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Review paper

Biodiversity hotspots: A shortcut for a more complicated concept

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ABSTRACT

In an era of human activities, global environmental changes, habitat loss and species extinction, conservation strategies are a crucial step toward minimizing biodiversity loss. For instance, oceans acidification and land use are intensifying in many places with negative and often irreversible consequences for biodiversity. Biodiversity hotspots, despite some criticism, have become a tool for setting conservation priorities and play an important role in decision-making for cost-effective strategies to preserve biodiversity in terrestrial and, to some extent, marine ecosystems. This area-based approach can be applied to any geographical scale and it is considered to be one of the best approaches for maintaining a large proportion of the world's biological diversity. However, delineating hotspots includes quantitative criteria along with subjective considerations and the risk is to neglect areas, such as coldspots, with other types of conservation value. Nowadays, it is widely acknowledged that biodiversity is much more than just the number of species in a region and a conservation strategy cannot be based merely on the number of taxa present in an ecosystem. Therefore, the idea that strongly emerges is the need to reconsider conservation priorities and to go toward an interdisciplinary approach through the creation of science-policy partnerships.

Contents

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1. Introduction

As demonstrated by several researches, maintaining biodiversity is essential to the supply of ecosystem services and not less important to support their health and resilience (Pereira et al., 2013). However, despite there being an international interest to sustain and protect biodiversity, its loss does not seem to slow down (Butchart et al., 2010). Although there has been an extension of protected areas (Pimm et al., 2014), these provide a still low species coverage (Venter et al., 2014) and do not appear to optimally protect biodiversity (Pimm et al., 2014). For instance, a recent analysis (Selig et al., 2014) for conservation priorities in marine environments by combining spatial distribution data for nearly 12,500 species with human impacts information, identified new areas of high conservation value that are located in Arctic and Antarctic Oceans and beyond national jurisdictions.

Overall, habitat change and their over-exploitation, pollution, invasive species and in particular climate change are the major causes for biodiversity loss. The combined effect of these anthropogenic pressures may have already started a critical transition toward a tipping point (Barnosky et al., 2012). In particular, climate is modifying rapidly forcing biodiversity to adapt either through the change of habitat and life cycles or the development of new physical traits (Berteaux et al., 2010). For instance, rising temperatures can lead to potential biodiversity increases in northern regions (i.e. northern biodiversity paradox) where low temperatures usually are a limiting factor for the establishment of many species (Berteaux et al., 2010). Given the importance that biodiversity plays, the understanding of the main threats to biodiversity is today than ever before a central objective in conservation biology.

Nowadays there is serious concern about the effectiveness of existing strategies for biodiversity protection. A central issue in conservation is to identify biodiversity-rich areas to which conservation resources should be directed. Based on the observation that some parts of the world have far more species than others, the area-based approaches are widely advocated for species conservation planning. Areas with high concentrations of endemic species (species that are found nowhere else on Earth) and with high habitat loss are often referred to as "hotspots" (Myers, 1988). The hotspot approach can be applied at any geographical scale and both in terrestrial and marine environments. However, hotspots represent conservation priorities in terrestrial ecosystems but remain largely unexplored in marine habitats (Worm et al., 2003) where the amount of data is still poor (Mittermeier et al., 2011).

Despite this lack of homogeneity in data between terrestrial and aquatic ecosystems, the recent concerns over loss of biodiversity have led to calls for the preservation of hotspots as a priority. As reported by Myers (2003) at the end of his article, "Edward O. Wilson, one of the leading authorities on conservation, described the hotspot approach as '*the most important contribution to conservation biology of the last century*'". Closely linked to the concept of biodiversity, the hotspot concept is used with increasing frequency in biology and conservation literature and often with different meanings. While in a strict sense, the meaning is based on an estimate of endemic species and habitat loss, in a broad sense it refers to any area or region with exceptionally high biodiversity at the ecosystem, species and genetic levels.

The aim of this work is to review the current literature on the general concept of hotspots. We first introduce the approach that lies behind the concept of hotspots, in both terrestrial and marine ecosystems. Next we discuss the main criticisms and controversies concerning this approach and we present the possibility of using different alternative metrics to identify hotspots. Then we bring to light the links between biodiversity hotspots and marine pelagic ecosystem processes and we briefly introduce the deep-sea, a realm for the most part unknown for which several key questions are still waiting for an answer. Finally, we briefly discuss additional approaches and criteria, such as costs, in order to highlight some challenges in assigning global conservation priorities.

2. Biodiversity hotspots

2.1. The biodiversity hotspots concept

The British ecologist Norman Myers first published the biodiversity hotspot thesis in 1988. Myers, although without quantitative criteria but relying solely on the high levels of habitat loss and the presence of an extraordinary number of plant endemism, identified ten tropical forest "hotspots" (Mittermeier et al., 2011). A subsequent analysis (Myers, 1990) added a further eight hotspots, including four in Mediterranean regions. Conservation International (CI—http://www.conservation.org) adopted Myers' hotspots as its institutional blueprint in 1989, and afterwards worked with him in a first systematic update of the global hotspots. Myers, Conservation International, and collaborators later revised estimates of remaining primary habitat and defined the hotspots formally as biogeographic regions with >1500 endemic vascular plant species and $\leq 30\%$ of original primary habitat (Myers et al., 2000). This collaboration, which led to an extensive global review (Mittermeier et al., 1999) and a scientific publication (Myers et al., 2000) saw the hotspots expand in area as well as in number, on the basis of both the better-defined criteria and new data. A second major revision and update in 2004 (Mittermeier et al., 2004) did not change the criteria but by redefining several hotspots boundaries, and by adding new ones that were suspected hotspots for which sufficient data either did not exist or were not easily accessible, brought the total to 34 biodiversity hotspots (Mittermeier et al., 2011). Recently, a 35th hotspot was added (Williams et al., 2011), the Forests of East Australia. The 35 biodiversity hotspots (Table 1, Fig. 1) that cover only 17.3% of the Earth's land surface are characterized by both exceptional biodiversity and considerable habitat loss (Myers et al., 2000). More precisely, hotspots maintain 77% of all endemic plant species, 43% of vertebrates (including 60% of threatened mammals and birds), and 80% of all threatened amphibians (Mittermeier et al., 2011; Williams et al., 2011).