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LETTER

Shortfalls and Solutions for Meeting National and Global Conservation Area Targets

Stuart H.M. Butchart[1], Martin Clarke[1], Robert J. Smith[2], Rachel E. Sykes[2], Jörn P.W. Scharlemann[3], Mike Harfoot[4,5], Graeme M. Buchanan[6], Ariadne Angulo[7], Andrew Balmford[8], Bastian Bertzky[4,9], Thomas M. Brooks[7,10,11], Kent E. Carpenter[12], Mia T. Comeros-Raynal[12], John Cornell[1], G. Francesco Ficetola[13], Lincoln D.C. Fishpool[1], Richard A. Fuller[14], Jonas Geldmann[15], Heather Harwell[12,16], Craig Hilton-Taylor[17], Michael Hoffmann[4,7], Ackbar Joolia[17], Lucas Joppa[5], Naomi Kingston[4], Ian May[1], Amy Milam[4], Beth Polidoro[12,18], Gina Ralph[12], Nadia Richman[19], Carlo Rondinini[20], Daniel B. Segan[21,22], Benjamin Skolnik[23], Mark D. Spalding[24], Simon N. Stuart[4,7,25,26], Andy Symes[1], Joseph Taylor[1], Piero Visconti[5], James E.M. Watson[21,22], Louisa Wood[4,27], & Neil D. Burgess[4,15]

[1] BirdLife International, Wellbrook Court, Cambridge, CB3 0NA, UK
[2] Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury CT2 7NR, UK
[3] School of Life Sciences, University of Sussex, Brighton BN1 9QG, UK
[4] United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge CB3 0DL, UK
[5] Microsoft Research Computational Science Laboratory, 21 Station Road, Cambridge CB1 FB, UK
[6] RSPB Centre for Conservation Science, RSPB Scotland, 2 Lochside View, Edinburgh Park, Edinburgh EH12 9DH, UK
[7] International Union for Conservation of Nature, Rue Mauverney 28, 1196 Gland, Switzerland
[8] Conservation Science Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK
[9] European Commission, Joint Research Centre (JRC), Via Enrico Fermi 2749, 21027 Ispra (VA), Italy
[10] World Agroforestry Center (ICRAF), University of the Philippines Los Baños, Laguna 4031, Philippines
[11] School of Geography and Environmental Studies, University of Tasmania, Hobart TAS 7001, Australia
[12] IUCN Marine Biodiversity Unit, Department of Biological Sciences, Old Dominion University, Norfolk, VA 23529, USA
[13] Laboratoire d'Ecologie Alpine (LECA), Université Grenoble-Alpes, F-38000 Grenoble, France
[14] School of Biological Sciences, University of Queensland, St Lucia, QLD 4072, Australia
[15] Center for Macroecology, Evolution, and Climate, Natural History Museum of Denmark, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen E, Denmark
[16] Department of Organismal and Environmental Biology, Christopher Newport University, Newport News, VA 23606, USA
[17] International Union for Conservation of Nature, 219c Huntingdon Road, Cambridge CB30DL, UK
[18] New College of Interdisciplinary Arts and Sciences, Arizona State University, Phoenix, AZ 85069, USA
[19] Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK
[20] Global Mammal Assessment Program, Department of Biology and Biotechnologies, Sapienza University of Rome, Viale dell'Università 32, 00185 Roma, Italy
[21] Global Conservation Program, Wildlife Conservation Society, Bronx, NY 10460, USA
[22] School of Geography, Planning and Environmental Management, University of Queensland, St Lucia, QLD 4072, Australia
[23] American Bird Conservancy, P.O. Box 249, 4249 Loudoun Avenue, The Plains, VA 20198-2237, USA
[24] The Nature Conservancy and Conservation Science Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK
[25] Department of Biology and Biochemistry, University of Bath, Bath BA2 7AY, UK
[26] Al Ain Zoo, P.O. Box 45553, Abu Dhabi, United Arab Emirates
[27] Department of Geography, University of Cambridge, Downing Place, Cambridge CB2 3EN, UK

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Correspondence
Stuart Butchart, BirdLife International, Wellbrook Court, Cambridge CB30NA, UK. Tel: +44 1223 279839; fax: +44 1223 277200.
E-mail: stuart.butchart@birdlife.org

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Abstract

Governments have committed to conserving ≥17% of terrestrial and ≥10% of marine environments globally, especially "areas of particular importance for biodiversity" through "ecologically representative" Protected Area (PA) systems or other "area-based conservation measures", while individual countries have committed to conserve 3–50% of their land area. We estimate that PAs currently cover 14.6% of terrestrial and 2.8% of marine extent, but 59–68% of ecoregions, 77–78% of important sites for biodiversity, and 57% of 25,380 species have inadequate coverage. The existing 19.7 million km^2 terrestrial PA network needs only 3.3 million km^2 to be added to achieve 17% terrestrial coverage. However, it would require nearly doubling to achieve, cost-efficiently, coverage targets for all countries, ecoregions, important sites, and species. Poorer countries have the largest relative shortfalls. Such extensive and rapid expansion of formal PAs is unlikely to be achievable. Greater focus is therefore needed on alternative approaches, including community- and privately managed sites and other effective area-based conservation measures.

Introduction

In 2010, in the face of ongoing biodiversity declines (Butchart *et al.* 2010), the 193 parties to the Convention on Biological Diversity adopted 20 "Aichi Targets" to be met by 2020 (CBD 2010). PAs spearhead global efforts to conserve nature (Chape *et al.* 2008), and Aichi Target 11 commits governments to conserving ≥17% of terrestrial and ≥10% of marine environments globally, especially "areas of particular importance for biodiversity" through "ecologically representative" PA systems or other "area-based conservation measures." As contributions toward this, many nations have set their own national commitments for PA coverage (ranging from 3% to 50% of land area), of which 43 are lower than 17% and 36 are greater (Table S1). Almost halfway through the period for implementing these commitments, and following the outcomes of the recent Sixth World Parks Congress which called for countries to act urgently to make progress on their commitments (World Parks Congress 2014), it is now timely to assess progress.

Previous global assessments of PA coverage of biodiversity have focused narrowly on species (Rodrigues *et al.* 2004a, 2004b; Watson *et al.* 2010; Cantú-Salazar *et al.* 2013), sites (Ricketts *et al.* 2005; Butchart *et al.* 2012), ecoregions and biomes (Jenkins & Joppa 2009), threatened vertebrates and ecoregions (Venter *et al.* 2014), the marine environment (Spalding *et al.* 2013), forests (Schmitt *et al.* 2009), or mountains (Rodríguez-Rodríguez *et al.* 2011). To provide a more comprehensive and integrated evaluation, we analyzed PA coverage of terrestrial and marine environments, countries, ecoregions, biogeographic provinces, biomes, and realms, 11,807 important sites for biodiversity, and 25,380 species' distributions (covering three times as many taxonomic groups as previous studies, and representing the first evaluation for marine taxa). We then used systematic conservation planning software to identify the extent to which the current global PA network needs to be augmented to meet Aichi Target 11 global and national targets.

Methods

Details of the spatial data sets we used are given in Table S2. For "areas of particular importance for biodiversity" as referred to in Aichi Target 11, we assessed the only two global site networks that have been identified using standardized criteria (Key Biodiversity Areas): Important Bird and Biodiversity Areas (IBAs; 11,220 sites of global avian significance: Butchart *et al.* 2012) and Alliance for Zero Extinction Sites (AZEs; 587 sites holding the last remaining population of one or more highly threatened species: Ricketts *et al.* 2005). For species, we assessed only those groups in which all species have been assessed (and mapped) for the IUCN Red List of Threatened Species (IUCN 2012).

We set "representation targets" for the percentage of each species' distribution to be covered by PAs, following Rodrigues *et al.* (2004a), Watson *et al.* (2010), and Venter *et al.* (2014), scaling targets by species' range size, decreasing from 100% for species with distributions <1,000 km^2 to 10% for species with distributions >250,000 km^2, and linearly interpolated on a log-linear scale between these two thresholds. We capped the area to be protected at 1 million km^2 for species with extremely large ranges (>10 million km^2, Figure S1), because landscape-scale conservation through sectoral policy interventions is generally more appropriate for such species. This cap affected 3.1% of species ($n = 789$, mainly birds and mammals). The target was treated as having been met if PA coverage was ≥95% of the target area.

To assess ecological representativeness of the PA network, we assumed a uniform target of 17% protection for each terrestrial ecoregion (Olson *et al.* 2001), given this is the approach recommended in guidance to CBD parties and widely used to assess progress toward achieving Aichi Target 11 (Woodley *et al.* 2012; CBD 2014; Juffe-Bignoli *et al.* 2014; Tittensor *et al.* 2014; Venter *et al.* 2014; Watson *et al.* 2014).

We projected all spatial data into Mollweide equal area projection, and processed in vector format using ESRI ArcGIS v10, calculating PA coverage through spatial intersections of PAs and conservation features (Tables S3 and S4). For all terrestrial coverage statistics, we followed established practice (e.g., Juffe-Bignoli *et al.* 2014; Venter *et al.* 2014) by excluding the Antarctic ecoregions "Marielandia Antarctic tundra" and "Maudlandia Antarctic desert" (Olson *et al.* 2001).

We estimated temporal trends in PA coverage using data on the year of PA establishment recorded in the January 2013 version of the World Database on Protected Areas. As this was unknown for 14.3% of terrestrial and 8.6% of marine PAs, we randomly assigned a year from another PA within the same country, or for countries with less than five PAs with known year of establishment, from all terrestrial or marine PAs, and then repeated this procedure 1,000 times, and plotted the median and 95% confidence intervals.

To identify the extent of additional land requiring conservation to meet different target-setting scenarios in the terrestrial environment, we built on the approaches of previous studies (e.g., Pressey *et al.* 1993; Faith *et al.* 2001; Rodrigues *et al.* 2004a; Watson *et al.* 2010; Pouzols *et al.* 2014; Venter *et al.* 2014), using the Marxan conservation planning software (Ball *et al.* 2009). This uses a simulated annealing approach to identify near-optimal portfolios of planning units that meet the specified conservation feature targets while minimizing costs (Ball *et al.* 2009). We used human population size as the planning unit cost (as a surrogate for opportunity cost and difficulty of establishing PAs in any new areas to be conserved), so that heavily populated planning units tended to be avoided unless they were essential for target attainment. This part of our analysis was restricted to terrestrial environments because comparable cost data are unavailable for marine environments.

We used a 30 × 30 km grid layer (with the scale chosen to balance the trade-offs between the coarseness of the underlying data sets, the size of most PAs, and the risk of commission errors), combined this with country/territory boundaries and calculated the area of "conservation features" (species, ecoregion, and country) found in each of the resultant 150,700 planning units, as well as the area in each planning unit of each of these conservation features covered by PAs and by unprotected IBAs or AZEs. We used the 1-km resolution Global Rural-Urban Mapping Project (GRUMPv1) data set (CIESIN *et al.* 2011) in ArcGIS to calculate for each planning unit the total human population size, and the human population size within PAs and within unprotected IBAs or AZEs.

Finally, we used these data to produce two conservation planning systems. The first listed for each planning unit the unprotected area of each conservation feature and the human population size on this unprotected land. It also included one "protected" planning unit that listed the total area of each conservation feature falling within the global PA network, and the total human population size found in the global PA network. This "protected" planning unit was set as automatically selected in Marxan, so the software would identify additional planning units that met the specified targets by complementing the existing PA network. The second planning system was identical, but combined unprotected IBAs and AZEs with PAs.

We assessed the extent of land (in addition to existing PAs) requiring conservation to achieve the following targets, adding them cumulatively in six different scenarios: (1) 17% global coverage; (2) country-specific national targets; (3) 17% coverage of each ecoregion; (4) 100% coverage of all unprotected IBAs/AZEs; (5) species-specific targets for all threatened amphibians, birds, crayfish, and mammals; (6) species-specific targets for all nonthreatened amphibians, birds, crayfish, and mammals. For each scenario, we ran Marxan 100 times, each with 100 million iterations. We identified which of the 100 portfolios had the lowest cost and determined its total area.

Our Marxan analyses were designed to estimate the area of land requiring effective conservation at a global scale. Individual country requirements are best assessed through national-scale analyses incorporating implementation-relevant factors that are best known and mapped at local scales (Smith *et al.* 2009). To help identify countries where such national analyses are a priority because the relative degree of PA expansion needed is likely to be largest, we calculated the percentage of planning units in each country that were selected by Marxan in scenario 6 (i.e., meeting targets for global, national, ecoregion, site, and species coverage). As the spatial resolution of our analysis led to potentially large commission errors for very small countries and territories, we focused on countries with an area of at least 20,000 km^2. We used Spearman's Rank tests to determine whether the per capita Gross Domestic Product (GDP) of each country was correlated with the percentage of planning units selected within it, its adjusted species richness and adjusted restricted-range species richness. These measures of richness used the data from the Marxan analyses, with restricted-range species defined as those with a global range of ≤50,000 km^2, and richness values adjusted by dividing by A^z, where A is country area, and z is 0.184 (derived from the species-area relationship using the data in our analysis).

Results

We estimate that PAs cover c.14.6% of terrestrial and 2.8% of marine environments, with 40% of countries and territories protecting ≥17% of their terrestrial area, but only 13% protecting ≥10% of marine areas under their national jurisdiction, and 0.2% of international waters beyond national jurisdictions protected (Figure 1, Table S3). Only 38% of countries have met their nationally set target for terrestrial PA coverage. Just 41% of terrestrial and 32% of marine (coastal/nearshore) ecoregions have met target levels of coverage, while only one-fifth of IBAs and AZEs are completely covered by PAs (Figures 1 and S2, Table S3). Finally, less than half of mammals, amphibians, marine bony fishes, cartilaginous fishes, lobsters and crayfish, mangroves and seagrasses have a sufficient proportion of their distributions covered by PAs to meet species-specific targets scaled by range size (Figure 1, Tables S3 and S4). PA coverage of suitable habitat within species' distributions was only marginally higher (Table S5).

Hence, although there has been substantial recent growth in PA coverage, in both absolute area (by 92% for terrestrial and 513% for marine environments since 1990) and coverage of biodiversity features (Figure 2),

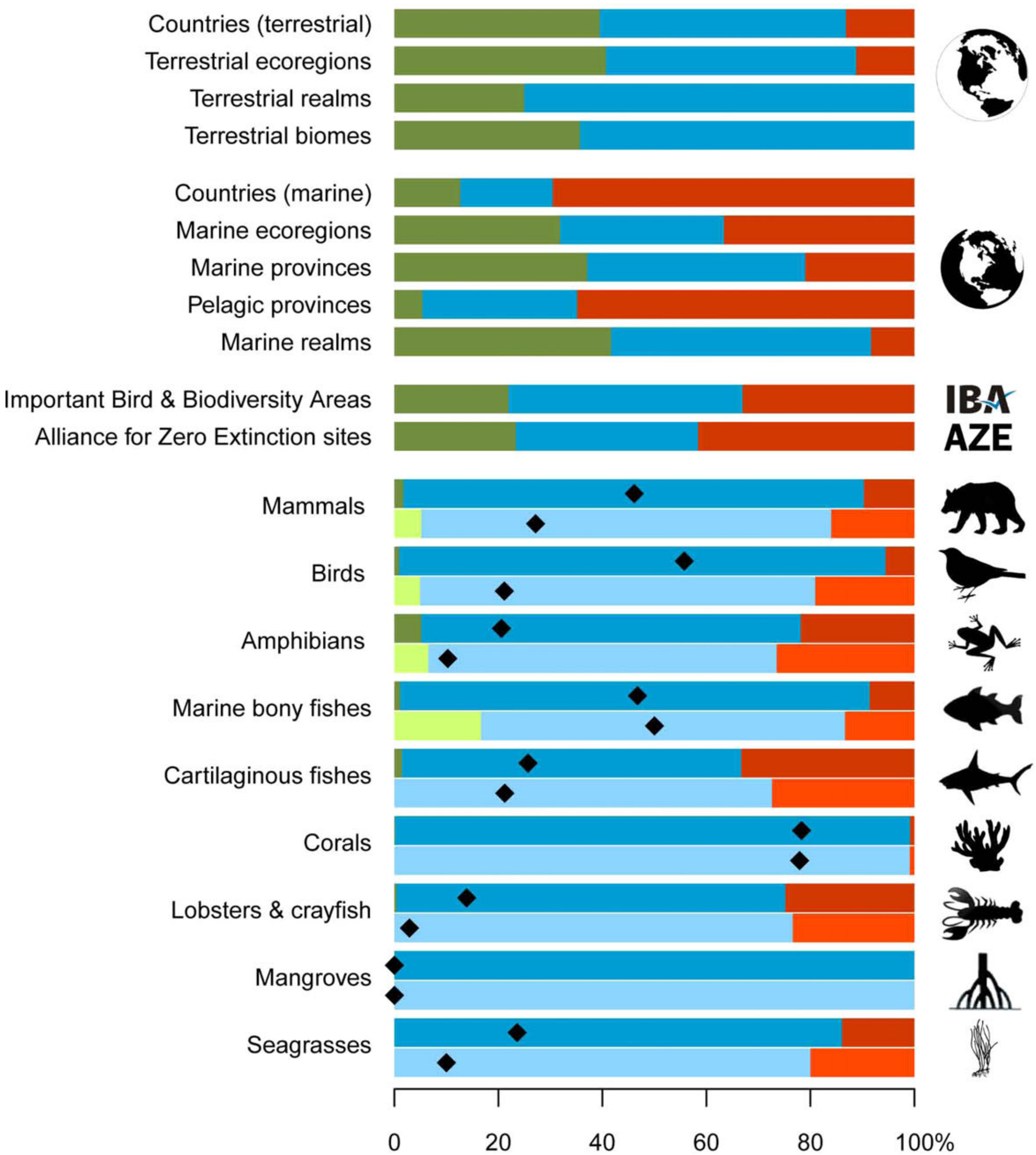

Figure 1 Protected area coverage of terrestrial and marine environments, ecoregions, realms, biomes, important sites, and species. For terrestrial and marine features, bars show the proportion with sufficient (≥17% for terrestrial, ≥10% for marine, green), partial (blue), or no (<2%, red) coverage. For sites and species, bars show the proportion with complete (≥98%, green), partial (2–97.9%, blue), or no (<2%, red) coverage. Results are shown separately for all species (upper bars) and threatened species (lower bars) in each taxonomic group. Black diamonds indicate the percentage of species in each group for which protected area coverage reaches target levels scaled by range size for each species.

this expansion has been inadequately targeted, and a considerable shortfall remains across the multiple elements of Target 11. To estimate the area of land required to meet this shortfall in the terrestrial environment, we considered the requirements for each element of Target 11 in turn. First, we found that 3.3 million km^2 of land is required in addition to the existing 19.7 million km^2 of PAs to meet the target of 17% global terrestrial PA coverage (excluding Antarctica, Figure 3). Second, 7.3 million km^2 outside existing PAs is needed to achieve 17% global coverage and also meet each country's nationally set coverage target, or 10.5 million km^2 to meet these

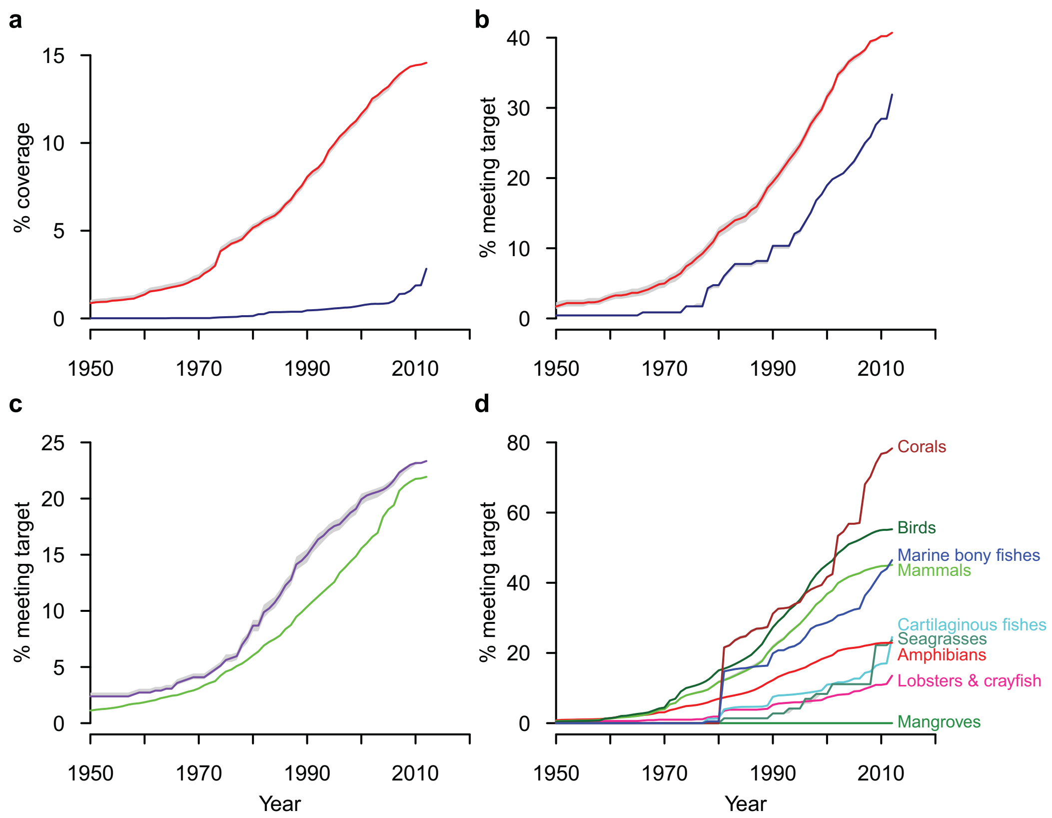

Figure 2 Temporal trends in protected area coverage. (a) Percentage of the terrestrial (red) and marine (blue) environment covered by protected areas. (b) Percentage of terrestrial (red) and marine (blue) ecoregions for which protected areas cover ≥17% and ≥10%, respectively. (c) Percentage of important sites for biodiversity (AZEs [violet] and IBAs [green]) for which protected areas cover ≥98% of their area. (d) Percentage of species in different taxonomic groups for which protected areas cover more than target levels scaled by range size for each species. Shading shows 95% CIs.

and also cover 17% of each ecoregion. Third, to achieve these three objectives and also completely cover all documented important sites for biodiversity would require an additional 12.0 million km^2 (i.e., including 3.8 million km^2 of unprotected IBAs/AZEs). Finally, meeting species-specific coverage targets for all (mapped) threatened or all terrestrial species as well would require 14.8 or 17.9 million km^2, respectively. Thus, the optimal solution equates to almost doubling the extent of the PA network to cover 27.9% of the global terrestrial area (Figure 3).

Costa Rica, Ecuador, and the Dominican Republic require the largest proportional increases in extent of land requiring conservation, with >53% of planning units within them requiring the establishment of conservation areas (Figure 4, Table S1). Countries requiring the largest proportional increases in conservation areas tended to have lower per capita GDP (Figure 4, $N = 151$, $r_s = -0.205$, $P = 0.011$), probably because countries with lower per capita GDP had higher levels of adjusted species richness ($N = 151$, $r_s = -0.476$, $P < 0.001$) and adjusted restricted-range species richness ($N = 151$, $r_s = -0.254$, $P = 0.002$).

Exploring the sensitivity of our estimates to different assumptions, we found that the total percentage of land requiring conservation was unchanged if the target area for each species was capped at 0.5 million km^2 instead of 1 million km^2, and reduced from 27.9% to 24.5% if the target for each species was halved, suggesting that our estimates were not substantially inflated by the representation targets set for broad-ranging species. Similarly, if the target for PA coverage of each ecoregion is reduced to 10% (as previously adopted by CBD parties; CBD 2004), the total percentage of land requiring conservation is reduced only marginally to 27.0%, while if the target for ecological representativeness is set at a larger spatial scale (17% coverage of each of 66 biome-realms, each of which represents an aggregation of up to 78 ecoregions; Olson *et al*. 2001), the total is reduced to 27.1%, indicating that our overall result is robust to varying interpretations of the text of Aichi Target 11.

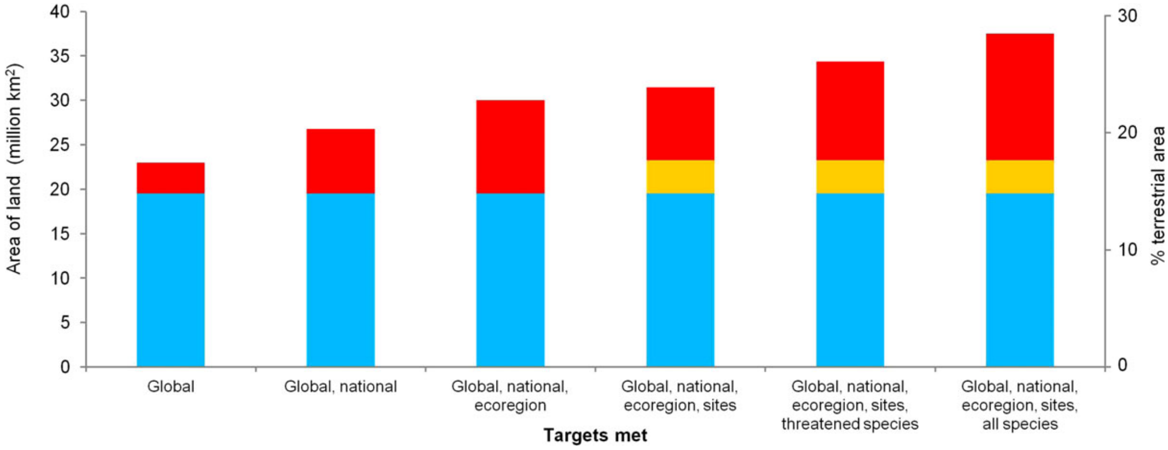

Figure 3 Area of land requiring conservation to meet conservation area targets under an optimal solution. For terrestrial environments globally, showing the contributions of existing protected areas (blue bars), unprotected important sites for biodiversity (IBAs/AZEs, orange bars) and other unprotected land (red bars) to meet targets for coverage of the global terrestrial area (17%), national terrestrial area (set individually by each country), ecoregions (17% each), sites (unprotected IBAs/AZEs) and species (set individually, scaled by range size).

Discussion

Meeting Target 11 will require greatly accelerated recognition and designation of effective conservation areas, with newly established or expanded reserves much better targeted toward important sites for biodiversity (Ricketts *et al.* 2005; Butchart *et al.* 2012) and areas that provide representative coverage of ecoregions and species (Venter *et al.* 2014). Those countries with the largest percentage of planning units requiring additional conservation areas to be established are priorities for local-scale conservation planning analyses, building on the data sets used here, to identify specific site priorities. Effective conservation of such sites should be integrated into these countries' National Biodiversity Strategies and Action Plans.

Some of the shortfall in PA coverage we found could be reduced simply through countries better documenting existing PAs (some lack spatial boundaries, and details of recently designated sites are often omitted), and improving their reporting of privately owned PAs (Lopoukhine & Dias 2012; Visconti *et al*. 2013).

However, even though 36 countries have set coverage targets >17%, the required substantial growth in land under conservation is highly unlikely to be achieved through further designation of formal PAs alone. Other "effective area-based conservation measures," as mentioned in Target 11 (CBD 2010; Jonas *et al.* 2014), will be essential, including locally managed marine (Govan 2009) or forest areas (Porter-Boland *et al.* 2012) and other indigenous and community-conserved areas (ICCA Registry 2014), sacred sites (Dudley *et al*. 2009), conservation easements and land trusts (Rissman *et al.* 2007), and sustainably managed forestry or fisheries (Lopoukhine & Dias 2012).

Species distribution maps are susceptible to commission errors, which may have affected our estimates of PA coverage, but (1) we used finer resolution maps than in previous studies (e.g., Hurlbert & Jetz 2007); (2) the species-specific representation targets we examined were defined as a proportion of the extent of occurrence (rather than area of occupancy); and (3) using human population density as a cost metric should reduce commission errors because selected areas are less likely to be those where species are absent owing to anthropogenic pressures like hunting or habitat loss. Our use of 30 × 30 km grid cells may also have introduced commission errors. However, because data on species' distributions and the location of their important sites are unavailable for most taxa, the shortfall in land for conservation is likely to be even larger than we estimated.

We did not address aspects of Target 11 relating to coverage of areas of importance for ecosystem services, and the requirement that PAs are "effectively and equitably managed," "well connected," and "integrated into the wider landscapes and seascapes" (CBD 2010). Key among these additional elements is the requirement for effective management of existing conservation areas (Leverington *et al.* 2010), with 77% of countries failing to achieve this currently (Coad *et al*. 2013). Species' populations and habitat extent/condition continue to decline within PA boundaries, owing to inadequate resources and increasing pressures such as expanding agriculture (Mora & Sale 2011; Laurance *et al.* 2012, 2014; Geldmann *et al.* 2013). Degradation of PAs, in

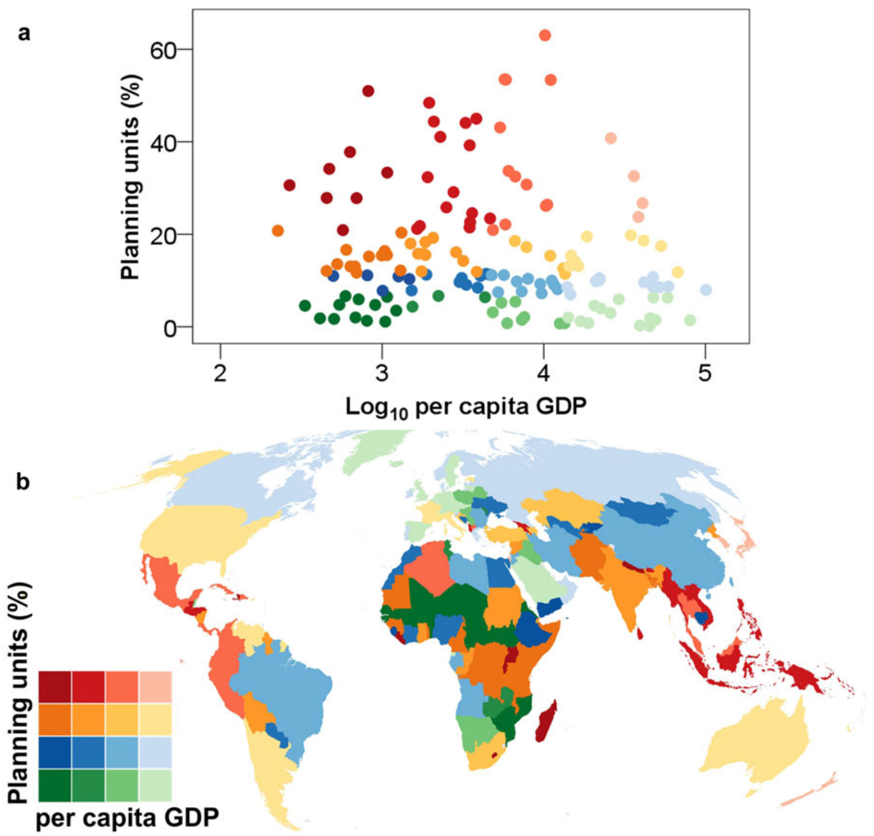

Figure 4 Proportion of planning units requiring conservation areas to be established within them for each country (a) plotted against log gross domestic product (GDP) per capita; and (b) mapped. Colors in the graph match those in the map legend.

combination with an increasing trend of PA degazettement and downsizing ("PADDD"), makes the challenge of meeting Aichi Target 11 even greater (Mascia *et al.* 2014, Watson *et al.* 2014).

Our terrestrial results are likely to be mirrored in the marine environment, where an additional concern is that recent progress in PA coverage has largely been driven by a handful of extremely large PAs (Spalding *et al.* 2013), while enforcement remains a problem across many sites (Dulvy 2013). Ongoing processes to identify "ecologically and biologically significant areas" (informed by IBAs/AZEs) at sea (Dunn *et al.* 2014) should help efforts to achieve the marine aspects of Target 11, as might large-scale area-based fisheries interventions (White & Costello 2014).

Expanded PA networks, augmented by alternative approaches, and more effective management of both will require investments in area-based conservation to be scaled-up substantially (at least 10-fold according to McCarthy *et al.* 2012). International financing mechanisms such as the Global Environment Facility should consider targeting increased resources at the poorer countries we identified (Table S1), as having the greatest need for expanded conservation areas, given the inequalities in wealth and the scale of these needs. Addressing these resource needs is an urgent imperative given the current pace of biodiversity loss (Butchart *et al.* 2010; Tittensor *et al*. 2014; Watson *et al.* 2014; WWF 2014).

Our results represent the most detailed assessment to date of PA coverage of biodiversity and of the expansion in land for conservation needed to meet Aichi Target 11. Delivering the World Parks Congress's "Promise of Sydney" (World Parks Congress 2014), including meeting national commitments and the multiple components of Aichi Target 11, will require considerably more land than the 17% headline figure for terrestrial coverage. A twin-track approach of better-targeted PA expansion alongside increased effort to develop and implement other effective area-based approaches (Jonas *et al.* 2014) is needed, integrated through improved prioritization, better international coordination (Pouzols *et al.* 2014), and greater resourcing.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Table S1. National targets for terrestrial conservation area coverage, current percentage coverage by PAs and unprotected IBAs/AZEs, and the percentage of planning units requiring the establishment of conservation areas for each country/territory, ranked from highest to lowest values for the last of these metrics.

Table S2. Spatial data sets used in the analyses.

Table S3. Current coverage by the world's protected areas.

Table S4. Current coverage by the world's protected areas and unprotected important sites for biodiversity conservation.

Table S5. Current coverage by the world's protected areas of suitable habitat within the distributions of mammals, birds, and amphibians.

Figure S1. Cumulative range size distribution for birds (red bars), mammals (blue bars), and amphibians (green bars), to illustrate the approach for setting representation targets scaled by taxonomic group.

Figure S2. Temporal trends in mean percentage area of (a) terrestrial (red) and marine (blue) ecoregions; and (b) IBAs (green) and AZEs (violet) covered by PAs.

Supplementary Data File: Protected area coverage of species, sites, countries, ecoregions, biomes, realms, and provinces (Excel file).

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