversity and to preserve and enhance life-supporting ecosystem processes, functions and services with the best possible use of financial resources. The areas where can be found the highest concentrations of endemic species and that also face the highest loss of natural habitats are called biodiversity hotspots. Globally, now there are 36 hotspots, covering 2.4 % of the Earth's land area and harbouring about 50 % of endemic plant species and 42 % of endemic terrestrial vertebrate species in the world. The areas can be compared in terms of species richness, endemism, natural habitat loss or territorial protection and nature conservation can be carried out in the most efficient way. The most important hotspots are Madagascar and the Indian Ocean Islands and Sundaland.

Keywords: biodiversity, hotspots, endemism, threats, conservation

INTRODUCTION

British ecologist Norman Myers first introduced the concept of terrestrial biodiversity hotspots, very important areas for biological conservation, in 1988 he identified ten hotspots in the tropical forest biome (Myers, 1988). At that time, there were no quantitative criteria to define areas of biodiversity hotspots (Mittermeier *et al.*, 2004). Two years later, in 1990, he added eight hotspots, including four areas of Mediterranean type ecosystems (Myers, 1990). Conservation International adopted Myers' concept of hotspots in 1989 (Mittermeier *et al.*, 1998) and in 1999 were introduced quantitative biodiversity hotspots identification criteria (Conservation International, 2014). Generally, such areas must meet two criteria: a hotspot must harbour 1,500 or more vascular plant species being endemics there and has to have lost at least 70 % of its original primary habitat. The number of hotspots increased to 25, covering 1.4 % of the Earth's land area and maintaining 44 % of the world's plant species and 35 % of terrestrial vertebrate species, and then again to 34. This number of hotspots lasted until 2011, comprising 2.3 % of the land surface and supporting more than 50% of endemic plant species and 42 % of the world's endemic terrestrial vertebrate species (CEPF, 2014). Now there are 36 hotspots, covering 2.4 % of the land surface. Forests of East Australia were identified in

2011 and North American Coastal Plain in 2016 (Williams *et al.*, 2011; Noss *et al.*, 2015; CEPF, 2016).

The boundaries of biodiversity hotspots were determined by common biological features. Each of the areas is a unique biogeographic unit. This is evident in the case of islands or archipelagos and the same is true for continental ecological islands in clearly defined units. Typical examples are the Philippines, Japan, the East Melanesian Islands, New Caledonia, Polynesia-Micronesia, New Zealand, the Caribbean Islands, Madagascar and the Indian Ocean Islands or Southwest Australia, the Caucasus and the Cape Floristic Province, respectively. In some other areas are the boundaries defined by the lines of recognized divisions such as Wallace's line between Wallacea and Sundaland, or according to the expert judgement (Myers *et al.*, 2000).

Along with the development of the terrestrial hotspots biodiversity concept were also identified the least endangered areas with high biodiversity. Wilderness areas are quantitatively defined as areas still harbouring more than 70 % of the original habitat area and with population density lower than 5 people per km². These criteria are met by 44 % of the land surface, but high biodiversity wilderness areas, which must also meet the criterion of more than 1,500 endemic plant species, cover only 6.1 % of the total area in 5 regions: Amazonia, the North American Deserts, the Congo Forests of Central Africa, the Miombo-Mopane Woodlands and Grasslands of Southern Africa and New Guinea. In the five areas is found 17 % of endemic plant species and 8 % of the world's endemic terrestrial vertebrate species (Mittermeier *et al.*, 2004). Besides terrestrial biodiversity hotspots there were also identified ten marine biodiversity hotspots: South Japan, the Gulf of Guinea, the North Indian Ocean, Eastern South Africa, the Cape Verde Islands, the West Caribbean, the Philippines, the Red Sea and the Gulf of Aden, the South Mascarene Islands, the Sunda Islands (Roberts *et al.*, 2002). There are many approaches, based on the ecological criteria of vulnerability and irreplaceability, and their combinations, how to identify global conservation priorities. Conservation International uses a two-pronged strategy for prioritizing global conservation. At the same time is focusing on the threatened and irreplaceable terrestrial biodiversity hotspots and on the high biodiversity wilderness areas, which are also irreplaceable but still largely intact and providing significant conservation opportunities (Conservation International, 2014).

The hotspot concept has also many critics. Peter Kareiva and Michelle Marvier (2003) argued that the hotspot idea attracted too many financial resources and other areas playing a significant ecological role are downplayed. By investing exclusively in hotspots we risk to lose important areas that contribute to many ecosystem services. Similarly Jepson and Canney (2001) think that biodiversity hotspots concept provides only a partial response. From another point of view, Cañadas *et al.* (2014) claim that hotspots are too large for effective conservation and they detect smaller hotspots within larger hotspots. Stork and Habel (2014) criticize identifying biodiversity hotspots without considering invertebrates. Marine biodiversity hotspots have also been the subject of controversy (Marchese, 2015).

BIODIVERSITY WITHIN HOTSPOTS

Natural environment and geographical conditions of biodiversity hotspots have been attracting over a long period a large number of fauna and flora species. There are, based on the CEPF (2014) data, more than 150,000 endemic plant species, half of all species of the world. The highest number of species, about 30,000 vascular plant species, grows in the Tropical Andes. The next hotspots ranked include Sundaland, the Mediterranean Basin and

Atlantic Forest with more than 20,000 species. Special attention should be paid to Madagascar and the Indian Ocean Islands, where 9 of 10 species are endemic.

The highest mammal species richness – 570 species – can be found in the Tropical Andes, similarly in Indo-Burma, Mesoamerica and the Eastern Afrotropical hotspot. The largest proportion of endemic species can be found within all the island hotspots; in the foreground is as usual Madagascar with 92.9 %. The top positions in bird diversity belong to the same four hotspots, complemented by species-rich hotspots Himalaya or South American Atlantic Forest or Tumbes-Chocó-Magdalena. Especially three regions are important with respect to amphibian diversity: American hotspots the Tropical Andes, Mesoamerica and Atlantic Forest; Southeast Asian hotspots Indo-Burma and Sundaland; East African hotspots Madagascar and the Indian Ocean Islands and the Eastern Afrotropical. On the other hand New Caledonia has no amphibian species. Most reptile species are located in the same three regions, the most important region being Central America and the Caribbean. The Mekong, Chao Phraya, Salween and Irrawaddy river basins are extremely rich in freshwater fish species, Indo-Burma is inhabited by 1,262 and Sundaland 950 species. Species-rich are also rivers and lakes of the East African Rift, the Eastern Afrotropical hotspot harbouring 893 species. The Cerrado gets ranking number four with 800 freshwater fish species.

THREATS FOR BIODIVERSITY

Threats in biodiversity hotspots are the same as those that threaten biodiversity worldwide, having been only more intensive there. Habitat fragmentation, degradation, destruction and loss are a pervasive threat affecting hotspots (Brooks *et al.*, 2002). Anthropogenic acceleration of climate change magnifies the effects of habitat fragmentation, degradation and loss (Thomas *et al.*, 2004). The average proportion of land area per hotspot with novel climate was modelled to be about 16 %. The distribution of novel and disappearing climate are principally concentrated at low latitudes (Bellard *et al.*, 2014). Predatory invasive alien species have already had a devastating impact on the island hotspots, where species evolved in the absence of predators. Introduction of invasive alien plant species, particularly those of Mediterranean-type vegetation, is also having massive ecosystem effects. Direct wildlife exploitation for food, pet trade, or medicine is a serious threat to all hotspots (CEPF, 2014). In biodiversity hotspots live about 2 billion people. However, the relationship between people and biodiversity is not simply one where presence of more people results in greater impacts on biodiversity. For human-biodiversity interactions is more important human activity than human density (Mittermeier *et al.*, 2004). Biodiversity hotspots are also notable centres of violent conflict (Dudley *et al.*, 2002).

EVALUATION OF HOTSPOTS' IMPORTANCE

The analysis by Myers *et al.* (2000) was driven by two criteria: species endemism and degree of threat, and considered five key factors: numbers of endemics and endemic/species ratios for plants and vertebrates, and habitat loss. Hotspots, which appeared most often in the top ten listings for each factor, were the leaders. Scientific knowledge has deepened, the number of hotspots has increased. These are the main reasons for the new analysis. In this analysis was used modified Myers' method for mutual comparison of the quality of biodiversity hotspots, which considered thirteen factors (instead of five): numbers of endemics and endemic/species ratios for plants, mammals, birds, amphibians, reptiles and freshwater fishes, and habitat loss. These factors do not carry equal weight, so they cannot be

combined into a single quantitative ranking. For the purposes of qualitative comparison were compiled the rankings of each factor. Due to the higher number of hotspots, 36 instead of 25 were considered top twelve listings for each factor. As a proxy indicator was used the sum of all factors rankings. For assessing the distribution of national parks in hotspots, was used a database (based on the WDPA dataset), analysed in GIS.

Biodiversity hotspots, appearing for all thirteen factors in the top twelve listings, are the most important on the world's terrestrial surface. These are Madagascar and the Indian Ocean Islands and Sundaland followed by the Philippines appearing twelve times and the Caribbean Islands appearing eleven times. All the areas are island hotspots, most of them being small areas, making them even more important. Next ranking numbers get to the Atlantic Forest, scoring also eleven times, Indo-Burma nine times, the Tropical Andes eight times and Mesoamerica and the Eastern Afrotropical seven times. The six richest hotspots in terms of biodiversity are those with the lowest proportion of the remaining natural vegetation, reaching in Madagascar and the Indian Ocean Islands and the Caribbean Islands hotspots 10 %, others displaying even smaller proportion.

Some other hotspots are hot conservation candidates because they greatly excel in one of the factors. The Mediterranean Basin has exceptional totals of endemic plants: 13,000, while the proportion of remaining natural vegetation is the smallest among all the hotspots. The Cape Floristic Region displays the second highest endemic species/area ratio for plants, just after the first New Caledonia. Although some of the biodiversity hotspots do not appear in the top twelve listings in any factor, they still must meet the criteria to qualify themselves as a hotspot and in comparison with the rest of the world have extraordinarily high species richness and endemism rate. The nine hotspots are Forests of East Australia, Himalaya, the California Floristic Province, the Chilean Winter Rainfall Valdivian Forests, Southwest Australia, Irano-Anatolian, Maputaland-Pondoland-Albany, the Caucasus and the Mountains of Central Asia.

Formerly 36 biodiversity hotspots covered an area of almost 24.9 million square kilometres, i.e. 16.7 % of the Earth's land surface (CEPF, 2014; CEPF, 2016). The area of the original primary habitat has been gradually decreasing there over the years, nowadays reaching 3.6 million square kilometres, i.e. 2.4 % of the Earth's land surface. The area of the original biodiversity hotspots' habitat was reduced by 85.5 %, only 14.5 % still remains. The average area of remaining vegetation is now only 100,224 km², which is almost seven times less than the original area. Generally, hotspots located outside the highly productive tropics in temperate or subtropical zone, have a larger proportion of the remaining natural vegetation. The northern hemisphere situated hotspots: the California Floristic Province, the Caucasus, the Mountains of Central Asia and Japan; and in the southern hemisphere: the Chilean Winter Rainfall-Valdivian Forests, the Succulent Karoo, the Cape Floristic Region, Maputaland-Pondoland-Albany, Southwest Australia and New Zealand, still having had 20 % or more of the original habitat area remaining. The only exception is the Mediterranean Basin, showing the lowest proportion due to the long-term and continuing human exposure. They are also located in developed countries (the United States, Japan, Australia, New Zealand), or in Chile and South Africa, known for their traditional and quite developed nature conservation.

The distribution of hotspots across biomes is very unequal. Of the total 36 biodiversity hotspots, 22 are located in the tropics, from very humid areas to sparsely wooded areas of savannas and grasslands. Seven hotspots are situated in the temperate forests biome: the Caucasus, the Irano-Anatolian hotspot, the Mountains of Central Asia, the Mountains of Southwest China, Japan, New Zealand and North American Coastal Plain; six can be characterised by the Mediterranean vegetation: the California Floristic Province, the Chilean

Winter Rainfall-Valdivian Forests, the Cape Floristic Region, Southwest Australia, the Mediterranean Basin and the Horn of Africa; and one – the Succulent Karoo – is desert.

NATURE CONSERVATION

Approximately 2.7 million square kilometres, i.e. 10.9 % of the total area of hotspots has already been at least officially protected. The proportion of protected areas varies between individual hotspots in a wide range from 3.2 % to 37 %. Two of the five most important hotspots, Madagascar and the Indian Ocean Islands, and Atlantic Forest, have the lowest proportion of area under some types of territorial protection, only 3.2 % and 4.1 %, respectively. Protected areas in IUCN categories I-IV provide higher levels of protection, because they control to various extent resource use and human presence. The average coverage of protected areas in categories I-IV is 5.0 % within the hotspots' original area, in total reaching 1,248,258 km². Generally, hotspots situated outside the tropics have above-average proportion of protected areas in IUCN categories I-IV, from New Zealand with 22.1 % to Japan with 5.9 %. The exception is again the Mediterranean Basin and then also a specific desert hotspot, namely the Succulent Karoo. National parks (as defined in national legislations) cover an area of 1,043,308.52 km², the proportion of the total hotspots' area is 4.2 %. In all 36 biodiversity hotspots has been established 1,858 national parks of the total number of 3,375 so far. Thus, in the hotspots is situated more than every second of the world's national parks, but only 24 % of their total area is there. It is caused by the low average size of national parks in the highly fragmented landscape of hotspots.

Biodiversity hotspots are irreplaceable areas at high risk, with significant species richness, diversity and endemism. They deserve the most attention in the process of conservation, together with high biodiversity wilderness areas, also irreplaceable but still largely intact. In 2000 was established the Critical Ecosystem Partnership Fund focusing exclusively on the funding of conservation activities in the areas of biodiversity hotspots, particularly from U.S. private foundations (Dalton, 2000). The concept has attracted over \$1 billion in conservation investments (Mittermeier *et al.*, 2011). Almost thirty of the 50 countries with the most underfunded biodiversity conservation programmes and projects host the global biodiversity hotspots: therefore, much more funding is required there (Waldron *et al.*, 2013).

CONCLUSION

Every day biodiversity is being lost at up to 1,000 times the natural rate. The extinction of species, habitat destruction, land conversion, climate change, pollution or the spread of invasive species are only some of the threats responsible for today's crisis (IUCN, 2010). For the first time in human history, the rate of species extinction may exceed that of species discovery (Wheeler *et al.*, 2012). Traditionally among the main responses to the current biodiversity crisis, there also is the establishment and effective management of protected areas to ensure the persistence of biodiversity not only in the hotspots (Bruner *et al.*, 2001). Surprisingly high number of currently existing protected areas are no more than “paper parks”, it means they have official designation, but lack management plans, funding, capacity or enforcement and in some cases, even borders. Mismanagement also includes biodiversity conservation (CEPF, 2014). The main objectives of the current global conservation should be, *inter alia*, ensuring long-term stability in the already declared protected areas, reducing fragmentation and then also establishing new protected areas in places with intact habitat with the highest conservation priority (Mittermeier *et al.*, 2004). Climate change is likely to

have a large impact on biodiversity. Establishing protected areas that remain resistant and resilient to climate change as well as new ones in novel ecosystems is a further challenge (Araújo *et al.*, 2004; Hannah *et al.*, 2007; Bellard *et al.*, 2014). Species movement including dispersal may be very difficult or impossible in heavily fragmented habitat (Thomas, 2011). Therefore, it is necessary to protect also the areas that will host target species in the near future and to establish, manage and protect the corridors, both linear ones and stepping stones (Mittermeier *et al.*, 2004). The long-term goal is to attempt to restore degraded habitats to provide increased connectivity and to decrease fragmentation (CEPF, 2014).

Biodiversity hotspots and high biodiversity wilderness areas are inhabited by two-thirds of endemic plant species and half of the world's endemic species of terrestrial vertebrates in only 8.5 % of the Earth's land surface. Hotspots provide us with the real measure of the conservation challenge. Unless we succeed in conserving this small fraction of the planet's land area, we will lose more than half of our natural heritage (CEPF, 2014).

To conclude, the analysis evaluates 36 instead of 25 hotspots that existed in 2000. The current available species data are more complete and accurate, so they allow consideration of 13 factors instead of 5 and more precise results of biodiversity hotspots' importance. Hotspots with the highest conservation priority are Madagascar and the Indian Ocean Islands, Sundaland, the Philippines and the Caribbean Islands, all island hotspots, with the lowest proportion of the remaining natural vegetation, located in the tropics. Effective conservation in the areas of biodiversity hotspots must be among the tasks of high priority at present and in the near future.

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