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1 **Climate change mitigation and nature conservation both require higher protected area targets**

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8

9 **Abstract**

10 Nations of the world have, to date, pursued nature protection and climate change mitigation and  
11 adaptation policies separately. Both efforts have failed to achieve the scale of action needed to halt  
12 biodiversity loss or mitigate climate change. We argue that success can be achieved by aligning  
13 targets for biodiversity protection with the habitat protection and restoration necessary to bring  
14 down greenhouse gas concentrations and promote natural and societal adaptation to climate  
15 change. Success, however, will need much higher targets for environmental protection than the  
16 present 10% of sea and 17% of land. A new target of 30% of the sea given high levels of protection  
17 from exploitation and harm by 2030 is under consideration and similar targets are being discussed  
18 for terrestrial habitats. We make the case here that these higher targets, if achieved, would make  
19 the transition to a warmer world slower and less damaging for nature and people.

20

21 **Keywords**

22 Biodiversity conservation; Natural climate solutions; Nature-based solutions

23

24 The year 2009 was a watershed in the progress of climate change [1, 2]. At a meeting at the Royal  
25 Society in London to examine the past and consider the future of tropical coral reefs, participants  
26 realised that global emissions, which by then stood at 386ppm CO<sub>2</sub>, had already exceeded the  
27 estimated 350ppm CO<sub>2</sub> tolerance of this ecosystem [1]. It was too late to simply reduce emissions; to  
28 secure a viable future for coral reefs some of the CO<sub>2</sub> already in the atmosphere would now have to  
29 be recaptured [1]. This recognition moved debate from consideration of how to avoid future  
30 problems, to the fixes required for those already existing, a conversation that still continues [3-5].

31 The Paris Agreement acknowledged this shift in perspective by incorporating carbon recapture in the  
32 two more ambitious Representative Concentration Pathways, RCP 2.6 (a stringent mitigation/low  
33 emissions scenario) and RCP 4.5 (a stabilisation/moderate emissions scenario) [6], more recently  
34 extended to include social and economic dimensions through Shared Socio-economic Pathways [7].  
35 The most effective way to quickly capture sufficient CO<sub>2</sub> from the atmosphere is via photosynthesis,  
36 so both RCPs include scenarios of mass reforestation and habitat restoration [4, 8]. But while climate  
37 change and emissions reduction are now high on the political agenda, addressing the global and  
38 accelerating deterioration of nature [9] is at least as urgent. In practice, however, biodiversity loss

39 receives far less attention and global actions to reverse it have been largely ineffective [9]. It is now  
40 widely recognised that synergies between climate change and biodiversity conservation mean that  
41 the two agendas must be pursued concurrently to meet societal and environmental goals, such as  
42 the UN's Sustainable Development Goals, Convention on Biological Diversity's Aichi Targets, and the  
43 Paris Agreement [9]. This recognition is now also reflected in global social movements aimed at  
44 driving political action [10].

45 While reducing emissions remains fundamental, mitigation is also essential [4]. Conserving and  
46 restoring natural habitats is among the most cost-effective emissions mitigation strategies available  
47 but while clear synergies exist between the objectives of biodiversity protection and carbon capture,  
48 there is also a risk that if conservation and climate change mitigation agendas are mis-aligned, one  
49 could easily undermine the other.

50 The last decade has seen a surge in research on the benefits and costs of nature-based solutions to  
51 climate change mitigation and adaptation and, as much of it acknowledges, there are trade-offs  
52 among outcomes [4]. For example, habitats that store the most carbon, or are best for flood control,  
53 or for pollution mitigation, are not necessarily the most diverse, intact, or natural. Hence the single-  
54 minded pursuit of a narrow goal, such as carbon storage or reduced consumption of fossil fuels,  
55 might well lead to policies antithetical to wildlife protection. An example of the former would be  
56 establishment of large-scale, low diversity plantations with the potential to sequester large amounts  
57 of CO<sub>2</sub> in repeatedly harvested timber but which could potentially hasten the disappearance of  
58 threatened species by co-opting space and blocking dispersal [11]. An example of the latter would be  
59 increased land conversion to facilitate crops for biofuels to reduce reliance on fossil fuels at the  
60 overall expense of carbon emissions and biodiversity [12]. It is critical to avoid such "bio-  
61 perversities" in any climate mitigation policies [13].

62 The numerous co-benefits from wildlife and habitat protection for climate mitigation and adaptation  
63 must be embedded in revised global ambitions. Climate solutions must promote conservation, while  
64 conservation efforts must work to counter climate change. Natural or restored habitats perform  
65 functions that are crucial in mitigating climate change and promoting societal adaptation. For  
66 example, wetlands, peat bogs and rainforests are often intense carbon sinks [14-16] while intact,  
67 vigorous wetlands and coral reefs form natural, self-repairing breakwaters that can protect coasts  
68 against sea level rise better than man-made defences [17]. Unfished mesopelagic fish populations  
69 promote carbon sequestration in the deep sea [18] and protecting marine animals and ecosystems  
70 can benefit carbon storage and prevent release of carbon already locked away [5, 19]. Natural and  
71 restored forested landscapes promote water retention and counter flooding while regulating climate  
72 and rainfall at local, regional and continental scales [20], while protected habitats in agricultural  
73 landscapes sustain populations of natural pollinators, predators that control pests, and facilitate  
74 seed dispersal [21, 22].

75 Existing global conservation targets (the 'Aichi targets') agreed through the Convention on Biological  
76 Diversity (CBD) [23], and later incorporated into the Sustainable Development Goals [24], run until  
77 2020. The Aichi targets have spurred governments to act and there have been some successes, but  
78 global biodiversity continues to decline [9]. Attention is now turning to the post-2020 agenda and,  
79 with the urgency of climate change well-recognised [25], there is a need to align conservation and  
80 climate change agendas so that both may see greater success and fulfil their essential roles in  
81 achieving the Sustainable Development Goals. The post-2020 CBD targets need a rapid increase in

82 ambition and action. For nature to substantially contribute to climate change mitigation higher  
83 coverages of intact ecosystems will be essential because of the reliance of ecosystem service  
84 delivery, including carbon sequestration and storage, on biodiversity and the crucial need to leave  
85 existing carbon stores intact. Moreover, given that many ecosystems are already degraded, ensuring  
86 continued provision of ecosystem services requires not only the precautionary protection of  
87 currently intact habitats, but also large-scale habitat restoration.

88 Providing greater space for recovery of intact, vibrant nature is not altruistic conservation, but is, we  
89 argue, an indispensable act of self-preservation, producing a cascade of benefits that will help  
90 maintain the habitability of the biosphere as the climate changes, thereby securing the wellbeing of  
91 generations to come. In truth, the goals of protecting 10% of marine habitats and 17% of those on  
92 land by 2020 (Aichi Target 11) were political and never considered sufficient to save nature, even  
93 without climate change, or to enable nature to contribute substantially to climate change mitigation.  
94 Based on the species-area relationship, regarded as one of ecology's few universal laws, protection  
95 of so little habitat will condemn thousands of species to extinction if habitat outside them is  
96 converted, degraded or lost. It is this logic that underpins calls for 'Nature Needs Half' [26], together  
97 with an understanding that ecosystem processes and services of the scale needed to sustain the  
98 wellbeing of life on Earth require large wildlife populations and huge expanses of intact and restored  
99 habitat.

100 Since the current Convention on Biological Diversity targets were agreed, new research has shown  
101 that future conservation success will depend on greatly increased coverage of fully and strongly  
102 protected areas and restored habitats. For example, in the oceans, a synthesis of 144 studies asked  
103 how much protected area coverage was needed to achieve, optimise or maximise benefits for six  
104 core environmental and/or socioeconomic objectives [27]. The goals were representation of  
105 biodiversity; ensuring ecological connectivity among protected sites; avoidance of population  
106 collapse; avoidance of adverse, fisheries-induced evolution; enhancement of fisheries yield; and  
107 meeting the needs of multiple stakeholder groups. The results consistently indicated that protecting  
108 several tens-of-percent of the sea is required to meet goals with average and median values of 37%  
109 and 35%, greatly exceeding the 5% or so of the ocean that is currently protected and the 10% target  
110 (<http://www.mpatlas.org>).

111 Climate change adds a new dimension to the question of how much protected area coverage is  
112 needed to assure conservation of wild nature. Climate change is already reducing wildlife population  
113 sizes and forcing range shifts as conditions alter [28, 29]. Protected areas counter such stresses by  
114 building up populations, and connectivity of populations and habitats is emerging as a key property  
115 in securing species persistence and resilience to rapid change [5]. Hence networked protected areas,  
116 especially where embedded within well-managed land- or seascapes, provide crucial stepping stones  
117 to accommodate range shifts and, where no further movements are possible, refuges of last resort  
118 [5]. Analyses suggest that adequate levels of population viability and connectivity can be achieved  
119 only with MPA coverages of 30% or more [27]. We are not aware of comparable analyses for  
120 terrestrial ecosystems, but figures are unlikely to be lower [30], given the more limited capacity for  
121 dispersal on land than in the sea [31].

122 Policies that target single objectives can lead to unintended consequences and a lack of alignment  
123 between goals as we argue above [11-13]. However, protected areas, with their multiple benefits to  
124 wildlife and human societies, offer a low-tech and cost-effective nature-based tool to simultaneously

125 pursue climate change mitigation and adaptation and staunch biodiversity loss [5, 32]. Of course,  
126 methods matter and the ability of protected areas to achieve multiple goals depends on factors such  
127 as level of protection, public engagement, governance, location, size, staff and budget but we have a  
128 large body of experience on how to effectively design and deliver protected areas [33, 34] and  
129 restoration programmes [35]. To date, much effort in marine protected area establishment has  
130 focussed on remote and more intact ecosystems [36] which, while important in delivering planetary  
131 benefits, is insufficient to address other immediate human needs. Extending benefits to more people  
132 will require greater protection efforts in populous regions in both sea and land.

133 Over the past decade, we have gained a much clearer scientific understanding of the role of natural  
134 ecosystems in human wellbeing and planetary processes, and the scale of the challenge from rapid  
135 climate change. Given the plight of natural ecosystems and humanity's reliance on them for our  
136 survival, there is an urgent need to increase protection targets set by the Convention on Biological  
137 Diversity to secure sufficient space for nature to thrive and adapt in our fast-changing world. This is  
138 so important because protected habitats must be part of frontline defence in efforts to mitigate  
139 climate change and to promote ecosystem and societal adaptation against its effects. Our goals need  
140 to coalesce in a joined-up strategy for planetary survival. For marine habitats, there is growing  
141 consensus that at least 30% of the sea should be protected by 2030 [36] and a similar level of  
142 ambition is justified on land [37-39], with protection targeted to achieve ecological representation  
143 and connectivity to support and restore nature and its wealth of services. For the next phase of  
144 reshaping global conservation ambitions, our focus must shift from saving nature, to harnessing the  
145 benefits of nature to save ourselves.

146

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148 **References**

- 149 [1] Veron, J. E. N., Hoegh-Guldberg, O., Lenton, T. M., Lough, J. M., Oburae, D. O., Pearce-Kelly, P.,  
150 Sheppard, C. R. C., Spalding, M., Stafford-Smith, M. G. & Rogers, A. D. 2009 The coral reef crisis: the  
151 critical importance of <350 ppm CO<sub>2</sub>. *Marine Poll Bull* **58**, 1428-1436.  
152 (DOI:10.1016/j.marpolbul.2009.09.009).
- 153 [2] Solomon, S., Plattner, G. K., Knutti, R. & Friedlingstein, P. 2009 Irreversible climate change due to  
154 carbon dioxide emissions. *Proc Natl Acad Sci U S A* **106**, 1704-1709. (DOI:10.1073/pnas.0812721106).
- 155 [3] Anthony, K., Bay, L. K., Costanza, R., Firn, J., Gunn, J., Harrison, P., Heyward, A., Lundgren, P.,  
156 Mead, D., Moore, T., et al. 2017 New interventions are needed to save coral reefs. *Nat Ecol Evol* **1**,  
157 1420-1422. (DOI:10.1038/s41559-017-0313-5).
- 158 [4] Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., Schlesinger, W.  
159 H., Shoch, D., Siikamäki, J. V., Smith, P., et al. 2017 Natural climate solutions. *PNAS* **114**, 11645.  
160 (DOI:10.1073/pnas.1710465114).
- 161 [5] Roberts, C. M., O'Leary, B. C., McCauley, D. J., Cury, P., Duarte, C. M., Lubchenco, J., Pauly, D.,  
162 Sáenz-Arroyo, A., Sumaila, U. R., Wilson, R. W., et al. 2017 Marine reserves can mitigate and  
163 promote adaptation to climate change. *PNAS* **114**, 6167-6175. (DOI:10.1073/pnas.1701262114).
- 164 [6] van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G. C.,  
165 Kram, T., Krey, V., Lamarque, J.-F., et al. 2011 The representative concentration pathways: an  
166 overview. *Clim Change* **109**, 5. (DOI:10.1007/s10584-011-0148-z).
- 167 [7] Rogelj, J., Popp, A., Calvin, K. V., Luderer, G., Emmerling, J., Gernaat, D., Fujimori, S., Strefler, J.,  
168 Hasegawa, T., Marangoni, G., et al. 2018 Scenarios towards limiting global mean temperature  
169 increase below 1.5 °C. *Nat Clim Change* **8**, 325-332. (DOI:10.1038/s41558-018-0091-3).
- 170 [8] Williamson, P. 2016 Emissions reduction: Scrutinize CO<sub>2</sub> removal methods. *Nature* **530**, 153-155.  
171 (DOI:10.1038/530153a).
- 172 [9] IPBES. 2019 Summary for policymakers of the global assessment report on biodiversity and  
173 ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem  
174 Services. IPBES secretariat, Bonn, Germany.
- 175 [10] Shah, D. 2019 Viewpoint: Extinction Rebellion: radical or rational? *Br J Gen Pract* **69**, 345.  
176 (DOI:10.3399/bjgp19X704357).
- 177 [11] Cannell, M. G. R. Environmental impacts of forest monocultures: water use, acidification,  
178 wildlife conservation, and carbon storage. In *Planted Forests: Contributions to the Quest for*  
179 *Sustainable Societies* (eds. J. R. Boyle, J. K. Winjum, K. Kavanagh & E. C. Jensen), pp. 236-262.
- 180 [12] Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes,  
181 D. & Yu, T.-H. 2008 Use of U.S. croplands for biofuels increases greenhouse gases through emissions  
182 from land-use change. *Science* **319**, 1238. (DOI:10.1126/science.1151861).
- 183 [13] Lindenmayer, D. B., Hulvey, K. B., Hobbs, R. J., Colyvan, M., Felton, A., Possingham, H., Steffen,  
184 W., Wilson, K., Youngentob, K. & Gibbons, P. 2012 Avoiding bio-perversity from carbon  
185 sequestration solutions. *Conserv Lett* **5**, 28-36. (DOI:10.1111/j.1755-263X.2011.00213.x).
- 186 [14] Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I. & Marbà, N. 2013 The role of coastal  
187 plant communities for climate change mitigation and adaptation. *Nat Clim Change* **3**, 961-968.  
188 (DOI:10.1038/NCLIMATE1970).
- 189 [15] Gamfeldt, L., Snä, T., Bagchi, R., Jonsson, M., Gustafsson, L., Kjellander, P., Ruiz-Jaen, M. C.,  
190 Fröberg, M., Stendahl, J., Philipson, C. D., et al. 2012 Higher levels of multiple ecosystem services are  
191 found in forests with more tree species. *Nat Commun* **4**, 1340. (DOI:10.1038/ncomms2328).

192 [16] Page, S. E., Rieley, J. O. & Banks, C. J. 2011 Global and regional importance of the tropical  
 193 peatland carbon pool. *Glob Chang Biol* **17**, 798-818. (DOI:10.1111/j.1365-2486.2010.02279.x).

194 [17] Beck, M. W. & Lange, G.-M. 2016 Managing coasts with natural solutions: guidelines for  
 195 measuring and valuing the coastal protection services of mangroves and coral reefs (Technical  
 196 Report). WAVES, World Bank, Washington, D.C.

197 [18] O'Leary, B. C. & Roberts, C. M. 2018 Ecological connectivity across ocean depths: implications  
 198 for protected area design. *Glob Ecol Conserv* **15**, e00431. (DOI:10.1016/j.gecco.2018.e00431).

199 [19] Wilmers, C. C., Estes, J. A., Edwards, M., Laidre, K. L. & Konar, B. 2012 Do trophic cascades affect  
 200 the storage and flux of atmospheric carbon? An analysis for sea otters and kelp forests. *Front Ecol*  
 201 *Environ* **10**, 409-415. (DOI:10.1890/110176).

202 [20] Ellison, D., Morris, C. E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarsa, D., Gutierrez, V.,  
 203 Noordwijk, M. v., Creed, I. F., Pokorny, J., et al. 2017 Trees, forests and water: cool insights for a hot  
 204 world. *Glob Environ Change* **43**, 51-61. (DOI:10.1016/j.gloenvcha.2017.01.002).

205 [21] Lentini, P. E., Martin, T. G., Gibbons, P., Fischer, J. & Cunningham, S. A. 2012 Supporting wild  
 206 pollinators in a temperate agricultural landscape: maintaining mosaics of natural features and  
 207 production. *Biol Conserv* **149**, 84-92. (DOI:10.1016/j.biocon.2012.02.004).

208 [22] Bianchi, F. J. J. A., Booij, C. J. H. & Tschamtkke, T. 2006 Sustainable pest regulation in agricultural  
 209 landscapes: a review on landscape composition, biodiversity and natural pest control. *Proc Royal Soc*  
 210 *B* **273**, 1715-1727. (DOI:10.1098/rspb.2006.3530).

211 [23] Convention on Biological Diversity. 2010 COP Decision X/2. Strategic plan for biodiversity 2011–  
 212 2020. (<https://www.cbd.int/decision/cop/?id=12268> accessed: 1 October 2019)

213 [24] United Nations. 2015 Transforming our world: the 2030 Agenda for Sustainable Development.  
 214 A/RES/70/1.

215 [25] IPCC. 2018 Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of  
 216 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the  
 217 context of strengthening the global response to the threat of climate change, sustainable  
 218 development, and efforts to eradicate poverty. World Meteorological Organization, Geneva,  
 219 Switzerland, 32 pp.

220 [26] Wilson, E. O. 2016 *Half-earth: our planet's fight for life*, Liveright; 272 p.

221 [27] O'Leary, B. C., Winther-Janson, M., Bainbridge, J. M., Aitken, J., Hawkins, J. P. & Roberts, C. M.  
 222 2016 Effective coverage targets for ocean protection. *Conserv Lett* **9**, 398-404.  
 223 (DOI:10.1111/conl.12247).

224 [28] Pinsky, M. L., Reygondeau, G., Caddell, R., Palacios-Abrantes, J., Spijkers, J. & Cheung, W. W. L.  
 225 2018 Preparing ocean governance for species on the move. *Science* **360**, 1189.  
 226 (DOI:10.1126/science.aat2360).

227 [29] Chen, I. C., Hill, J. K., Ohlemüller, R., Roy, D. B. & Thomas, C. D. 2011 Rapid range shifts of  
 228 species associated with high levels of climate warming. *Science* **333**, 1024.  
 229 (DOI:10.1126/science.1206432).

230 [30] Svancara, L. K., Brannon J., R., Scott, M., Groves, C. R., Noss, R. F. & Pressey, R. L. 2005 Policy-  
 231 driven versus evidence-based conservation: a review of political targets and biological needs.  
 232 *BioScience* **55**, 989-995. (DOI:10.1641/0006-3568(2005)055[0989:pvecar]2.0.co;2).

233 [31] Kinlan, B. P. & Gaines, S. D. 2003 Propagule dispersal in marine and terrestrial environments: a  
 234 community perspective. *Ecology* **84**, 2007-2020. (DOI:10.1890/01-0622).

- 235 [32] Leverington, F. J., Laemos Costa, K., Pavese, H., Lisle, A. & Hockings, M. 2010 A global analysis of  
236 protected area management effectiveness. *Environmental Management* **46**, 685-698.  
237 (DOI:10.1007/s00267-010-9564-5)).
- 238 [33] Gill, D. A., Mascia, M. B., Ahmadi, G. N., Glew, L., Lester, S. E., Barnes, M., Craigie, I., Darling, E.  
239 S., Free, C. M., Geldmann, J., et al. 2017 Capacity shortfalls hinder the performance of marine  
240 protected areas globally. *Nature* **543**, 665-669. (DOI:10.1038/nature21708).
- 241 [34] Edgar, G. J., Stuart-Smith, R. D., Willis, T. J., Kininmonth, S., Baker, S. C., Banks, S., Barrett, N. S.,  
242 Becerro, M. A., Bernard, A. T. F., Berkhout, J., et al. 2014 Global conservation outcomes depend on  
243 marine protected areas with five key features. *Nature* **506**, 216-220. (DOI:10.1038/nature13022).
- 244 [35] Bayraktarov, L., Saunders, M. I., Abdullah, S., Mills, M., Beher, J., Possingham, H. P., Mumby, P. J.  
245 & Lovelock, C. E. 2016 The cost and feasibility of marine coastal restoration. *Ecol Appl.*  
246 (DOI:10.1890/15-1077).
- 247 [36] IUCN. 2016 Motion 053 - Increasing marine protected area coverage for effective marine  
248 biodiversity conservation.  
249 ([https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC\\_2016\\_RES\\_050\\_EN.pdf](https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2016_RES_050_EN.pdf) accessed:  
250 1 October 2019)
- 251 [37] Baillie, J. & Zhang, Y.-P. 2018 Space for nature. *Science* **361**, 1051.  
252 (DOI:10.1126/science.aau1397).
- 253 [38] Dinerstein, E., Vynne, C., Sala, E., Joshi, A. R., Fernando, S., Lovejoy, T. E., Mayorga, J., Olson, D.,  
254 Asner, G. P., Baillie, J. E. M., et al. 2019 A global deal for nature: guiding principles, milestones, and  
255 targets. *Science Advances* **5**, eaaw2869. (DOI:10.1126/sciadv.aaw2869).
- 256 [39] Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., Hahn, N.,  
257 Palminteri, S., Hedao, P., Noss, R., et al. 2017 An Ecoregion-Based Approach to Protecting Half the  
258 Terrestrial Realm. *BioScience* **67**, 534-545. (DOI:10.1093/biosci/bix014).

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