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Area-based conservation in the 21st century

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Abstract

Humanity will soon define a new era for nature – one that seeks to correct decades of underwhelming responses to the global biodiversity crisis. Area-based conservation efforts, which include both protected areas and other effective area-based conservation measures, are likely to extend and diversify. But persistent shortfalls in ecological representation, management effectiveness and measurable biodiversity outcomes diminish the potential role of area-based conservation in stemming biodiversity loss. Here we show how protected area expansion by governments since 2010 has had limited success in increasing biodiversity coverage, and identify four emergent issues that –if addressed – will enhance the performance of area-based conservation post-2020. We close with recommendations for a broad biodiversity agenda that maximises the potential of area-based conservation. Parties to the Convention on Biological Diversity must recognise that area-based conservation primarily focuses on local threats to species and ecosystems, and needs enhanced emphasis on biodiversity outcomes to better track and fund its contribution to global conservation efforts.

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Introduction

Governments, policy makers and much of the conservation community have long heralded protected areas as a fundamental cornerstone of biodiversity conservation[1,2] (Box 1). The importance of other effective area-based conservation measures (OECMs) is also beginning to be recognised[3-7]. OECMs were defined by the Convention on Biological Diversity (CBD) in 2018 as places outside the protected area estate that provide effective biodiversity conservation, such as some private conservation initiatives, water catchment areas and territories conserved by Indigenous peoples and local communities. Both protected areas and OECMs (collectively referred to herein as 'area-based conservation') are acknowledged in the 2030 Agenda for Sustainable Development[8] and the CBD. In particular, the CBD's current ten-year Strategic Plan for Biodiversity[9] – agreed by 168 countries in 2010 – has an explicit target (Aichi Target 11) that calls for "at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and OECMs, and integrated into the wider landscape and seascape" by 2020.

Since 2010, protected areas have expanded from covering 12.7% to 15.0% of global land and freshwater environments and from 1.6% to 7.8% of the marine realm[10]. While it is not yet possible to track their global extent systematically, OECMs have also expanded since 2010[11]. Yet amongst the encouraging expansion of area-based conservation, there is growing concern that nations are paying less attention to the qualitative elements of Aichi Target 11 – such as the need for area-based conservation to be representative, connected and effectively managed[12-17]. Moreover, some long-standing issues, including poor resourcing and governance and lack of management effectiveness, continue to compromise the ability of protected areas to conserve biodiversity and ecosystems[18-24]. As a consequence, there is a risk that humanity could meet the areal components of Aichi Target 11 but fail to deliver on the overall strategic goal for which it was established - to "improve the status of biodiversity by safeguarding ecosystems, species, and genetic diversity"[9].

A post-2020 Global Biodiversity Framework will be agreed at the fifteenth Conference of the Parties to the CBD in China in 2020. This new strategic plan will likely be humanity's last chance to halt global biodiversity loss[10]. The urgency to act has emboldened calls for a substantial expansion of area-based conservation globally[25-28] and fundamental changes in how environmental targets are framed and implemented[18,23,29-31]. It is therefore timely to assess the achievements and failures of national area-based conservation efforts over the past decade and place these findings within the wider context of the global biodiversity crisis. We then identify emergent issues that will influence area-based conservation policy and performance post-2020 and conclude with views on how the targeting and tracking of area-based conservation must be redefined to ensure it remain relevant in the 21st century.

The performance of protected areas since 2010

It is clear that Aichi Target 11 has encouraged some nations to expand area-based conservation efforts, particularly in the marine realm. Australia, Gabon and Brazil for instance have all grown their protected area estates by >20% since 2010 (Fig. 1). Here, we review how the recent expansion of protected areas globally has affected the qualitative components of Target 11. Where possible, we also provide an up to date temporal analysis

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(between 2010 to 2019) on the performance of protected areas against the qualitative components of Target 11 (Fig. 2). We omit reference to OECMs in this section as a database showing the global extent of these sites is not yet available[11] (see Supplementary Methods for details of calculations).

Protected areas being "ecologically representative"

The concept of being "ecologically representative" has been interpreted as the coverage of species or ecoregions (areas containing geographically distinct assemblages of species[32,33]), especially those that threatened with extinction[13,16,32,34-37]. Most evidence to date suggests significant shortfalls in either approach. For species, Butchart and colleagues[16] showed that less than half of all known mammals, amphibians, lobsters, crayfish, mangroves, seagrasses, bony fishes, cartilaginous fishes and threatened birds had a sufficient proportion of their distributions covered by protected areas in 2013. An additional analysis showed that coverage of migratory bird species was particularly poor, with only 9% having their migratory flyway adequately protected[38] in 2013. The global marine protected area estate also had noticeable coverage shortfalls for mammalian species diversity (62% covered), taxonomic diversity (74% covered), functional diversity (78% covered) and threatened species (37% covered) in 2016[39].

We re-analysed how expansion of the global protected area estate between 2010 and 2019 affected coverage of 4,854 vertebrate species listed as Vulnerable, Endangered or Critically Endangered (herein 'threatened' species) on the IUCN Red List[40] (Figure 2). Eighty-two (1.7%) of these species gained some level of protection for the first time in the last decade, and 87.8% (n = 4,264) of all species assessed had some portion of their geographic rage protected by 2019 (a change from 85.0% in 2010). While the majority of species assessed had some level of protection, only one-quarter had adequate representation in the global protected area estate in 2019 (from 23.7% in 2010) (representation targets for individual species were set according to their geographic range[16,35,36]; see Supplementary Methods for details of calculations).

Seventy-four threatened species had their representation target met between 2010 and 2019, and 43.2% (n = 16) of threatened marine mammal species received adequate representation in the global protected area estate in the last decade. However, 74.8% of threatened birds, amphibians and terrestrial mammals were still inadequately protected as of 2019, and 605 threatened species remain without any representation at all (Table S1). In the last decade, the proportion of species with adequate protection grew by only three percent for birds (to 34.5%; n = 462 to 499) and just one percent for amphibians (to 13.0%; n = 255 to 276) and terrestrial mammals (to 36.9%; n = 406 to 423), suggesting that the vast majority of new protected areas have not been established in locations that would safeguard species that had poor levels of protection in 2010[13,14]. Importantly, these coverage shortfalls are not solely driven by antecedent placement of protected areas – terrestrial and marine protected areas established post-2010 do not appear to have targeted species at risk of extinction[14,41,42].

To assess coverage of ecoregions, we followed previous studies[16,34,37] that contrasted coverage of ecoregions against targets of 17% protection for terrestrial ecoregions and 10% for coastal and shelf marine ecoregions or off-shelf pelagic regions. We found that 40.4% (n = 351) of ecoregions were at least 17% protected in 2019 (from 36.4% in 2010), and 38 ecoregions transitioned from zero to at least 17% coverage over the last decade (Figure 2; Table S2). We also found that over one-fifth (21.5%) of land protected since 2010 covered

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tropical and subtropical grassland ecoregions (Table S3) – a critically endangered biome[32] - while 34.4% of land protected since 2010 covered dry or desert ecoregions, which are relatively species poor and over-represented[32]. In 2019, 128 ecoregions (15.1%) remain <2% protected (Table S2). Tropical and subtropical dry broadleaf forest ecoregions, in particular, remain chronically under-protected (<1% of new land protected covered this biome in the last decade) given their high biodiversity and rapid rate of habitat loss over the last two decades[32,43].

We also assessed coverage of marine ecoregions[33] and off-shelf pelagic regions[44] between 2010 and 2019. The number of marine ecoregions with ≥10% coverage increased substantially to 56.5% (n = 101) over the past decade (from 38.8% in 2010), with much of this growth occurring over ecoregions within the Southern Ocean (0.6 million km^2; 3.9% of all new marine protected area). However, marine protected area expansion could have been more strategic –the number marine ecoregions with ≥10% coverage for every hectare of ocean protected has declined since 2010 (Figure 2). Coverage in off-shelf pelagic regions remain much lower on average, despite 89.0% (13.6 million km^2) of new marine protected area targeting these regions since 2010. Eleven percent (n = 4) of off-shelf pelagic regions are now ≥10% protected (from 2.7% in 2010). Much of this new coverage focused on remote Antarctic waters, not areas in the high seas where marine biodiversity faces elevated human pressures[41].

Protected areas covering "areas of particular importance for biodiversity and ecosystem services"

The Key Biodiversity Area (KBA) approach[45] offers a global standard for identifying marine, terrestrial and freshwater sites that contribute significantly to the global persistence of biodiversity. Over 15,000 KBAs have been identified, and host nations are encouraged to ensure that these sites are managed in ways that ensure the persistence of their key biodiversity elements, although this does not necessarily mean inclusion within a protected area[45]. The 2018 Protected Planet report[34] found that, between 2010 and 2018, average coverage of marine KBAs increased from 5.0 to 15.9%. This report also found average coverage was greater, but advanced at a much slower rate, for terrestrial (43.3% to 46.6%) and freshwater (41.1% to 43.5%) KBAs[34]. Our analysis showed similar coverage estimates for terrestrial and freshwater KBAs but higher estimates of average coverage of marine KBAs (20.8% protected on average by 2019) (Figure 2).

Wilderness areas are ecologically intact land and seascapes that are predominantly free of human-driven biophysical disturbance[46,47]. They underpin planetary life-support systems[48] and are critical for the long-term persistence of imperilled species[49], especially in a time of climate change[50]. Only 4.9% of marine wilderness areas were protected in 2017[46], and protected areas established between 1990 and 2015 covered just 8.3% of terrestrial wilderness areas[51]. When compared to these previous studies, our analysis shows coverage for marine wilderness areas has increased in recent years (8.5% protected in 2019 versus 2.0% protected in 2010). This is despite marine wilderness areas often being in international waters, making protected area establishment complicated from a legal perspective. Our analysis also shows that the consideration of protected areas established pre-1990 and post-

2015 nearly trebles previous estimates of terrestrial wilderness coverage (22.1% protected by 2019) (Figure 2).

Aichi Target 11 further requires protected areas to conserve "areas of particular importance for […] ecosystem services". Among the multitude of services that healthy, functioning ecosystems provide[10,52], our ability to track coverage of carbon storage and sequestration is arguably the most advanced. Previous assessments of the amount of carbon stored in protected areas have been confined to national or regional scales[34,53]. We used a new global dataset (Soto-Navarro, C. *et al.* pers. comm; see Supplementary Information) to track coverage of biomass and soil carbon over the last decade. In 2010, 22.6% (94.4 gigatonnes) of the world's biomass carbon was inside protected areas. By 2019, this proportion had increased only slightly to 23.7% (99.0 gigatones), indicating that post-2010 terrestrial protected areas captured less carbon per hectare than those established pre-2010 (Figure 2). Protected areas hold a lower proportion of soil carbon, ranging from 13.9% (379.9 gigatonnes) in 2010 to 14.6% (400.5 gigatonnes) in 2019. Large unprotected repositories of soil carbon are prevalent across north-east North America, Russia and south-east Asia (Figure S1).

Incomplete mapping of other ecosystem services, including those pertaining to provision (e.g. fisheries, timber), regulation (e.g. coastal armouring, soil stabilisation) and culture (e.g. education, recreation), makes it difficult to track their coverage. The expansion of OECMs will be driven largely by ecosystem services, such as those relating to climate stabilisation and watershed protection, necessitating better understanding and documentation of these values. However, 44% of coral reef tourism value and 20% of coral reef coastal protection in 2018 depended on protected areas[34]. The global protected area estate also holds approximately 29% of all coral reef fisheries biomass and contributes to 31% of all mangrove fishery catch[34]. Moreover, nearly two-thirds of the global population is living downstream of the world's protected areas as potential users of freshwater provisioned by these areas[54].

Protected areas being "well connected" and "integrated into the wider landscape and seascape"

Well-connected ecosystems are critical for maintaining important ecological and evolutionary processes, including species migration, gene flow and range shifts, especially when species face rapid climatic and environmental changes[55,56]. In 2016, only 30% of terrestrial ecoregions were at least 17% covered by protected areas that were theoretically reachable by species[57]. At the global scale, the percentage of connected terrestrial protected areas increased from 6.5% to 8.1% between 2010 and 2014, before decreasing 7.7% in 2018[58]. These assessments did not account for the permeability of unprotected land between protected areas, but show how the global protected area system is becoming increasingly fragmented, akin to land and seascapes generally[59,60].

Connectivity is an important consideration for marine protected areas because, among other reasons, it helps to maintain networks of local populations[61] and to replenish fish populations on fished reefs[62]. High levels of connectivity also correspond to areas of enriched coral diversity[63]. Marine protected areas should therefore accommodate movement patterns among habitats that are critical to the life history of marine species (e.g. home ranges, nursery grounds, migration corridors, spawning aggregations)[64]. There have been no global-scale assessments of connectivity among marine or freshwater protected areas, but regional-scale studies show them to have limited connectivity for species with a dispersive larval stage[65].

Protected area management effectiveness

Citizen science, earth observation technology and assessments of individual area-based conservation efforts have all advanced over the last decade[66-68]. Studies that intersect these data with networks of protected areas (so as to assess their effectiveness) show that, on average, protected areas slow but fail to completely halt human pressures and biodiversity loss within their borders[69-73].

A recent assessment shows that over 12,000 protected areas established prior to 1995 were, on average, ineffective at reducing human pressures inside their borders between 1995 and 2010[74]. An earlier study found that one-third of all protected land was under intense human pressure at the start of this decade[73]. This study by Jones and colleagues also found that human pressure had increased in 55% of protected areas between 1993 and 2009[73]. As for marine protected areas, 94% of those created before 2014 permit fishing activities[75] – a key driver of poor marine protected areas effectiveness[76]. Moreover, marine protected areas that prohibit the taking of living or dead natural resources (i.e. no-take marine reserves) are subject to illegal fishing activities[77]. There is, however, clear evidence that many protected areas do effectively abate human pressures. For example, marine protected areas reduce fishing vessel traffic[78] and the negative effects of some non-native species[79]. Terrestrial protected areas have been found to reduce rates of deforestation and forest degradation below those observed in nearby unprotected areas[80,81], and to reduce increases in human pressure in wilderness areas[82]. Protected areas established and managed by Indigenous people are particularly effective at avoiding deforestation in regions with high deforestation pressure[83]. By lowering rates of deforestation inside their borders, tropical protected areas reduced carbon emissions from land use change by around 29% (4.88 gigatonnes) between 2000 and

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2012[84]. Moreover, 54.8% of studies that assess their role in reducing deforestation show protected areas also reduce deforestation rates in surrounding, unprotected lands, whereas 11.8% show protected area establishment increases deforestation in surroundings areas[85].

In terms of biodiversity outcomes, several studies have reported beneficial effects of protected areas on species abundance and diversity[72,86,87]. For example, a study of 447 terrestrial protected areas showed them to be effectively maintaining populations of birds and mammals within their boundaries[88]. Another study showed bird and mammal populations between 2007 and 2014 increased in abundance (17% of cases) or exhibited no change (22% of cases) within 15 protected areas (22 % of populations declined while 39% were detected too infrequently to assess occupancy changes)[89]. A review of 218 marine protected areas found that, on average, fish biomass is nearly double inside protected areas than in matched non-protected areas[21]. Marine protected areas also promote the recovery of fish populations[90,91]. No-take marine reserves, in particular, result in significant increases in species richness, density and biomass in both tropical and temperate systems[21,92-94], as well as being effective at restoring trophic function[95,96] and lowering levels of coral disease[97].

Equitable management in protected areas

Some nations have made clear commitments – beyond those stipulated in Aichi Target 11 - to improve protected area management equity[98]. Yet few studies have scrutinised the outcomes of such commitments because there is substantial variability in how equitable management is defined and assessed for protected areas[99,100]. There is evidence showing protected areas that integrate local people as stakeholders often result in higher conservation and socioeconomic outcomes[101,102]. For example, some community-managed terrestrial protected areas are more effective than nationally-designated protected areas at reducing deforestation pressures in Brazil, Namibia and Australia[83,103], and community-managed marine protected areas that are long-established and well-enforced enhance economic and social well-being[104,105]. Furthermore, a recent review of eleven countries across four continents showed terrestrial protected areas do not impinge on efforts to alleviate poverty[106]. However, limited data on the location and prevalence of equitably managed protected areas currently precludes a more complete understanding of their social and biodiversity outcomes[21,107].

Emerging issues for area-based conservation

Our analyses revel that countries will almost certainly fall short on achieving the quality components of Aichi Target 11[34]. The continued expansion of area-based conservation without addressing these shortfalls will lead to poor outcomes for biodiversity. We argue that at least four emergent issues must be considered and acted upon by governments, scientists, policy makers and other stakeholders to address current failings of area-based conservation in the coming decade.

The expanding opportunities for area-based conservation

Opportunities to enhance land and water management practices that help to conserve biodiversity are expanding. Private conservation initiatives and Indigenous and community conserved areas (ICCAs) can be formally recognised as protected areas or "other effective area-based conservation measures" (OECMs), or achieve recognition on their own terms. Yet until recently, ICCAs and private conservation initiatives have been overlooked in national conservation policies, strategies and reports[4]. Indigenous Peoples manage or have tenure rights over at least 37% of all remaining intact landscapes on Earth[3], and ICCAs have been in existence since humans began to govern and manage landscapes and seascapes purposefully[108]. A recent study by Schuster and colleagues showed indigenous managed lands support higher concentrations of biodiversity than formal protected areas[109], which exemplify the critical role that ICCAs can play in global biodiversity conservation efforts and the importance of working with Indigenous Peoples to increase ICCA coverage in their territories. Private conservation initiatives too have been established in various forms for well over a century[4], and in some regions out-number nationally-designated protected areas[110]. A recent assessment of South Africa's Cape Floristic region showed 25% of large carnivore species and 22% of mesoherbivores (50-500 kilograms in weight) could only be supported in areas that were at least partly privately managed[111].

Wider recognition of private conservation and ICCAs are likely to drive rapid expansion in the global protected area and OECM networks over the coming years. Recognition of OECMs is no mere formality (Box 1) as they have stricter benchmarks for biodiversity conservation than many nationally-recognised protected areas, and by formalising their role, owners recognise an obligation to biodiversity conservation and undergo public scrutiny of their management practices[5]. The wider recognition of OECMs could help address at least four current shortfalls of the global protected area estate. First, Indigenous and community sites could address management equity shortfalls because they are managed by and for the benefit of a diverse set of actors. More diverse management and siting arrangements should also help these areas to address current shortfalls in ecological representation and coverage of important areas for biodiversity. Over 76% of unprotected KBAs were at least partly covered by one or more potential OECMs in 2018[6], and compared to protected areas with government

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ownership, OECMs may prove to be more socially acceptable in productive land and seascapes[112,113] and thus enhance coverage of poorly protected species[13,14]. Finally, OECMs could enhance the connectivity of protected area networks, helping them to become better integrated within wider landscapes and seascapes[113]. Recognising and enhancing OECMs in inshore marine habitat, farmlands and managed forests will be particularly valuable in this regard, provided species composition and ecological functions can be restored in such areas[114].

Expanding the conservation estate provides an opportunity to make meaningful contributions to global biodiversity conservation efforts if new sites can overcome issues currently faced by many protected areas, including inadequate resourcing and monitoring. A switch to a broader interpretation of area-based conservation will also require major changes in how governments and conservation actors uphold human rights and social safeguards, particularly on Indigenous and community areas. It will mean, for example, governments, conservation actors, Indigenous people and private entities working together towards shared goals as equal partners. Conservation outside government-run protected areas may enhance opportunities for private financing of biodiversity conservation, but clear operating procedures will be needed to ensure that involvement from private industry does not compromise the integrity of conservation management[115]. More generally, efforts must be made to ensure the whole conservation estate contributes substantively to biodiversity conservation globally. National governments cannot, for example, be permitted to view OECMs as a cheap and easy way to reach areal components of global area-based conservation targets, without due assessment of how they deliver positive and sustained biodiversity outcomes[23].

The increasing dynamism of Earth's protected area estate

Throughout much of the 20th century, protected areas were considered permanent features of land and seascapes - legally protected in perpetuity. Today, protected areas face an increasingly uncertain future due to poor management by governments. A recent analysis showed that while 2.5 million km^2 of land and sea were added to the global protected area estate annually between 2006 and 2018, around 1.1 million km^2 were recorded as removed each year[116]. While many areal changes were bureaucratic in origin (e.g. changed data sharing policies), some of this loss can be attributed to an increase in protected area downgrading, downsizing, and degazettement (PADDD) events. Over 1,500 PADDD events affected over one-third of Australia's protected area network (416,740 km^2) between 1997 and 2014[117]. Qin and colleagues[118] also found 23 PADDD events that have affected UNESCO World Natural Heritage Sites – protected areas with "outstanding universal value", meaning they are so exceptional as to transcend national boundaries and are important for present and future generations of all humanity (e.g. Virunga, Serengeti and Yosemite National Parks).

Official justifications for PADDD events are rarely made transparent, but most (62%) appear to be associated with activities that are in stark conflict with protected areas objectives[2], including industrial-scale resource extraction and infrastructure development[119]. Moreover, only 5% of PADDD events are ever partially or fully reversed[120]. PADDD events can also accelerate forest loss and fragmentation[121] and may restrict dispersal and migration of wide ranging species[122]. Many PADDD events are also going undocumented, particularly in marine systems[123] and in privately protected areas[110]. Their poor documentation makes it difficult to assess risk of future PADDD events and how they will affect the quality of protected area networks, or their capacity to conserve biodiversity in perpetuity.

It is important for any review of area-based conservation targets to account for protected area dynamics, particularly if they result in backsliding on commitments to biodiversity. However, dynamism could signal attempts to expand or enhance protected areas, either through improved resourcing and management[124,125], or by enacting more conservation-focused regulation[126,127]. Alongside clear guidelines for documenting PADDD events, there is therefore a clear need to develop a separate protocol that can track and incentivise the continuum of changes to protected areas that can improve their ability to conserve biodiversity. We suggest that such changes be characterised collectively as protected area gazettement, expansion and enhancement (PAGEE). Clear, transparent tracking around both PAGEE and PADDD events will ensure nations address, and not exacerbate, current shortfalls in protected area networks globally.

The need for more adequate measures of effectiveness

Numerous approaches have been used to track the capacity of area-based conservation to abate human pressures and maintain biodiversity (Table 1). All these approaches have merit, but the conservation community remains too reliant on measures of effectiveness that are coarse or do not capture biodiversity outcomes of area-based conservation. For example, the Global Database on Protected Area Management Effectiveness (GD-PAME) provides useful information on the intention and means (including funding) of protected areas, but the majority of GD-PAME methodologies collect very limited quantitative information on how species and ecosystems have responded to protected area management activities[68]. The most used GD-PAME methodology – the Management Effectiveness Tracking Tool (METT) – was not developed to assess a detailed evaluation of biodiversity outcomes[128] and cannot therefore be used to measure the state of biodiversity in protected areas.

High resolution maps of ecological change across land and seascapes, including forest cover change[129] and changes in cumulative human pressure[130,131], have helped to advance some measures of effectiveness for area-based conservation. For example, changes in cumulative human pressure, when available at relatively fine spatial resolution (1km^2) and available for multiple time steps[130], are significantly correlated with trends in species risk of extinction[132]. However, ecological changes across land and seascapes do not always explain local biodiversity patterns[133]. Moreover, the temporal resolution of cumulative human pressure mapping lags behind that of forest cover mapping efforts and some maps of human pressure are at spatial resolutions (e.g. 77sqkm[131]) that preclude assessments of many small, but crucially important[134], protected areas. Coarse measures of effectiveness also arise when only a subset of biodiversity threats is represented in mapping efforts. Threats such as invasive species and hunting pressure are not directly captured in any global maps of cumulative pressure, despite being among the major drivers of biodiversity loss globally[135].

There are substantial practical challenges to assessing area-based conservation effectiveness more precisely and accurately[136]. Assessing the local-scale population response of a threatened species to environmental change, for example, in most cases requires long-term field monitoring data. New global-scale citizen science initiatives are rapidly expanding the coverage and increasing the frequency of biodiversity data across the planet[67], and will play a crucial role in improving measures of area-based conservation effectiveness. Measures that combine near-real-time change in human pressures with on-ground reporting of management capacity and biodiversity trends, will also enable area-based conservation outcomes to be reported with much greater accuracy and reliability. Studies of area-based conservation effectiveness could also make better use of scenario analysis and models to generate more predictive measures of outcomes[137] and account for uncertainty in composite indicators of environmental condition[138].

Resourcing shortfalls in area-based conservation

Among the most cited reasons for the poor performance of area-based conservation is a lack of resourcing (or related issues such as weak enforcement[77] or inadequate staff capacity[21]). Studies undertaken nearly two decades ago estimated a shortfall of $1-1.7 billion per year just to manage existing protected areas[139,140]. More recently, an assessment of more than 2,000 protected areas (representing ~23% of the global terrestrial protected area estate by area) found 47% (48% by area) suffer from inadequate staff and budget resources, with inadequate resourcing particularly pronounced in the Neotropics[22]. Staff and budget capacity shortfalls are also prevalent in the marine realm, and help to explain why many marine protected areas are ineffective or have inequitable management processes[21].

Compounding resource shortfalls at existing sites are the costs associated with expanding area-based conservation efforts. One estimate suggests that the costs of covering all unprotected and partially protected Important Bird Areas (the avian subset of KBAs) would cost $50.7 billion annually, combined with a further $7.11 billion per annum for managing these sites[141]. Current and future resourcing needs could be met if the contribution of area-based conservation to national economies was fairly recognised. Recent estimates place the direct value generated by visits to protected areas at $600 billion USD, and the indirect value from consumer surplus (the net value to visitors from their vast, above what they actually paid) at a further $250 billion annually[142]. However, there remain issues with how funding for area-based conservation is generated, retained and reinvested[143]. An emerging approach to financing area-based conservation includes funding from private industry, who in many countries are legally required to offset biodiversity impacts of development projects[144]. Yet this approach risks simply displacing, rather than supplementing current funding for biodiversity conservation[145]. There is therefore an urgent need for more transparent tracking of how private industry operations contribute (positively or negatively) to strategic goals for biodiversity[146].

Future-proofing area-based conservation

For all the achievements of area-based conservation, biodiversity is still declining globally at rates unprecedented in human history[10]. Humanity must transform how species and ecosystems are conserved[10]. In this final section, we define what this transformation could entail and how area-based conservation could play a role within it. This role recognises that area-based conservation acts primarily on local threats to species and ecosystems, and that clear conservation objectives, defined in terms of biodiversity outcomes, are needed to better track and fund the contribution of area-based conservation to global conservation efforts.

Placing area-based conservation within a broader conservation agenda

No matter how well-sited, resourced or managed, area-based conservation can only act on a subset of drivers of, and pressures contributing to, global biodiversity loss (Figure 3). For example, expecting protected areas to maintain genetic diversity, abundant populations and functional ecosystems, as well as contributing to sustainable management of agriculture and forestry, is likely asking too much. First and foremost protected areas must conserve biodiversity[2]. Many will also conserve ecosystem services and vulnerable human societies, but a large proportion of these wider societal goals will be met by OECMs and other forms of sympathetic land and water management. To stem the global loss of biodiversity, however, it is now clear that effective area-based conservation must be met with transformative change across all sectors of society[10,147]. Good siting, resourcing and management are themselves dependent on external socio-economic factors, including local and national governance, regulation of natural resource extraction and consumption and other underlying drivers of anthropogenic impacts on the environment[14,148]. We therefore need a new, bold environmental agenda that will make biodiversity conservation mainstream.

Most countries show glimpses of mainstreaming biodiversity conservation across sectors of society. For example, the Chinese government's "Ecological Red Lines" strategy involves identifying areas that require strict protection within planned development footprints to improve ecological functions and to ensure the sustainable supply of ecological goods and services[149]. In Portugal, the legally binding "National Ecological Reserve" aims to retain areas of ecological value or defend areas that are susceptible to natural hazards[150]. And in Brazil, the 2001 Forest Code stipulated that private landowners in the Amazon biome should conserve 80% of their property in native vegetation, and 20% if located in other biomes[151].

While encouraging, existing efforts to integrate biodiversity into broader land and sea planning frameworks have major limitations. A number of these efforts have been criticised for their superficial integration of biodiversity[136], or for containing loopholes that lead to perverse environmental outcomes[152]. Environmental safeguards that exist in broad planning frameworks also remain largely subservient to economic development[153] and are subject to frequent policy changes, which create uncertainty in the minds of land and sea managers[151,154,155]. As a result, many national biodiversity conservation strategies rely almost entirely on networks of protected areas – made evident by nations making progress toward achieving Aichi Target 11, but little or no progress towards the other Aichi targets, such as preventing species extinctions[147]. This is despite biodiversity conservation underpinning many of the Sustainable Development Goals[8].

Area-based conservation must be recognised as *one* essential solution to conservation problems, but not the *only* solution. The conservation community must elevate the importance of other interventions that work in concert with area-based conservation, such as payments for ecosystem services policies, carbon pricing schemes, legislation that limits industrial encroachment on lands and seas deemed important for biodiversity or ecosystem services, the coordination of restoration efforts on degraded land, coasts and seas, eliminating subsidies for activities harmful to biodiversity, and human development programs aimed at incorporating traditional knowledge and reducing inequalities (Figure 3). Getting these interventions right is just as important for biodiversity globally as addressing shortfalls of area-based conservation, and much can be learnt from what made combinations of conservation interventions successful in the past (e.g. Costa Rica greatly reducing deforestation rates with a suite of cross-sectoral interventions[156]). Integrating biodiversity more effectively into other conservation interventions would both reduce unrealistic expectations from area-based conservation and provide more effective landscape and seascape-scale responses.

Rethinking target formulation and evaluation of area-based conservation

Once their role in a broad conservation agenda has been defined, post-2020 targets for area-based conservation will need to be formulated[30]. Any such targets will need to recognise that individual protected areas and OECMs are not created equal, and what is required for these areas to be effective is complex - including elements of governance, management and ecological design. As such, we suggest that nations and – when appropriate – other management bodies be required under the CBD to better define, collate and publish the objectives of individual protected areas and OECMs. It will then be possible to assess how individual sites tracking toward their stated objectives, and how area-based conservation contributes to broader national and international biodiversity conservation strategies. Existing repositories (e.g. GD-PAME[68]; World Database on Protected Areas[157]; National Biodiversity Strategies and Action Plans) could be augmented to house these objectives, provided the repositories receive sufficient funding and resources.

An objective for a protected area or OECM should reflect the responsibility these sites have for species and ecosystems of conservation concern and their potential to maintain or restore them to a favourable conservation status[23]. Progress towards these objectives should constitute an integral part of area-based conservation effectiveness reports and could be aggregated taxonomically or geographically to assess progress towards broader biodiversity goals[23,158]. A new standard for recognising protected areas or OECMs that deliver meaningful outcomes for biodiversity – the IUCN Green List of Protected and Conserved Areas[159] – could energise progress toward stated objectives, provided the standard is used for systematic assessments and to build capacity in under-performing sites, rather than a mechanism to identify the best area-based conservation efforts. Nations could be further encouraged if area-

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based conservation targets would only be considered achieved if its appropriate contribution to reaching broader biodiversity goals could be clearly demonstrated.

Conclusions

Area-based conservation will remain the cornerstone of conservation long into the 21st century. But governments have dramatically underinvested in protected areas and OECMs and been weak in legally protecting them. In addition to correcting these shortfalls, humanity needs to do more by making biodiversity conservation part of all aspects of life. Governments must define a new, bold era for nature that will make biodiversity conservation mainstream. We then need to invest more resources and intellectual energy in consolidating area-based conservation efforts and ensuring biodiversity conservation is a far stronger part of managed land and seas.

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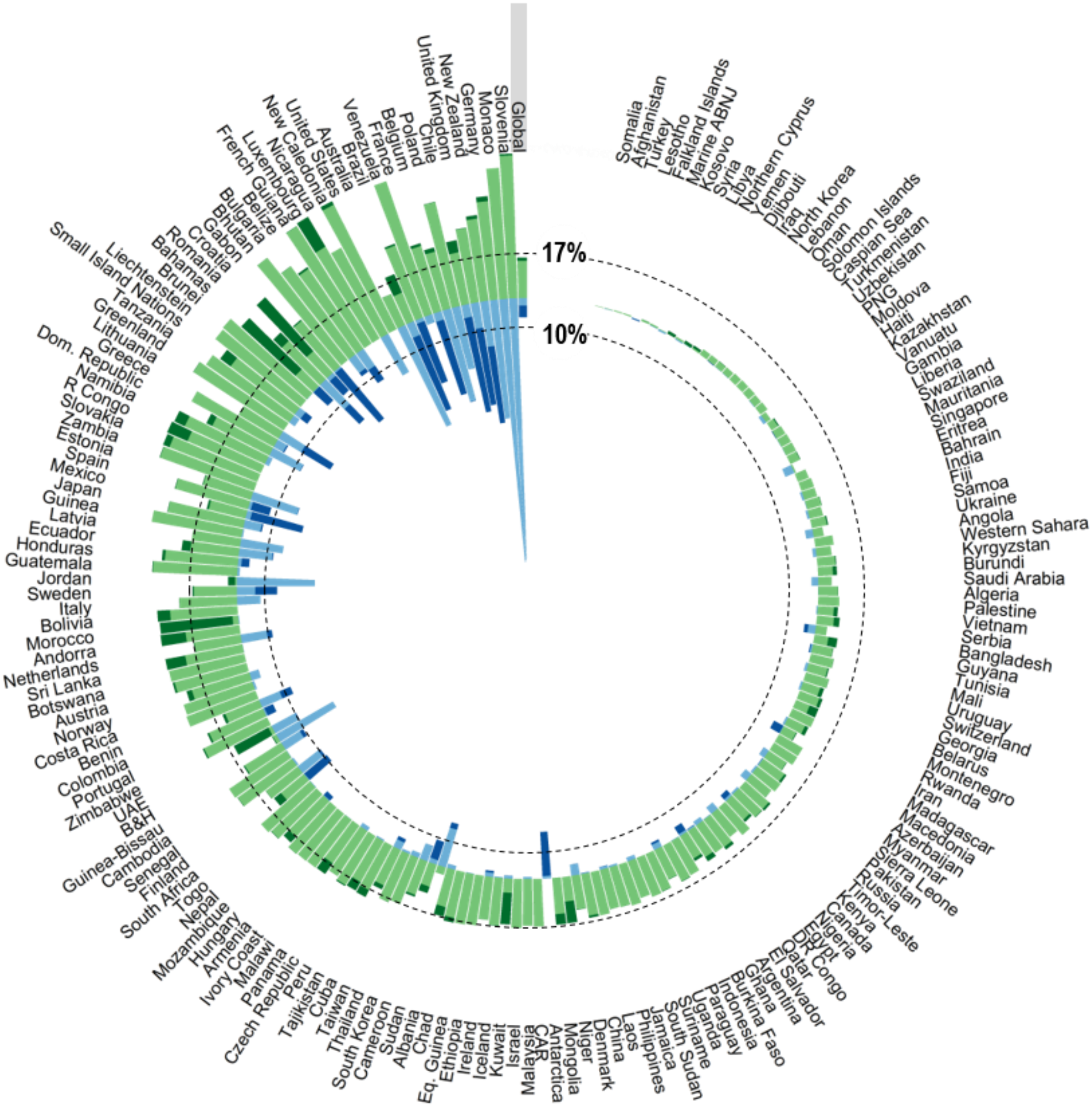

Fig. 1. Areal coverage (%) of marine (blue bars) and terrestrial (green bars) protected areas on Earth. For each country of group of countries, protected areas coverage in 2010 (lighter bars) is made distinct from growth in coverage by 2019 (darker bars). Progress toward a globally agreed target - to have 17% of land and inland waters and 10% of coastal and marine areas to protected by 2020 (black dashed circles) - is promising but incomplete.

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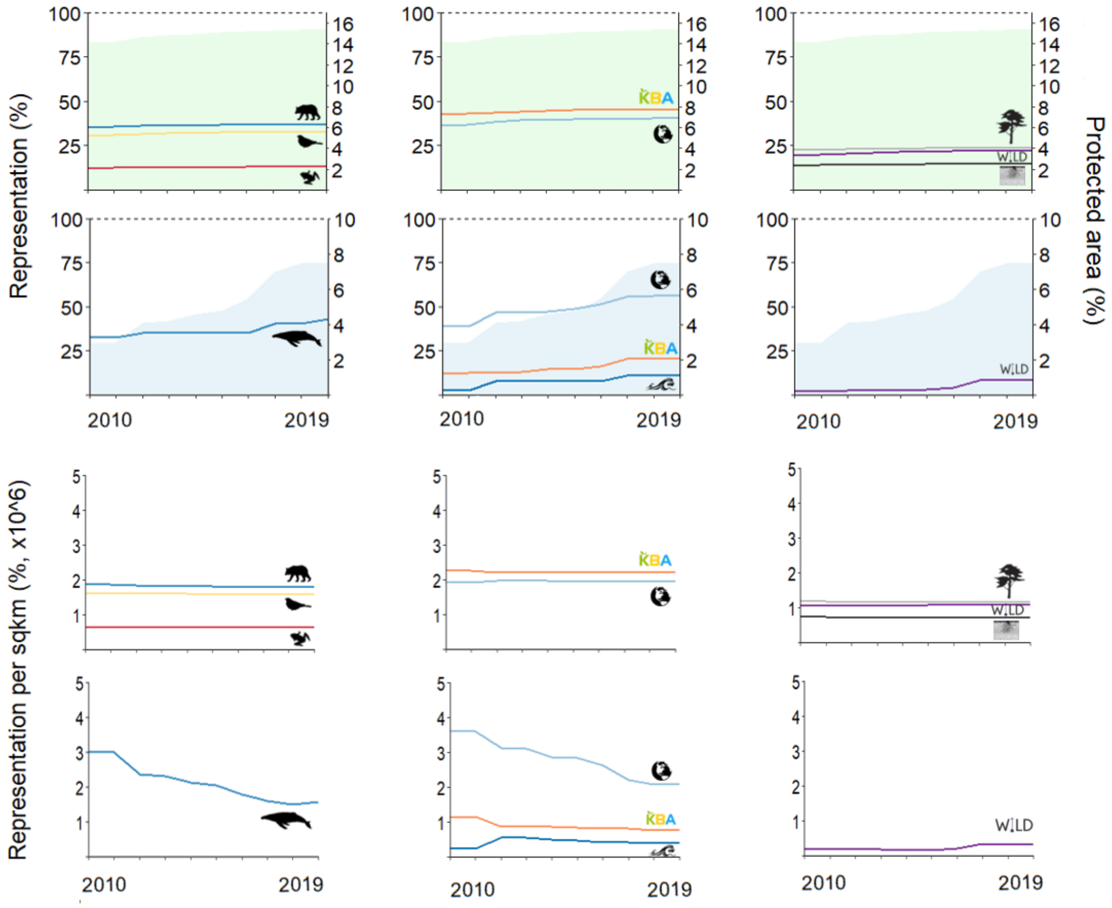

Fig. 2. Representation of biodiversity and ecosystem service values within the global protected area estate between 2000 and 2019. The top panel shows average representation of values as terrestrial (green shading) and marine (blue shading) protected area estates near 17% and 10% of global land and sea surfaces, respectively. The bottom panel shows representation of values per area of land or sea protected. For threatened vertebrate species (left-hand plots), trend lines show the proportion of species within each taxonomic group that have had their individual representation targets met (these targets are proportional to species' geographic range). Trend lines for ecoregions (planet icon; centre plots) and off-shelf pelagic regions (wave icon; centre plots) show the proportion these features that are at least 17% protected (for terrestrial ecoregions) or at least 10% protected (for marine ecoregions or off-shelf pelagic regions). Trend lines for all other features, including Key Biodiversity Areas (KBA icon; centre plots), wilderness areas (wild icon; right-hand plots), biomass carbon (tree icon; right-hand plots) and soil carbon (soil icon; right-hand plots) represent global averages.

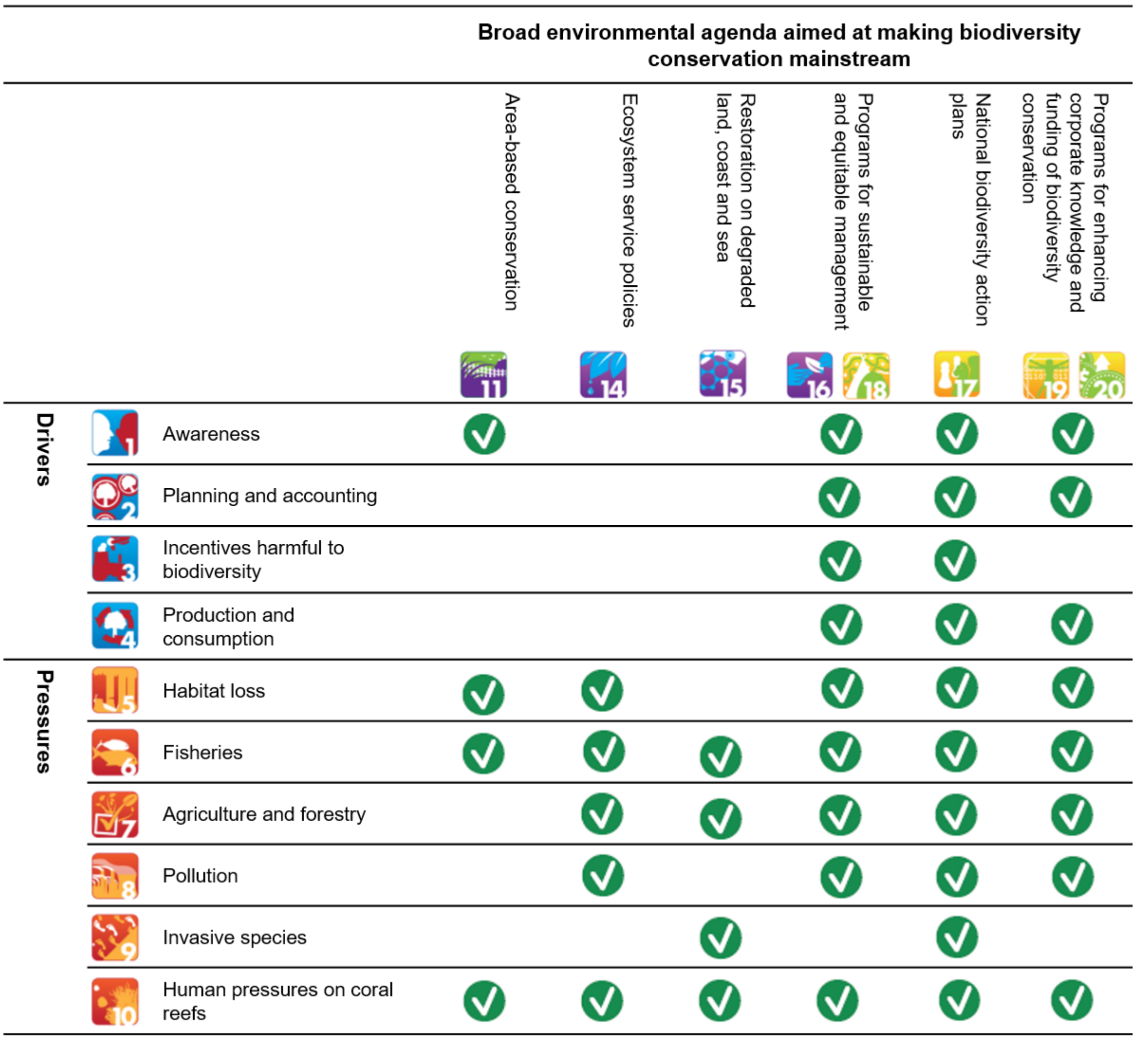

Fig. 3. A role for area-based conservation as part of a suite of conservation strategies in a post-2020 environmental agenda. The post-2020 Global Biodiversity Framework should seek to address all drivers of, and pressures contributing to, global biodiversity loss, including those captured in Aichi Biodiversity Targets contained in the current Strategic Plan on Biodiversity of the Convention on Biological Diversity (blue and orange icons). Area-based conservation is well-suited to play a central role in abating some human pressures – primarily local threats to species and ecosystems (green tick icons). Other conservation interventions mentioned or implied in the Aichi Targets (purple and yellow icons), remain underutilised despite being well suited to abate human pressures or drivers of biodiversity loss that area-based conservation is in many cases unable to act on. Post-2020, better integration of biodiversity values into all conservation interventions will see them to contribute more substantively to global goals for nature.

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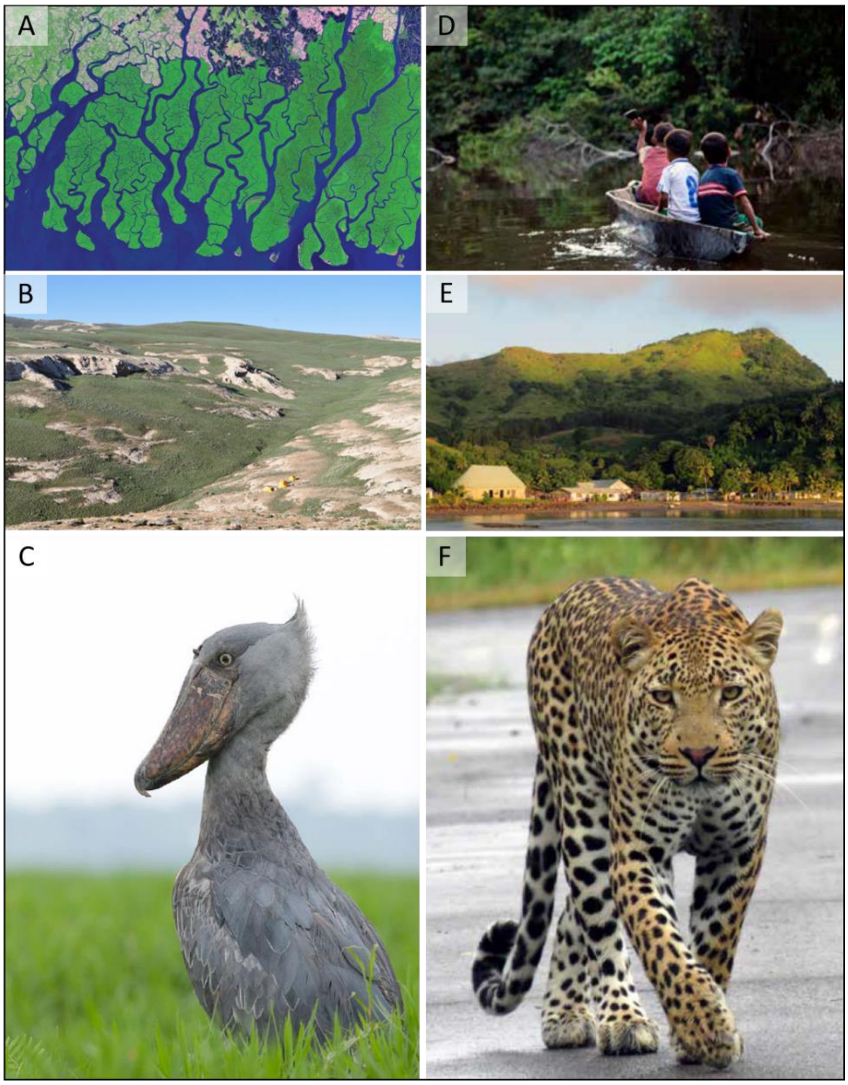

Box 1. Protected areas and other area-based conservation measures (OECMs) are complementary area-based conservation measures. Their distinguishing feature is that a protected area has a primary conservation objective[2] whereas an OECM delivers the effective in-situ conservation of biodiversity, regardless of its objectives[7]. (**A**) Protected areas are playing a central role in conserving the Sundarbans mangroves of Bangladesh and India (©NASA/JPL), (**B**) the Bamyan Plateau in Afghanistan (©N. Jahed/WCS) and (**C**) the Shoebill stork (*Balaeniceps rex*) that ranges from South Sudan to Zambia (©Daniel Field). **(D)** OECMs can be sites that prioritise conservation but this objective is not legally recognised by the governing body (e.g. a conservation concession in Loreto Region, Peru ©Bruno Monteferri), (**E**) places where conservation is effective but only a secondary management objective (e.g. a locally managed marine area on Totoya Island, Fiji ©Stacy Jupiter), or (**F**) ancillary conservation where conservation happens more-or-less by accident (e.g., the Hoedspruit Airforce Base, South Africa ©Hoedspruit Airforce Base).

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Table 1 Understanding the effectiveness of area-based conservation depends on the question being asked. Commonly asked questions imply different spatial scales and measurements, and are subject to strengths and weakness. Globally we have weak direct measures of the biodiversity outcomes of individual protected areas or OECMs.

	Scale	What is Measured	Strengths (+) and Weaknesses (-)
"Are area-based conservation efforts in the right place?"	Global and regional	1. Coverage of species, especially species at risk 2. Coverage of ecoregions 3. Coverage of 'important' areas, such as Key Biodiversity Areas	+ Can assess broad extent and examine cost per unit area of meeting area-based conservation targets + Robust methods to establish appropriate counterfactuals that control for bias - Coarse scale that might not be adequate of local planning - Inaccuracies in global data sets
"What is the ecological condition of a protected area or OECM?"	Individual sites	1. Species population time series trends 2. Measures of ecological integrity or health	+ Accurate and precise + Can include Traditional Ecological Knowledge where available - Costly and requires considerable scientific input for both design and analysis - There is no other substitute for this kind of overall assessment
"What is the ecological condition of area-based conservation efforts?"	Individual sites, aggregated to national, regional and global scales	1. Species population time series trends 2. Presence of key species or functional groups (e.g. predators, pollinators) 3. Change in the state of an environmental condition (e.g. forest cover, fish biomass) 4. Changes in cumulative human pressure	+ Human pressures are often useful proxies for broad-scale biodiversity impacts + Often cheap and non-invasive (e.g. derived from satellites) - Often miss important drivers of biodiversity loss (e.g. disease, pollution, poaching) and do not always explain local or regional biodiversity patterns - Often difficult to develop appropriate counterfactual scenarios to assess what conditions would have been like in the absence of protection
"Is the management of area-based conservation effective?"	Individual sites, aggregated to national, regional and global scales	1. Resource adequacy (e.g. staff, training, funding) 2. Adequacy of planning and enforcement	+ Established assessment frameworks and methodologies that can be conducted rapidly + Growing coverage of global protected area estate - Database established but at present does not record assessment results, only that assessments have taken place - Most methodologies were not designed to measure biodiversity outcomes of protected areas and OECMs

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Supplementary figures and tables

Figure S1. The terrestrial protected area network overlaid on a global map of biomass and soil carbon.

Table S1. Threatened birds, amphibians and mammals who remain without any formal protection as of 2019.

Table S2 Protected area coverage (%) of terrestrial ecoregions in 2010 and 2019.

Table S3 Growth in coverage of terrestrial ecoregions as the global protected area estate expanded between 2010 and 2019.

References

1 Watson, J. E. M., Dudley, N., Segan, D. B. & Hockings, M. The performance and potential of protected areas. *Nature* **515**, 67-73, doi:10.1038/nature13947 (2014).

2 Dudley, N., Shadie, P. & Stolton, S. Guidelines for applying protected area management categories. (International Union for the Conservation of Nature,, Gland, Switerland, 2008).

3 Garnett, S. T. *et al.* A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability* **1**, 369-374, doi:10.1038/s41893-018-0100-6 (2018).

4 Stolton, S., Redford, K. H. & Dudley, N. The Futures of Privately Protected Areas. (Gland, Switzerland, 2014).

5 Dudley, N. *et al.* The essential role of other effective area-based conservation measures in achieving big bold conservation targets. *Global Ecology and Conservation* **15**, e00424 (2018).

6 Donald, P. F. *et al.* The prevalence, characteristics and effectiveness of Aichi Target 11' s "other effective area-based conservation measures"(OECMs) in Key Biodiversity Areas. *Conservation Letters*, e12659 (2019).

7 IUCN WCPA. Guidelines for Recognising and Reporting Other Effective Area-based Conservation Measures. (Switzerland, 2019).

8 UN General Assembly. Transforming our world : the 2030 Agenda for Sustainable Development, 21 October 2015, A/RES/70/1, available at: https://www.refworld.org/docid/57b6e3e44.html. (2015).

9 Convention on Biological Diversity. COP 10 Decision X/2: Strategic Plan for Biodiversity 2011–2020, available at: http://www.cbd.int/decision/cop/?id=12268. (2011).

10 IPBES. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (IPBES secretariat, Bonn, Germany, 2019).

11 UNEP-WCMC & IUCN. World Database on other effective area-based conservation measures (WD-OCEM) [On-line]. (UNEP-WCMC, Cambridge, UK 2019).

12 Schulze, K. *et al.* An assessment of threats to terrestrial protected areas. *Conservation Letters* **11**, doi:10.1111/conl.12435 (2018).

13 Klein, C. J. *et al.* Shortfalls in the global protected area network at representing marine biodiversity. *Scientific Reports* **5**, doi:10.1038/srep17539 (2015).

14 Venter, O. *et al.* Bias in protected-area location and its effects on long-term aspirations of biodiversity conventions. *Conservation Biology* **32**, 127-134 (2018).

15 Mouillot, D. *et al.* Global marine protected areas do not secure the evolutionary history of tropical corals and fishes. *Nature Communications* **7**, doi:10.1038/ncomms10359 (2016).

16 Butchart, S. H. M. *et al.* Shortfalls and Solutions for Meeting National and Global Conservation Area Targets. *Conservation Letters* **8**, 329-337, doi:10.1111/conl.12158 (2015).

17 Juffe-Bignoli, D. *et al.* Achieving Aichi Biodiversity Target 11 to improve the performance of protected areas and conserve freshwater biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems* **26**, 133-151, doi:10.1002/aqc.2638 (2016).

18 Maron, M., Simmonds, J. S. & Watson, J. E. M. Bold nature retention targets are essential for the global environment agenda. *Nature Ecology & Evolution* **2**, 1194-1195, doi:10.1038/s41559-018-0595-2 (2018).

19 Geldmann, J. *et al.* Changes in protected area management effectiveness over time: A global analysis. *Biological Conservation* **191**, 692-699, doi:10.1016/j.biocon.2015.08.029 (2015).

20 Di Minin, E. & Toivonen, T. Global Protected Area Expansion: Creating More than Paper Parks. *Bioscience* **65**, 637-638, doi:10.1093/biosci/biv064 (2015).

21 Gill, D. A. *et al.* Capacity shortfalls hinder the performance of marine protected areas globally. *Nature* **543**, 665-669, doi:10.1038/nature21708 (2017).

22 Coad, L. *et al.* Widespread shortfalls in protected area resourcing undermine efforts to conserve biodiversity. *Frontiers in Ecology and the Environment* **17**, 259-264, doi:10.1002/fee.2042 (2019).

23 Visconti, P. *et al.* Protected area targets post-2020. *Science* **364**, 239-241, doi:10.1126/science.aav6886 (2019).

24 Barnes, M. D., Glew, L., Wyborn, C. & Craigie, I. D. Prevent perverse outcomes from global protected area policy. *Nature Ecology & Evolution* **2**, 759-762, doi:10.1038/s41559-018-0501-y (2018).

25 Dinerstein, E. *et al.* A Global Deal For Nature: Guiding principles, milestones, and targets. *Science Advances* **5**, eaaw2869 (2019).

26 Noss, R. F. *et al.* Bolder Thinking for Conservation. *Conservation Biology* **26**, 1-4, doi:10.1111/j.1523-1739.2011.01738.x (2012).

27 Wilson, E. O. *Half-Earth: Our Planet's Fight for Life*. (Liveright Publishing Corporation, 2016).

28 O'Leary, B. C. *et al.* Effective Coverage Targets for Ocean Protection. *Conservation Letters* **9**, 398-404, doi:10.1111/conl.12247 (2016).

29 Bull, J. W. *et al.* Net positive outcomes for nature. *Nature Ecology & Evolution*, doi:10.1038/s41559-019-1022-z (2019).

30 Mace, G. M. *et al.* Aiming higher to bend the curve of biodiversity loss. *Nature Sustainability* **1**, 448-451, doi:10.1038/s41893-018-0130-0 (2018).

31 Watson, J. E. M. & Venter, O. A global plan for nature conservation. *Nature* **550**, 48-49, doi:10.1038/nature24144 (2017).

32 Dinerstein, E. *et al.* An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm. *BioScience* **67**, 534-545, doi:10.1093/biosci/bix014 (2017).

33 Spalding, M. D. *et al.* Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. *BioScience* **57**, 573-583, doi:10.1641/b570707 (2007).

34 UNEP-WCMC IUCN and NGS. Protected Planet Report 2018. (Cambridge UK; Gland, Switzerland; and Washington, D.C., USA., 2018).

35 Rodrigues, A. S. L. *et al.* Global Gap Analysis: Priority Regions for Expanding the Global Protected-Area Network. *BioScience* **54**, 1092-1100, doi:10.1641/0006-3568(2004)054[1092:ggaprf]2.0.co;2 (2004).

36 Venter, O. *et al.* Targeting global protected area expansion for imperiled biodiversity. *Plos Biology* **12**, e1001891, doi:10.1371/journal.pbio.1001891 (2014).

37 Tittensor, D. P. *et al.* A mid-term analysis of progress toward international biodiversity targets. *Science* **346**, 241-244 (2014).

38 Runge, C. A. *et al.* Protected areas and global conservation of migratory birds. *Science* **350**, 1255-1258, doi:10.1126/science.aac9180 (2015).

39 Brum, F. T. *et al.* Global priorities for conservation across multiple dimensions of mammalian diversity. *Proceedings of the National Academy of Sciences* **114**, 7641-7646 (2017).

40 IUCN. The IUCN Red List of Threatened Species. Version 2019-2. Available at: http://www.iucnredlist.org. Downloaded on 10 September 2019. (2019).

41 O'Hara, C. C., Villaseñor-Derbez, J. C., Ralph, G. M. & Halpern, B. S. Mapping status and conservation of global at-risk marine biodiversity. *Conservation Letters* **12**, e12651, doi:10.1111/conl.12651 (2019).

42 Stevenson, S. L., Woolley, S. N. C., Barnett, J. & Dunstan, P. Testing the presence of marine protected areas against their ability to reduce pressures on biodiversity. *Conservation Biology* **1**, 1-32, doi:10.1111/cobi.13429 (2019).

43 Watson, J. E. M. *et al.* Persistent disparities between recent rates of habitat conversion and protection and implications for future global conservation targets. *Conservation Letters* **9**, 413-421, doi:10.1111/conl.12295 (2016).

44 Spalding, M. D., Agostini, V. N., Rice, J. & Grant, S. M. Pelagic provinces of the world: A biogeographic classification of the world's surface pelagic waters. *Ocean & Coastal Management* **60**, 19-30 (2012).

45 IUCN. A Global Standard for the Identification of Key Biodiversity Areas, Version 1.0., (Gland, Switzerland, 2016).

46 Jones, K. R. *et al.* The location and protection status of Earth's diminishing marine wilderness. *Current Biology* **28**, 2506-2512. e2503 (2018).

47 Allan, J. R., Venter, O. & Watson, J. E. Temporally inter-comparable maps of terrestrial wilderness and the Last of the Wild. *Scientific Data* **4**, 170187 (2017).

48 Watson, J. E. M. *et al.* The exceptional value of intact forest ecosystems. *Nature Ecology & Evolution* **2**, 599-610, doi:10.1038/s41559-018-0490-x (2018).

49 Di Marco, M., Ferrier, S., Harwood, T. D., Hoskins, A. J. & Watson, J. E. M. Wilderness areas halve the extinction risk of terrestrial biodiversity. *Nature* **573**, 582-585, doi:10.1038/s41586-019-1567-7 (2019).

50 Martin, T. G. & Watson, J. E. M. Intact ecosystems provide best defence against climate change. *Nature Climate Change* **6**, 122-124, doi:10.1038/nclimate2918 (2016).

51 Watson, J. E. *et al.* Catastrophic declines in wilderness areas undermine global environment targets. *Current Biology* **26**, 2929-2934 (2016).

52 Stolton, S. & Dudley, N. *Arguments for Protected Areas*. (Earthscan 2010).

53 Nogueira, E. M., Yanai, A. M., de Vasconcelos, S. S., Graca, P. & Fearnside, P. M. Carbon stocks and losses to deforestation in protected areas in Brazilian Amazonia. *Regional Environmental Change* **18**, 261-270, doi:10.1007/s10113-017-1198-1 (2018).

54 Harrison, I. J. *et al.* Protected areas and freshwater provisioning: a global assessment of freshwater provision, threats and management strategies to support human water security. *Aquatic Conservation: Marine and Freshwater Ecosystems* **26**, 103-120, doi:10.1002/aqc.2652 (2016).

55 Magris, R. A. *et al.* Biologically representative and well-connected marine reserves enhance biodiversity persistence in conservation planning. *Conservation Letters* **11**, e12439, doi:10.1111/conl.12439 (2018).

56 Mendenhall, C. D., Karp, D. S., Meyer, C. F. J., Hadly, E. A. & Daily, G. C. Predicting biodiversity change and averting collapse in agricultural landscapes. *Nature* **509**, 213-217, doi:10.1038/nature13139 (2014).

57 Saura, S., Bastin, L., Battistella, L., Mandrici, A. & Dubois, G. Protected areas in the world's ecoregions: How well connected are they? *Ecological Indicators* **76**, 144-158, doi:10.1016/j.ecolind.2016.12.047 (2017).

58 Saura, S. *et al.* Global trends in protected area connectivity from 2010 to 2018. *Biological Conservation* **238**, 108183 (2019).

59 Taubert, F. *et al.* Global patterns of tropical forest fragmentation. *Nature* **554**, 519-522 (2018).

60 Halpern, B. S. *et al.* Recent pace of change in human impact on the world's ocean. *Scientific Reports* **9**, 11609, doi:10.1038/s41598-019-47201-9 (2019).

61 Johnson, D. W., Christie, M. R., Pusack, T. J., Stallings, C. D. & Hixon, M. A. Integrating larval connectivity with local demography reveals regional dynamics of a marine metapopulation. *Ecology* **99**, 1419-1429, doi:10.1002/ecy.2343 (2018).

62 Harrison, Hugo B. *et al.* Larval Export from Marine Reserves and the Recruitment Benefit for Fish and Fisheries. *Current Biology* **22**, 1023-1028, doi:https://doi.org/10.1016/j.cub.2012.04.008 (2012).

63 Wood, S., Paris, C. B., Ridgwell, A. & Hendy, E. J. Modelling dispersal and connectivity of broadcast spawning corals at the global scale. *Global Ecology and Biogeography* **23**, 1-11, doi:10.1111/geb.12101 (2014).

64 Green, A. L. *et al.* Larval dispersal and movement patterns of coral reef fishes, and implications for marine reserve network design. *Biological Reviews* **90**, 1215-1247, doi:10.1111/brv.12155 (2015).

65 Endo, C. A. K., Gherardi, D. F. M., Pezzi, L. P. & Lima, L. N. Low connectivity compromises the conservation of reef fishes by marine protected areas in the tropical South Atlantic. *Scientific Reports* **9**, 11, doi:10.1038/s41598-019-45042-0 (2019).

66 Watson, J. E. M. & Venter, O. Mapping the Continuum of Humanity's Footprint on Land. *One Earth* **1**, 175-180, doi:https://doi.org/10.1016/j.oneear.2019.09.004 (2019).

67 Chandler, M. *et al.* Contribution of citizen science towards international biodiversity monitoring. *Biological Conservation* **213**, 280-294, doi:https://doi.org/10.1016/j.biocon.2016.09.004 (2017).

68 Coad, L. *et al.* Measuring impact of protected area management interventions: current and future use of the Global Database of Protected Area Management Effectiveness. *Philosophical Transactions of the Royal Society B-Biological Sciences* **370**, doi:10.1098/rstb.2014.0281 (2015).

69 Craigie, I. D. *et al.* Large mammal population declines in Africa's protected areas. *Biological Conservation* **143**, 2221-2228 (2010).

70 Hallmann, C. A. *et al.* More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PloS one* **12**, e0185809 (2017).

71 Cinner, J. E. *et al.* Gravity of human impacts mediates coral reef conservation gains. *Proceedings of the National Academy of Sciences* **115**, E6116-E6125 (2018).

72 Gray, C. L. *et al.* Local biodiversity is higher inside than outside terrestrial protected areas worldwide. *Nature Communications* **7**, 12306 doi:10.1038/ncomms12306 (2016).

73 Jones, K. R. *et al.* One-third of global protected land is under intense human pressure. *Science* **360**, 788-791 (2018).

74 Geldmann, J., Manica, A., Burgess, N. D., Coad, L. & Balmford, A. A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures. *Proceedings of the National Academy of Sciences*, 201908221, doi:10.1073/pnas.1908221116 (2019).

75 Costello, M. J. & Ballantine, B. Biodiversity conservation should focus on no-take Marine Reserves: 94% of Marine Protected Areas allow fishing. *Trends in Ecology & Evolution* **30**, 507-509, doi:https://doi.org/10.1016/j.tree.2015.06.011 (2015).

76 Zupan, M. *et al.* Marine partially protected areas: drivers of ecological effectiveness. *Frontiers in Ecology and the Environment* **16**, 381-387, doi:10.1002/fee.1934 (2018).

77 Bergseth, B. J., Gurney, G. G., Barnes, M. L., Arias, A. & Cinner, J. E. Addressing poaching in marine protected areas through voluntary surveillance and enforcement. *Nature Sustainability* **1**, 421-426, doi:10.1038/s41893-018-0117-x (2018).

78 White, T. D. *et al.* Assessing the effectiveness of a large marine protected area for reef shark conservation. *Biological Conservation* **207**, 64-71, doi:https://doi.org/10.1016/j.biocon.2017.01.009 (2017).

79 Giakoumi, S. & Pey, A. Assessing the Effects of Marine Protected Areas on Biological Invasions: A Global Review. *Frontiers in Marine Science* **4**, doi:10.3389/fmars.2017.00049 (2017).

80 Spracklen, B. D., Kalamandeen, M., Galbraith, D., Gloor, E. & Spracklen, D. V. A Global Analysis of Deforestation in Moist Tropical Forest Protected Areas. *Plos One* **10**, doi:10.1371/journal.pone.0143886 (2015).

81 Herrera, D., Pfaff, A. & Robalino, J. Impacts of protected areas vary with the level of government: Comparing avoided deforestation across agencies in the Brazilian Amazon. *Proceedings of the National Academy of Sciences of the United States of America* **116**, 14916-14925, doi:10.1073/pnas.1802877116 (2019).

82 Anderson, E. & Mammides, C. The role of protected areas in mitigating human impact in the world's last wilderness areas. *Ambio*, doi:10.1007/s13280-019-01213-x (2019).
83 Nolte, C., Agrawal, A., Silvius, K. M. & Soares-Filho, B. S. Governance regime and location influence avoided deforestation success of protected areas in the Brazilian Amazon. *Proceedings of the National Academy of Sciences* **110**, 4956-4961 (2013).
84 Bebber, D. P. & Butt, N. Tropical protected areas reduced deforestation carbon emissions by one third from 2000–2012. *Scientific Reports* **7**, 14005 (2017).
85 Fuller, C., Ondei, S., Brook, B. W. & Buettel, J. C. First, do no harm: A systematic review of deforestation spillovers from protected areas. *Global Ecology and Conservation*, e00591 (2019).
86 Gamero, A. *et al.* Tracking Progress Toward EU Biodiversity Strategy Targets: EU Policy Effects in Preserving its Common Farmland Birds. *Conservation Letters* **10**, 395-402, doi:10.1111/conl.12292 (2017).
87 Cazalis, V., Belghali, S. & Rodrigues, A. S. L. Using a large-scale biodiversity monitoring dataset to test the effectiveness of protected areas in conserving North-American breeding birds. *bioRxiv*, 433037, doi:10.1101/433037 (2018).
88 Barnes, M. D. *et al.* Wildlife population trends in protected areas predicted by national socio-economic metrics and body size. *Nature Communications* **7**, doi:10.1038/ncomms12747 (2016).
89 Beaudrot, L. *et al.* Standardized Assessment of Biodiversity Trends in Tropical Forest Protected Areas: The End Is Not in Sight. *Plos Biology* **14**, 21, doi:10.1371/journal.pbio.1002357 (2016).
90 Kerwath, S. E., Winker, H., Götz, A. & Attwood, C. G. Marine protected area improves yield without disadvantaging fishers. *Nature Communications* **4**, 2347, doi:10.1038/ncomms3347 (2013).
91 Speed, C. W., Cappo, M. & Meekan, M. G. Evidence for rapid recovery of shark populations within a coral reef marine protected area. *Biological Conservation* **220**, 308-319, doi:https://doi.org/10.1016/j.biocon.2018.01.010 (2018).
92 Caselle, J. E., Rassweiler, A., Hamilton, S. L. & Warner, R. R. Recovery trajectories of kelp forest animals are rapid yet spatially variable across a network of temperate marine protected areas. *Scientific reports* **5** (2015).
93 Emslie, Michael J. *et al.* Expectations and Outcomes of Reserve Network Performance following Re-zoning of the Great Barrier Reef Marine Park. *Current Biology* **25**, 983-992, doi:https://doi.org/10.1016/j.cub.2015.01.073 (2015).
94 Campbell, S. J., Edgar, G. J., Stuart-Smith, R. D., Soler, G. & Bates, A. E. Fishing-gear restrictions and biomass gains for coral reef fishes in marine protected areas. *Conservation Biology* **32**, 401-410, doi:10.1111/cobi.12996 (2018).
95 Mumby, P. J. *et al.* Trophic cascade facilitates coral recruitment in a marine reserve. *Proceedings of the National Academy of Sciences* **104**, 8362-8367 (2007).
96 Boaden, A. & Kingsford, M. Predators drive community structure in coral reef fish assemblages. *Ecosphere* **6**, 1-33 (2015).

97 Lamb, J. B., Williamson, D. H., Russ, G. R. & Willis, B. L. Protected areas mitigate diseases of reef-building corals by reducing damage from fishing. *Ecology* **96**, 2555-2567 (2015).

98 Bacon, E. *et al.* Aichi Biodiversity Target 11 in the like-minded megadiverse countries. *Journal for Nature Conservation* **51**, 125723, doi:https://doi.org/10.1016/j.jnc.2019.125723 (2019).

99 Zafra-Calvo, N. *et al.* Towards an indicator system to assess equitable management in protected areas. *Biological Conservation* **211**, 134-141, doi:https://doi.org/10.1016/j.biocon.2017.05.014 (2017).

100 Rees, S. E., Foster, N. L., Langmead, O., Pittman, S. & Johnson, D. E. Defining the qualitative elements of Aichi Biodiversity Target 11 with regard to the marine and coastal environment in order to strengthen global efforts for marine biodiversity conservation outlined in the United Nations Sustainable Development Goal 14. *Marine Policy* **93**, 241-250, doi:https://doi.org/10.1016/j.marpol.2017.05.016 (2018).

101 Oldekop, J., Holmes, G., Harris, W. & Evans, K. A global assessment of the social and conservation outcomes of protected areas. *Conservation Biology* **30**, 133-141 (2016).

102 Christie, P. *et al.* Why people matter in ocean governance: Incorporating human dimensions into large-scale marine protected areas. *Marine Policy* **84**, 273-284, doi:https://doi.org/10.1016/j.marpol.2017.08.002 (2017).

103 Corrigan, C. *et al.* Quantifying the contribution to biodiversity conservation of protected areas governed by indigenous peoples and local communities. *Biological Conservation* **227**, 403-412 (2018).

104 Ban, N. C. *et al.* Well-being outcomes of marine protected areas. *Nature Sustainability* **2**, 524-532, doi:10.1038/s41893-019-0306-2 (2019).

105 Bennett, N. J. & Dearden, P. From measuring outcomes to providing inputs: Governance, management, and local development for more effective marine protected areas. *Marine Policy* **50**, 96-110, doi:https://doi.org/10.1016/j.marpol.2014.05.005 (2014).

106 Mammides, C. Evidence from eleven countries in four continents suggests that protected areas are not associated with higher poverty rates. *Biological Conservation* **241**, 108353, doi:https://doi.org/10.1016/j.biocon.2019.108353 (2020).

107 Mcowen, C. J. *et al.* Sufficiency and Suitability of Global Biodiversity Indicators for Monitoring Progress to 2020 Targets. *Conservation Letters* **9**, 489-494, doi:10.1111/conl.12329 (2016).

108 Jonas, H. D. *et al.* Will 'Other Effective Area-Based Conservation Measures' Increase Recognition and Support for ICCA? *Parks* **23**, 63-78 (2017).

109 Schuster, R. *et al.* Optimizing the conservation of migratory species over their full annual cycle. *Nature Communications* **10**, 1754, doi:10.1038/s41467-019-09723-8 (2019).

110 De Vos, A., Clements, H. S., Biggs, D. & Cumming, G. S. The dynamics of proclaimed privately protected areas in South Africa over 83 years. *Conservation Letters* **0**, e12644, doi:10.1111/conl.12644 (2019).

111 Clements, H. S., Kerley, G. I. H., Cumming, G. S., De Vos, A. & Cook, C. N. Privately protected areas provide key opportunities for the regional persistence of large- and

medium-sized mammals. *Journal of Applied Ecology* **56**, 537-546, doi:10.1111/1365-2664.13300 (2019).

112 Chown, S. L., van Rensburg, B. J., Gaston, K. J., Rodrigues, A. S. L. & van Jaarsveld, A. S. Energy, species richness, and human population size: conservation implications at a national scale. *Ecological Applications* **13**, 1233-1241, doi:10.1890/02-5105 (2003).

113 Shabtay, A., Portman, M. E., Manea, E. & Gissi, E. Promoting ancillary conservation through marine spatial planning. *Science of The Total Environment* **651**, 1753-1763, doi:https://doi.org/10.1016/j.scitotenv.2018.10.074 (2019).

114 Banks-Leite, C. *et al.* Using ecological thresholds to evaluate the costs and benefits of set-asides in a biodiversity hotspot. *Science* **345**, 1041-1045, doi:10.1126/science.1255768 (2014).

115 Burmester, B. Upgrading or unhelpful? Defiant corporate support for a marine protected area. *Marine Policy* **63**, 206-212, doi:10.1016/j.marpol.2015.03.019 (2016).

116 Lewis, E. *et al.* Dynamics in the global protected-area estate since 2004. *Conservation Biology* **33**, 570-579 (2019).

117 Cook, C. N., Valkan, R. S., Mascia, M. B. & McGeoch, M. A. Quantifying the extent of protected-area downgrading, downsizing, and degazettement in Australia. *Conservation Biology* **31**, 1039-1052, doi:10.1111/cobi.12904 (2017).

118 Qin, S. *et al.* Protected area downgrading, downsizing, and degazettement as a threat to iconic protected areas. *Conservation Biology* **0**, 1-11, doi:10.1111/cobi.13365 (2019).

119 Golden Kroner, R. E. *et al.* The uncertain future of protected lands and waters. *Science* **364**, 881-886, doi:10.1126/science.aau5525 (2019).

120 Mascia, M. B. *et al.* Protected area downgrading, downsizing, and degazettement (PADDD) in Africa, Asia, and Latin America and the Caribbean, 1900–2010. *Biological Conservation* **169**, 355-361 (2014).

121 Forrest, J. L. *et al.* Tropical Deforestation and Carbon Emissions from Protected Area Downgrading, Downsizing, and Degazettement (PADDD). *Conservation Letters* **8**, 153-161, doi:10.1111/conl.12144 (2015).

122 Symes, W. S., Rao, M., Mascia, M. B. & Carrasco, L. R. Why do we lose protected areas? Factors influencing protected area downgrading, downsizing and degazettement in the tropics and subtropics. *Global Change Biology* **22**, 656-665, doi:10.1111/gcb.13089 (2016).

123 Roberts, K. E., Valkan, R. S. & Cook, C. N. Measuring progress in marine protection: A new set of metrics to evaluate the strength of marine protected area networks. *Biological Conservation* **219**, 20-27, doi:https://doi.org/10.1016/j.biocon.2018.01.004 (2018).

124 Costelloe, B. *et al.* Global biodiversity indicators reflect the modeled impacts of protected area policy change. *Conservation letters* **9**, 14-20 (2016).

125 Pringle, R. M. Upgrading protected areas to conserve wild biodiversity. *Nature* **546**, 91-99, doi:10.1038/nature22902 (2017).

126 Kuempel, C. D., Adams, V. M., Possingham, H. P. & Bode, M. Bigger or better: The relative benefits of protected area network expansion and enforcement for the

conservation of an exploited species. *Conservation Letters* **11**, e12433, doi:10.1111/conl.12433 (2018).

127 Allan, J. R. *et al.* Gaps and opportunities for the World Heritage Convention to contribute to global wilderness conservation. *Conservation Biology* **32**, 116-126 (2018).

128 Stolton, S., Hockings, M., Dudley, N., MacKinnon, K. & Whitten, T. Reporting progress in protected areas. A site-level management effectiveness tracking tool. (Gland, Switzerland, 2007).

129 Hansen, M. C. *et al.* High-resolution global maps of 21st-century forest cover change. *Science* **342**, 850-853 (2013).

130 Venter, O. *et al.* Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nature Communications* **7**, e12558, doi:10.1038/ncomms12558 (2016).

131 Geldmann, J., Joppa, L. N. & Burgess, N. D. Mapping change in human pressure globally on land and within protected areas. *Conservation Biology* **28**, 1604-1616 (2014).

132 Di Marco, M., Venter, O., Possingham, H. P. & Watson, J. E. M. Changes in human footprint drive changes in species extinction risk. *Nature Communications* **9**, 4621, doi:10.1038/s41467-018-07049-5 (2018).

133 Wilkie, D. S., Bennett, E. L., Peres, C. A. & Cunningham, A. A. The empty forest revisited. *Annals of the New York Academy of Sciences* **1223**, 120-128 (2011).

134 Wintle, B. A. *et al.* Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. *Proceedings of the National Academy of Sciences* **116**, 909-914, doi:10.1073/pnas.1813051115 (2019).

135 Maxwell, S., Fuller, R. A., Brooks, T. M. & Watson, J. E. M. The ravages of guns, nets and bulldozers. *Nature* **536**, 143-145, doi:10.1038/536143a (2016).

136 Maron, M. *et al.* The many meanings of no net loss in environmental policy. *Nature Sustainability* **1**, 19-27, doi:10.1038/s41893-017-0007-7 (2018).

137 Nicholson, E. *et al.* Scenarios and Models to Support Global Conservation Targets. *Trends in Ecology & Evolution* **34**, 57-68, doi:https://doi.org/10.1016/j.tree.2018.10.006 (2019).

138 Burgass, M. J., Halpern, B. S., Nicholson, E. & Milner-Gulland, E. J. Navigating uncertainty in environmental composite indicators. *Ecological Indicators* **75**, 268-278, doi:https://doi.org/10.1016/j.ecolind.2016.12.034 (2017).

139 James, A. N., Gaston, K. J. & Balmford, A. Balancing the Earth's accounts. *Nature* **401**, 323-324 (1999).

140 Bruner, A. G., Gullison, R. E. & Balmford, A. Financial Costs and Shortfalls of Managing and Expanding Protected-Area Systems in Developing Countries. *BioScience* **54**, 1119-1126, doi:10.1641/0006-3568(2004)054[1119:fcasom]2.0.co;2 (2004).

141 McCarthy, D. P. *et al.* Financial Costs of Meeting Global Biodiversity Conservation Targets: Current Spending and Unmet Needs. *Science* **338**, 946-949, doi:10.1126/science.1229803 (2012).

142 Balmford, A. *et al.* Walk on the wild side: estimating the global magnitude of visits to protected areas. *PLoS Biology* **13**, e1002074 (2015).

143 Rylance, A., Snyman, S. & Spenceley, A. The contribution of tourism revenue to financing protected area management in southern Africa. *Tourism Review International* **21**, 139-149 (2017).

144 Githiru, M. *et al.* Should biodiversity offsets help finance underfunded Protected Areas? *Biological Conservation* **191**, 819-826 (2015).

145 Pilgrim, J. D. & Bennun, L. Will biodiversity offsets save or sink protected areas? *Conservation Letters* **7**, 423-424 (2014).

146 Smith, T. *et al.* Biodiversity means business: reframing global biodiversity goals for the private sector. *Conservation Letters* (2019).

147 Díaz, S. *et al.* Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science* **366**, eaax3100, doi:10.1126/science.aax3100 (2019).

148 Harfoot, M. B. *et al.* Present and future biodiversity risks from fossil fuel exploitation. *Conservation Letters* **11**, e12448 (2018).

149 Lü, Y., Ma, Z., Zhang, L., Fu, B. & Gao, G. Redlines for the greening of China. *Environmental Science & Policy* **33**, 346-353, doi:https://doi.org/10.1016/j.envsci.2013.05.007 (2013).

150 Vergilio, M. H. D. & Calado, H. The concept of the Portuguese National Ecological Reserve: constraints and impossibilities in the Azores Archipelago. *Journal of Environmental Planning and Management* **58**, 1015-1033, doi:10.1080/09640568.2014.907134 (2015).

151 Soares-Filho, B. *et al.* Cracking Brazil's Forest Code. *Science* **344**, 363-364, doi:10.1126/science.1246663 (2014).

152 Azevedo, A. A. *et al.* Limits of Brazil’s Forest Code as a means to end illegal deforestation. *Proceedings of the National Academy of Sciences* **114**, 7653-7658, doi:10.1073/pnas.1604768114 (2017).

153 Alamgir, M. *et al.* High-risk infrastructure projects pose imminent threats to forests in Indonesian Borneo. *Scientific Reports* **9**, 140, doi:10.1038/s41598-018-36594-8 (2019).

154 Evans, M. C. Deforestation in Australia: drivers, trends and policy responses. *Pacific Conservation Biology* **22**, 130-150 (2016).

155 Crouzeilles, R., Feltran-Barbieri, R., Ferreira, M. S. & Strassburg, B. B. Hard times for the Brazilian environment. *Nature Ecology & Evolution* **1**, 1213 (2017).

156 Kleinn, C., Corrales, L. & Morales, D. Forest area in Costa Rica: a comparative study of tropical forest cover estimates over time. *Environmental Monitoring and Assessment* **73**, 17-40 (2002).

157 UNEP-WCMC & IUCN. World Database on Protected Areas (WDPA) [On-line]. (UNEP-WCMC, Cambridge, UK 2019).

158 Jantke, K., Kuempel, C. D., McGowan, J., Chauvenet, A. L. M. & Possingham, H. P. Metrics for evaluating representation target achievement in protected area networks. *Diversity and Distributions* **25**, 170-175, doi:10.1111/ddi.12853 (2019).

159 IUCN and WCPA. IUCN Green List of Protected and Conserved Areas: Standard, Version 1.1. . (Gland, Switzerland, 2017).