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Protected areas in the world's ecoregions: How well connected are they?

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ABSTRACT

Protected areas (PAs) are the main instrument for biodiversity conservation, which has triggered the development of numerous indicators and assessments on their coverage, performance and efficiency. The connectivity of the PA networks at a global scale has however been much less explored; previous studies have either focused on particular regions of the world or have only considered some types of PAs.

Here we present, and globally assess, ProtConn, an indicator of PA connectivity that (i) quantifies the percentage of a study region covered by protected connected lands, (ii) can be partitioned in several components depicting different categories of land (unprotected, protected or transboundary) through which movement between protected locations may occur, (iii) is easy to communicate, to compare with PA coverage and to use in the assessment of global targets for PA systems.

We apply ProtConn to evaluate the connectivity of the PA networks in all terrestrial ecoregions of the world as of June 2016, considering a range of median dispersal distances (1–100 km) encompassing the dispersal abilities of the large majority of terrestrial vertebrates.

We found that 9.3% of the world is covered by protected connected lands (average for all the world's ecoregions) for a reference dispersal distance of 10 km, increasing up to 11.7% for the largest dispersal distance considered of 100 km. These percentages are considerably smaller than the global PA coverage of 14.7%, indicating that the spatial arrangement of PAs is only partially successful in ensuring connectivity of protected lands. The connectivity of PAs largely differed across ecoregions. Only about a third of the world's ecoregions currently meet the Aichi Target of having 17% of the terrestrial realm covered by well-connected systems of PAs. Finally, our findings suggest that PAs with less strict management objectives (allowing the sustainable use of resources) may play a fundamental role in upholding the connectivity of the PA systems.

Our analyses and indicator make it possible to identify where on the globe additional efforts are most needed in expanding or reinforcing the connectivity of PA systems, and can be also used to assess whether newly designated sites provide effective connectivity gains in the PA system by acting as corridors or stepping stones between other PAs. The results of the ProtConn indicator are available, together with a suite of other global PA indicators, in the Digital Observatory for Protected Areas of the Joint Research Centre of the European Commission.

1. Introduction

Protected areas (PAs) are essential for biodiversity conservation. The fate of many endangered species, the preservation of healthy ecosystems with high species and genetic richness, and the delivery of ecosystem services from natural habitats strongly depend on PA systems that are well designed and managed. For this reason, many studies have presented and delivered indicators on the coverage, land cover trends, pressures, performance, and management efficiency of PAs (e.g. Joppa et al., 2008; Nelson and Chomitz, 2011; Joppa and Pfaff, 2011; Laurance et al., 2012; Geldmann et al., 2013; Nolte et al., 2013; Coetzee et al., 2014; Marino et al., 2015; Gray et al., 2016). These studies and indicators provide very valuable information on different aspects of PAs, but they have not explicitly considered the PA system as a network of sites potentially linked through spatial and temporal interactions. Because of these links and interactions, it may not be possible to evaluate the functioning of the network as a whole as the sum of its individual parts (PA) separately considered.

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There is indeed a growing recognition that PAs cannot be conceived and managed as "islands" isolated from other PAs and from the rest of the landscape context (Laurance et al., 2012). Even if a given area is designated as protected because of the local biodiversity values it presents, such as high species richness and presence of endangered or endemic species, and even when all the appropriate conservation measures are taken inside that PA, declines in biodiversity within the PA may still occur as a result of the extinction debts produced by the lack of connectivity with other (ideally protected) populations and natural habitats (Kuussaari et al., 2009; Pressey et al., 2015). In addition, it is projected that climate change will make some PAs inhospitable for many of the species they currently harbor, requiring species to move to new locations matching their environmental requirements, typically at higher latitudes or altitudes (Thomas et al., 2012; Beale et al., 2013). In the absence of connectivity in the PA systems, individual PAs may turn into climatic traps under warming, hampering their ability to meet their long-term conservation goals. Therefore, the connectivity of PAs, defined as the ease of species movements and other ecological flows among protected locations, is at the forefront of the concerns for biodiversity conservation.

The scientific evidence on the importance of PA connectivity has already translated into global commitments at the political level. In the 10th meeting of the Convention on Biological Diversity (CBD) around 200 parties to the CBD (i.e. most of the world's governments) adopted a Strategic Plan for Biodiversity for the 2011–2020 period including twenty Aichi Biodiversity Targets (CBD, 2010). In Aichi Target 11 the international community agreed to increase by 2020 the terrestrial area under protection to at least 17% in 'effectively and equitably managed, ecologically representative and well connected systems of protected areas' (CBD, 2010). Despite the importance of these global goals for PAs, the definition and supporting material of Aichi Target 11 (CBD, 2011) does not specify a quantitative criterion or indicator to be used to track progress towards the connectivity element of this target. This lack of available indicators and of quantifiable aspects has prevented consistent interpretation by signatories, and has made it difficult to stimulate and quantify progress towards the Aichi Target 11 element on well-connected PA systems, as is also the case for other Aichi Targets (Butchart et al., 2016). On the other hand, there are very few studies that have quantified the connectivity of the terrestrial PA networks, particularly at a global scale. To our knowledge, none of the existing studies has provided information that can be used to report against the connectivity component of the global Aichi Target 11, because they have only covered some countries, regions or continents (e.g. Minor and Lookingbill, 2010; Gurrutxaga et al., 2011; Opermanis et al., 2012; Mazaris et al., 2013; Wegmann et al., 2014; Maiorano et al., 2015; Belote et al., 2016), because they have mapped connectivity patterns or priority areas but have not provided an indicator that can be used to assess PA connectivity targets (e.g. Gurrutxaga et al., 2011; Wegmann et al., 2014; Belote et al., 2016), and/or because, even if they are global, they have only considered some types of PAs (Santini et al., 2016), omitting a large part of the protected lands that may contribute to connectivity and related Aichi Targets.

Here we present Protected Connected (ProtConn), an indicator of the connectivity of PA systems that improves the detail and comprehensiveness of previous related assessments mainly by depicting different categories of land through which movement between protected locations may occur, including the assessment of the contribution of transboundary PAs to connectivity (i.e. how PAs outside a study region help to connect those PAs inside). ProtConn is based on graph theory (network analysis) and accounts for both the land area that can be reached within PAs and that reachable through the connections between different PAs. We assess this indicator globally for all the world's terrestrial ecoregions, as large units of land with similar environmental conditions and distinctive species composition, using the information on PAs as of June 2016. In our assessment, we do not consider the heterogeneity of the landscape matrix in between PAs, because the resistance to species movement by different land covers has been shown to be highly variable among and within species (Goosem, 2001; Rytwinski and Fahrig, 2012; Gastón et al., 2016). Rather, we provide a more general analysis at the global level that is not attached to the details of particular species but focuses on the connectivity of PA systems as given by the coverage and spatial arrangement of PAs and by the range of dispersal distances that have been observed for the majority of terrestrial vertebrates.

By doing so, we aim to provide an indicator of PA connectivity which can be directly used by the CBD and its parties to assess progress towards Aichi Target 11 and other future targets, as well as by the European Union (EU) to support its Green Infrastructure Strategy where PAs such as Natura 2000 sites form the backbone of a broader EU Biodiversity Strategy to 2020. For this purpose, the ProtConn indicator has been developed to support and further enrich the Digital Observatory for Protected Areas (DOPA) of the Joint Research Centre of the European Commission (Dubois et al., 2013, 2015), which can be accessed at http://dopa.jrc.ec.europa.eu/ . DOPA is a set of web services and applications that, using global reference datasets, provides a broad range of consistent and comparable indicators on the state of and pressures on PAs worldwide (Dubois et al., 2016). The information provided by the ProtConn indicator, together with other global indicators on PAs available in DOPA, can be used, for example, to support spatial planning, resource allocation, strategies for improving the PA networks, and national and international reporting.

2. Methods

2.1. Spatial layers: sources and processing

2.1.1. Protected areas

We downloaded the public version of the World Database on Protected Areas (WDPA) for June 2016 as a file geodatabase from Protected Planet (http://www.protectedplanet.net/). WDPA is managed by the World Conservation Monitoring Centre (WCMC) of the United Nations Environment Programme (UNEP) in collaboration with the International Union for Conservation of Nature (IUCN), and is collated from national and regional datasets (IUCN and UNEP-WCMC, 2016). WDPA includes all sites designated at a national level (e.g. national parks), under regional agreements (e.g. the Natura 2000 network in the European Union) and under international conventions and agreements (e.g. natural World Heritage sites), which for June 2016 gives about 200,000 terrestrial PAs. As in other global PA assessments (e.g. UNEP-WCMC and IUCN, 2016), we excluded from subsequent analysis those PAs with a "proposed" or "not reported" status, sites reported as points without an associated reported area, and UNESCO Man and the Biosphere Reserves (as their buffer areas and transition zones may not meet the IUCN protected area definition, and because most of their core areas overlap with other protected areas); these excluded sites were about 3% of the total number of terrestrial PAs reported in the WDPA. We considered all PA types, including PAs with not reported or not assigned IUCN category in the WDPA, in consistency with other analyses of global targets for PAs (e.g. UNEP-WCMC and IUCN, 2016). For PAs reported in the WDPA as points with unknown boundaries but including a reported area, a geodesic circular buffer with an area equal to the reported value was created and used in the analysis, similarly to previous studies (e.g. Gray et al., 2016; UNEP-WCMC and IUCN, 2016). The PA polygons (including the buffered points) were dissolved to remove all overlaps between different designa-