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# Protected area connectivity: Shortfalls in global targets and country-level priorities

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ABSTRACT

Connectivity of protected areas (PAs) is crucial for meeting their conservation goals. We provide the first global evaluation of countries' progress towards Aichi Target 11 of the Convention on Biological Diversity that is to have at least 17% of the land covered by well-connected PA systems by 2020. We quantify how well the terrestrial PA systems of countries are designed to promote connectivity, using the Protected Connected (ProtConn) indicator. We refine ProtConn to focus on the part of PA connectivity that is in the power of a country to influence, i.e. not penalizing countries for PA isolation due to the sea and to foreign lands. We found that globally only 7.5% of the area of the countries is covered by protected connected lands, which is about half of the global PA coverage of 14.7%, and that only 30% of the countries currently meet the Aichi Target 11 connectivity element. These findings suggest the need for considerable efforts to improve PA connectivity globally. We further identify the main priorities for improving or sustaining PA connectivity in each country: general increase of PA coverage, targeted designation of PAs in strategic locations for connectivity, ensuring permeability of the unprotected landscapes between PAs, coordinated management of neighbouring PAs within the country, and/or transnational coordination with PAs in other countries. Our assessment provides a key contribution to evaluate progress towards global PA connectivity targets and to highlight important strengths and weaknesses of the design of PA systems for connectivity in the world's countries and regions.

## 1. Introduction

Protected areas (PAs) are critical for biodiversity conservation. Well designed and managed PA systems can effectively safeguard species and ecosystems, and deliver essential ecosystem services to people (Rands et al., 2010; Watson et al., 2014; UNEP-WCMC and IUCN, 2016). Connectivity of PA systems is necessary to facilitate large-scale ecological and evolutionary processes such as gene flow, migration and species range shifts. These processes are all essential for the persistence of viable populations, especially when facing climatic and environmental changes in increasingly transformed and fragmented landscapes (Kuussaari et al., 2009; Krosby et al., 2010; Beale et al., 2013). Improving or sustaining PA connectivity is therefore a primary concern for the effective conservation and management of biodiversity (Ervin et al., 2010; Laurance et al., 2012; Juffe-Bignoli et al., 2014).

The importance of PA connectivity is also recognized in global biodiversity targets adopted by the world's governments. In 2010, the parties to the United Nations Convention on Biological Diversity (CBD) adopted a Strategic Plan for Biodiversity for the 2011–2020 period, including the 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). However, the CBD has neither provided a clear definition of the term 'well-connected', nor guidance on how to measure PA connectivity (Bertzky et al., 2012; Butchart et al., 2016), which has made it difficult to stimulate and track progress towards the Aichi Target 11 connectivity element. Recently, the first global assessments on PA connectivity have been reported (Santini et al., 2016; Saura et al., 2017). In particular, Saura et al. (2017) proposed the Protected Connected indicator (ProtConn), which considers different categories of land (unprotected, protected or transboundary) through which movement between protected locations may occur. ProtConn can be compared with PA coverage and used directly to quantify shortfalls, or successes, in achieving the connectivity element of Aichi Target 11. Saura et al. (2017) used ProtConn to examine the connectivity of PA systems for all terrestrial ecoregions, but a country-level evaluation can provide a more policy-relevant assessment since most political decisions on development and management of PA networks are taken at the national level. In addition, the analyses in Saura

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et al. (2017) did not distinguish between different causes of PA isolation but amalgamated them in the obtained connectivity scores. When extending the method to a country-level analysis, it is important to recognise that some of these causes will be outside the control or jurisdiction of a country; for example, PAs that are naturally separated by the sea or that are separated by the lands of other nations (e.g. Alaska and the rest of the USA).

Here we provide the first global evaluation of countries' progress towards the Aichi Target 11 element on well-connected PA systems. We quantify the percentage of each country that is covered by lands that are both protected and connected, using a refined version – called $\text{ProtConn}_{\text{Bound}}$ – of the ProtConn indicator. $\text{ProtConn}_{\text{Bound}}$ is obtained by separating three different potential sources of PA isolation: limitations of the design of the PA system in a country, natural isolation of PAs by the sea, and isolation due to intervening land belonging to other countries. Through this distinction, $\text{ProtConn}_{\text{Bound}}$ focuses on the part of PA connectivity that is within the power of a country to influence, allowing for a fair comparison which does not systematically penalize countries with multiple islands or landmasses. In our assessment, we consider a range of median dispersal distances (1–100 km) encompassing the dispersal abilities of the large majority of terrestrial vertebrates, and we do not account for heterogeneity of the unprotected land between PAs. Our focus is on the structure and spatial arrangement of the network of PAs, and on the number, size and coverage of PAs in a country, rather than on the particularities of the landscape matrix and of the variable species-specific responses to it. Our aim is to assess how well the PA systems themselves are designed to support or promote connectivity, and how self-sufficient they are to do so in the long term.

We further interpret the detailed results of the indicator to identify, for each country, the main strategic priorities to improve or sustain PA connectivity. Our classification shows, from a connectivity perspective, whether a country should prioritize: general increase of PA coverage; targeted designation of PAs in strategic locations for connectivity; ensuring permeability of the unprotected landscapes in between PAs; coordinated management of neighbouring PAs within the country; or transnational coordination with PAs in other countries. This classification approach highlights important strengths and weaknesses of the design of PA systems for connectivity in the world's countries and regions, and is illustrated in more detail for selected examples.

Our final goal is to provide a country-level indicator of PA connectivity which can be directly used by the CBD, its Parties and the CBD-mandated Biodiversity Indicators Partnership (BIP[1]), to promote and assess progress towards Aichi Target 11 and future PA connectivity targets.

## 2. Methods

### 2.1. Protected areas

We downloaded the public version of the World Database on Protected Areas (WDPA) for June 2016 from Protected Planet.[2] The 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). In June 2016, the WDPA contained around 200,000 terrestrial PAs. As in other recent global PA assessments (e.g. UNEP-WCMC and IUCN, 2016), we (i) excluded PAs with a "proposed" or "not reported" status, sites reported as points without an associated reported area, and UNESCO Man and the Biosphere Reserves, (ii) considered all PA types, including PAs for which the WDPA does not indicate an IUCN management category ("not reported" or "not assigned"), and (iii) included those PAs provided in the WDPA as points with unknown boundaries but with a reported area (about 6% of all PAs), using a geodesic circular buffer with an area equal to the reported value. The PA polygons (including the buffered points) were dissolved to remove all overlaps between different designation types and avoid double counting (e.g. where the same area is designated both as a National Park and as a World Heritage Site). The PA polygons in the dissolved layer could hence correspond to several overlapping or adjacent PAs. In order to facilitate computation of the inter-PA distance calculations on the dissolved vector layer (see Section 2.3) we reduced the number of vertices in the polygons using the Simplify Geometries tool in QGIS 2.12 with a tolerance of 100 m.

### 2.2. Land and countries

To exclude marine PAs and the marine portion of coastal PAs from our analysis, we clipped the above-described PA polygon layer with the land mask obtained from the Global Administrative Unit Layers (GAUL) for year 2015, developed by the Food and Agricultural Organization (FAO) of the United Nations.[3] The resultant polygons were converted to single parts, yielding a set of individual terrestrial PA polygons, hereafter referred to simply as PAs for brevity. We calculated the area of each PA using the Mollweide projection. For computational feasibility of the connectivity calculations, we removed those PA polygons with an area smaller than 1 $km^2$. This size threshold is consistent with other previous analysis on PAs at global or European scales (Leroux et al., 2010; Opermanis et al., 2012; Santini et al., 2016; Saura et al., 2017) and retained 99.8% of the total land area covered by PAs globally.

PAs were assigned to each country based on the ISO3 country code reported in the WDPA. For 17 PAs, most of them World Heritage Sites, multiple ISO3 codes were reported in the WDPA; these PAs were intersected with the GAUL country boundaries to distribute their area between the countries. Consistent with other global assessments (UNEP-WCMC and IUCN, 2016) and information systems on PAs,[4] we here refer to the ISO3 coded geographical entities as "countries", and report our results at this country level. It should be noted, however, that in some cases these ISO3 codes correspond to territories under the sovereignty of other nations, even if they are usually separately considered in this type of assessments. Some examples are Réunion Island, a French overseas territory located in the Indian Ocean, or Greenland, a self-governing territory that is part of the Kingdom of Denmark. In our analyses, we obtained, after excluding Antarctica, a total of 233 countries (ISO3 codes) that had some area under protection according to the PA size threshold used in this study, i.e. with at least one PA polygon with an area exceeding or equal to 1 $km^2$. The area of each country, which is used in the calculation of the indicators described below, was calculated from GAUL using the Mollweide projection, excluding any disputed territories (sovereignty unsettled) as mapped in GAUL. The use of the ISO3 codes in the WDPA and of the GAUL definitions of country boundaries and disputed territories does not imply any endorsement by the authors, nor any official position by the European Commission, on the sovereignty of these lands.

### 2.3. Dispersal kernels, inter-PA distances and transboundary PAs

To assess the connectivity of PA systems, we considered four median dispersal distances ($d_{med}$) of 1, 10, 30 and 100 km. This 1–100 km range covers the median dispersal abilities of the majority of terrestrial species (Saura et al., 2017), and matches the one used in a previous PA connectivity analysis for the USA (Minor and Lookingbill, 2010). Since 10 km is the central value of the log-transformed range of dispersal

[1] https://www.bipindicators.net/.

[2] https://www.protectedplanet.net/.

[3] http://www.fao.org/geonetwork/srv/en/metadata.show?id=12691.

[4] https://www.protectedplanet.net/, http://dopa-explorer.jrc.ec.europa.eu/dopa_explorer/.