PROTECTED AREAS

One-third of global protected land is under intense human pressure

Kendall R. Jones,[1,2]* Oscar Venter,[3] Richard A. Fuller,[2,4] James R. Allan,[1,2] Sean L. Maxwell,[1,2] Pablo Jose Negret,[1,2] James E. M. Watson[1,2,5]

In an era of massive biodiversity loss, the greatest conservation success story has been the growth of protected land globally. Protected areas are the primary defense against biodiversity loss, but extensive human activity within their boundaries can undermine this. Using the most comprehensive global map of human pressure, we show that 6 million square kilometers (32.8%) of protected land is under intense human pressure. For protected areas designated before the Convention on Biological Diversity was ratified in 1992, 55% have since experienced human pressure increases. These increases were lowest in large, strict protected areas, showing that they are potentially effective, at least in some nations. Transparent reporting on human pressure within protected areas is now critical, as are global targets aimed at efforts required to halt biodiversity loss.

In response to massive worldwide biodiversity loss (*1*), the global extent of protected land has roughly doubled in size since the 1992 Earth Summit in Rio de Janeiro, Brazil, with more than 202,000 protected areas now covering 14.7% of the world's terrestrial area (*2*). The recent expansion has been closely associated with Aichi Biodiversity Target 11, which mandates the inclusion of at least 17% of terrestrial areas in effectively managed and ecologically representative protected areas by 2020 (*3*). Protected areas have various management objectives, ranging from strict biodiversity conservation areas [International Union for Conservation of Nature (IUCN) categories I and II] to zones permitting certain human activities and sustainable resource extraction (IUCN categories III to VI), but the primary objective of all protected areas with an IUCN category is to conserve nature (*4*). As such, maintaining the ecological integrity and natural condition of these areas is essential to ensure the protection of species, habitats, and the ecological and evolutionary processes that sustain them (*3*).

The increasing growth and overall extent of protected areas is deservedly celebrated as a conservation success story (*5*), and there is no doubt that well-managed protected areas can preserve biodiversity (*6*, *7*). However, despite the clear relationship between human activities and biodiversity decline (*8*), and the prevalence of these activities inside many protected areas (*9*), there has been only one global assessment of multiple human pressures within protected areas (*10*). This study mapped human pressure at a coarse scale, considered only a small subset of global protected areas (n = 8950), and did not consider many important human pressures, such as roads and navigable waterways (*11*), livestock grazing (*12*), and urbanization (*13*). A comprehensive analysis of cumulative human pressure within protected areas, and how this has changed since the Convention on Biological Diversity was ratified in 1992, is necessary to assess how human pressure inside protected areas may impede progress toward international conservation targets (*3*).

Here we use the most comprehensive global map of human pressure on the environment [the human footprint; (*14*)] to quantify the extent and intensity of human pressure within protected areas and how this has changed since 1992. The human footprint provides a single pressure metric that combines data on built environments, intensive agriculture, pasture lands, human population density, nighttime lights, roads, railways, and navigable waterways (*14*). The presence of these pressures is directly linked to constraints on and declines in biodiversity (*8*, *15*, *16*). We delineate areas of intense human pressure in protected areas (human footprint ≥ 4; see methods) and explore how excluding these areas would affect measurements of progress toward Aichi Biodiversity Target 11. We also assess the impact of protected-area size and IUCN management category on patterns of human pressure within protected areas.

We find that the average human footprint score within protected areas is 3.3, almost 50% lower than the global mean of 6.16 (*14*). Despite this, human activities are prevalent across many protected areas, with only 42% of protected land free of any measurable human pressure (figs. S1 and S2). Areas under intense human pressure make up 32.8% (6,005,249 km^2) of global protected land (Fig. 1), and more than half (57%) of all protected

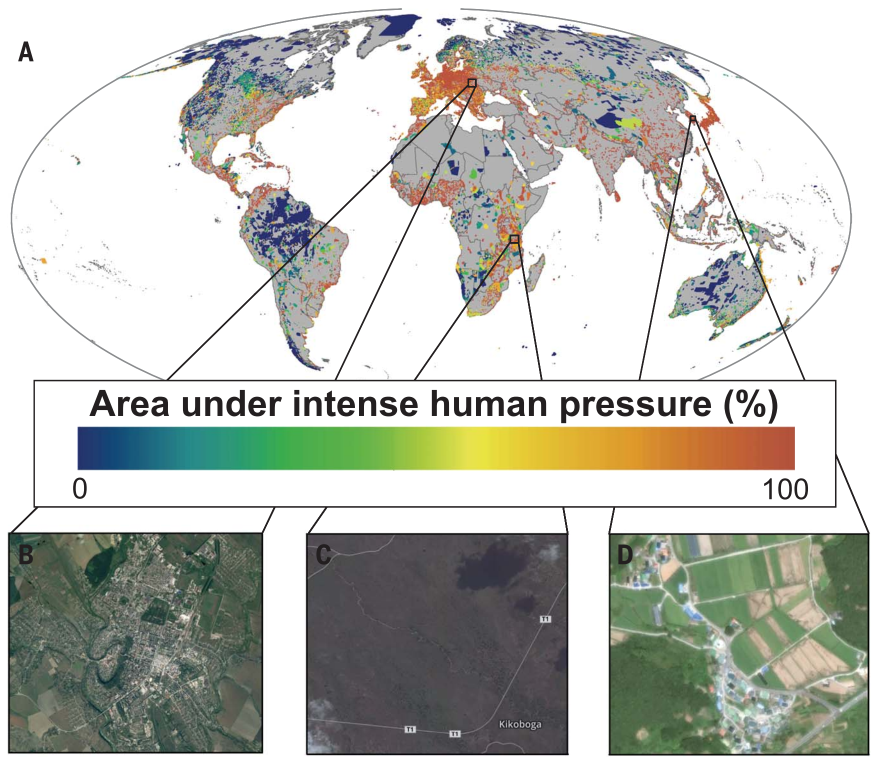

Fig. 1. Human pressure within protected areas. (**A**) Proportion of each protected area that is subject to intense human pressure, spanning from low (blue) to high (orange) levels. (**B**) Kamianets-Podilskyi, a city within Podolskie Tovtry National Park, Ukraine. (**C**) Major roads fragment habitat within Mikumi National Park, Tanzania. (**D**) Agriculture and buildings within Dadohaehaesang National Park, South Korea. [Photo credits: Google Earth]

[1]School of Earth and Environmental Sciences, The University of Queensland, St. Lucia, Queensland 4072, Australia. [2]Centre for Conservation and Biodiversity Science, The University of Queensland, St. Lucia, Queensland 4072, Australia. [3]Ecosystem Science and Management Program, University of Northern British Columbia, Prince George, British Columbia V2N 4Z9, Canada. [4]School of Biological Sciences, University of Queensland, Brisbane, Queensland 4072, Australia. [5]Wildlife Conservation Society, Global Conservation Program, Bronx, NY 10460, USA.
*Corresponding author. Email: k.jones10@uq.edu.au

areas contain only land under intense human pressure (concentrated in western Europe, southern Asia, and Africa; Fig. 1). Just 4334 protected areas (10% of analyzed areas; see methods) are completely free of intense human pressure (Fig. 1), and these primarily occur in remote areas of high-latitude nations, such as Russia and Canada.

Protected areas with strict biodiversity conservation objectives (IUCN categories I and II) are subject to significantly lower levels of human pressure (Kruskal-Wallis test; $H = 5045.2$, $P < 0.001$; fig. S3A), and a lower proportion of their area under is intense human pressure (Kruskal-Wallis test; $H = 4609.6$, $P < 0.001$; fig. S3B), compared to those permitting a wider range of human activities (Table 1). This effect is not sensitive to the threshold used to determine intense human pressure (fig. S4), and there are still a considerable number of less-strict protected areas (IUCN categories III to VI) under low human pressure (fig. S4). Smaller protected areas are much more likely to have high levels of human pressure than larger protected areas (Fig. 2; linear regression, t value = −58.02, $P < 0.001$). Nonetheless, many small protected areas contain low human pressure (Fig. 2), and they can be crucial for providing habitat in highly modified landscapes (*17*). This is especially true in protected areas where biodiversity has persisted under high human influence and traditional management practices (IUCN category VI) can maintain biodiversity values (*18*).

Mean human pressure has increased substantially since the Earth Summit, both worldwide [9% increase; (*14*)] and within protected areas (6% increase; table S1). Human pressure increased in 55% (n = 11,390) of protected areas designated in or before 1993, with substantial increases (mean human footprint increase > 1) occurring in 10% (n = 3966; fig. S5). Although strict protected areas (IUCN categories I and II) have the lowest current levels of human pressure, IUCN management category does not appear to affect the rate at which human pressure has increased (table S1). Protected areas designated after 1993 have a lower level of intense human pressure within their borders, compared to those designated in or before 1993, suggesting that recent protected-area establishment may be targeting a higher percentage of area under low human pressure (Table 1).

The most concerning increases in human pressure are in those landscapes that were intact when a protected area was designated. Within protected areas designated during or before 1993, 280,000 km^2 of land has changed from a low– to an intense–human pressure category (table S1). Strict protected areas (IUCN categories I and II) lost far less of their low-pressure land than non-strict protected areas (3.6 versus 8%; fig. S6), and, by far, the largest losses occurred in those without an IUCN category (17%; fig. S6).

Human pressure inside protected areas is likely compromising national progress toward Convention on Biological Diversity obligations. Almost three-quarters of nations (n = 137, 70%) have >50% of their protected land under intense human pressure (fig. S7 and table S2). If one assumes that protected land under intense human pressure does not contribute toward conservation targets, we show that 74 of the 111 nations that have reached a level of 17% protected-area coverage would drop out of that list (fig. S7 and table S2). Moreover, the protection of some biomes (for example, mangroves and temperate forests) would decrease by >70% (Fig. 3A). Although 301 (38% of) ecoregions (ecologically

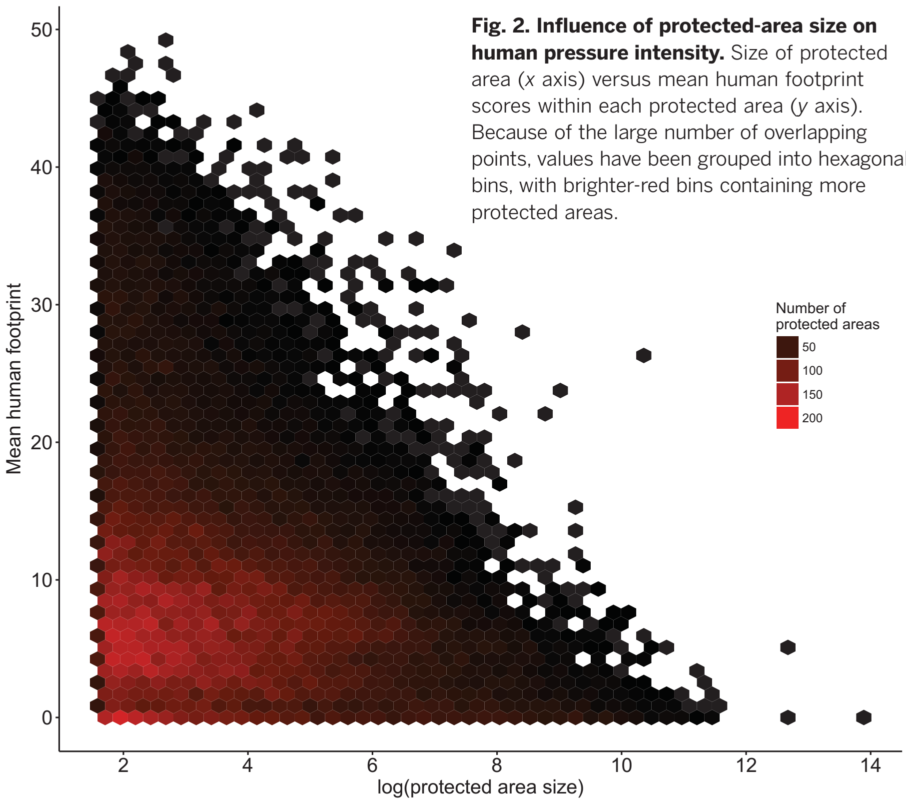

Fig. 2. Influence of protected-area size on human pressure intensity. Size of protected area (*x* axis) versus mean human footprint scores within each protected area (*y* axis). Because of the large number of overlapping points, values have been grouped into hexagonal bins, with brighter-red bins containing more protected areas.

Table 1. Influence of protected-area category on current human pressure. Strict biodiversity conservation areas (IUCN categories I and II) contain lower levels of human pressure than protected areas that permit a broader range of activities (for example, nonindustrial resource use; IUCN categories III to VI). NA represents those protected areas without an assigned IUCN category. Protected areas smaller than 5 km^2 are excluded.

IUCN category	Number of protected areas (area in km^2)	Mean human footprint	Area under intense pressure (%)
I	3,992 (2,089,560)	1.27	12.4
II	3,628 (4,529,337)	2.12	24.1
III	1,672 (199,062)	2.42	24.0
IV	7,412 (2,410,055)	3.68	36.6
V	8,378 (2,557,816)	5.21	45.8
VI	2,365 (2,859,949)	2.4	26.4
NA	14,481 (4,502,128)	4.38	44.2
All protected areas	41,928 (19,147,911)	3.26	32.8
Protected areas established before 1993	22,046 (11,048,058)	3.36	34.9
Protected areas established after 1993	19,882 (8,099,852)	3.13	29.7

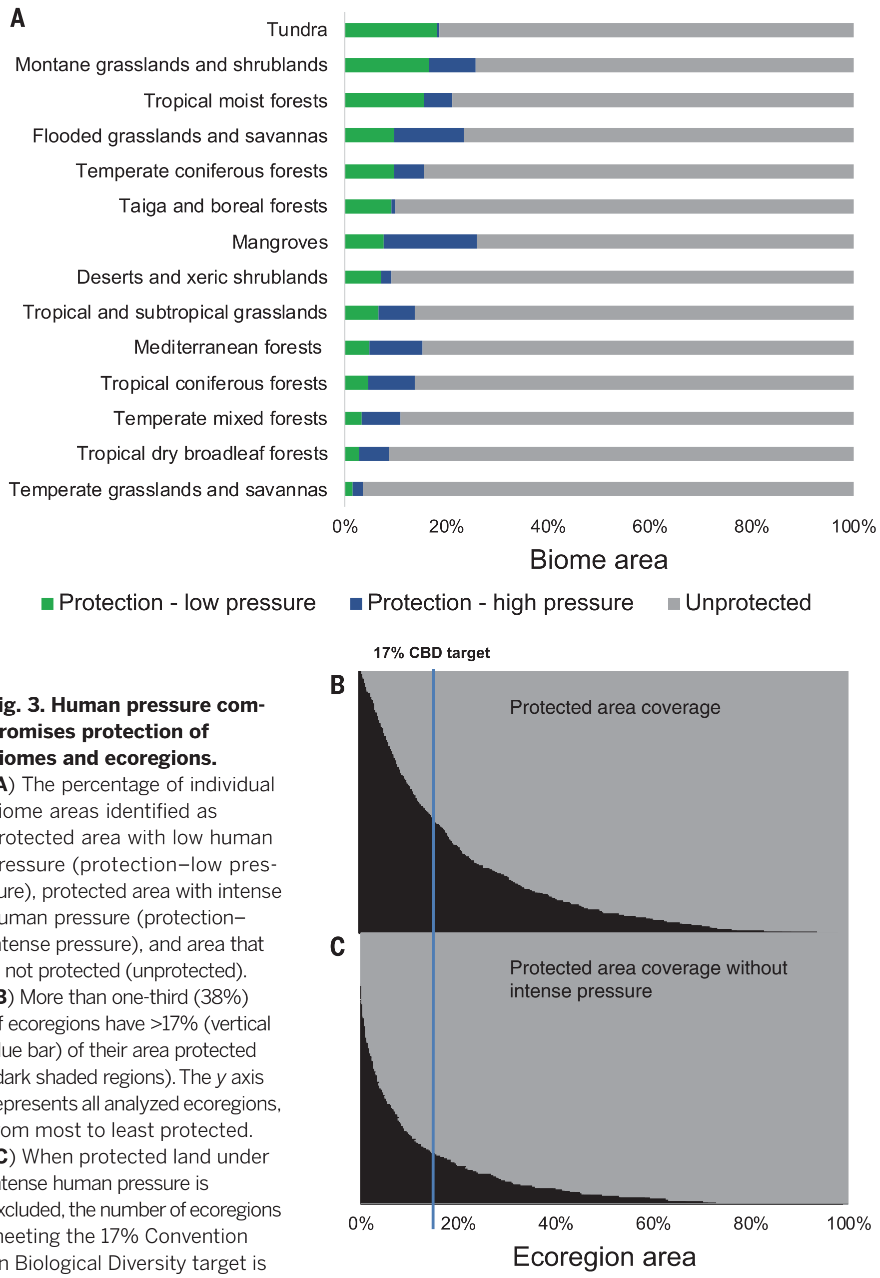

Fig. 3. Human pressure compromises protection of biomes and ecoregions. (**A**) The percentage of individual biome areas identified as protected area with low human pressure (protection–low pressure), protected area with intense human pressure (protection–intense pressure), and area that is not protected (unprotected). (**B**) More than one-third (38%) of ecoregions have >17% (vertical blue bar) of their area protected (dark shaded regions). The *y* axis represents all analyzed ecoregions, from most to least protected. (**C**) When protected land under intense human pressure is excluded, the number of ecoregions meeting the 17% Convention on Biological Diversity target is almost halved (21%).

similar areas) currently have more than 17% coverage inside protected areas (Fig. 3B), excluding land subject to intense human pressure would almost halve this (n = 167, 21%; Fig. 3C). These results make a clear case that nations reporting solely on the area of protected land may be overestimating the true level of protection for biodiversity and highlight the need for international reporting on protected areas to include robust, reproducible measures of human pressure and ecological condition (*5*). It is also important to note that we are unable to capture the full range of human impacts on biodiversity, such as ecological shifts associated with changing climate and disturbance regimes (*19*), which should also be incorporated into measures of protected-area condition.

Although we show that human pressure may be compromising the conservation value of protected lands worldwide, we are not suggesting that high-pressure protected areas be degazzetted (abolished) or defunded. On the contrary, it is crucial that nations recognize the profound conservation gains that can be realized by "upgrading" (increasing the strictness of protection zones) and restoring degraded protected areas, while respecting the needs of local people (*20*). A crucial part of this will be combatting the chronic underfunding of protected areas worldwide, which will require recognizing and quantifying the return on investment that well-managed protected areas provide, through preservation of cultural heritage, improvements in economic and social well-being, and the natural capital they hold (*21*, *22*). Funding could also be increased through mechanisms that allow nations to trade or offset conservation funding and commitments, so wealthy nations can support conservation in poorer nations (*23*). Our finding that there is no relationship between the degree of human pressure and IUCN categories III to VI points to a need for nations to categorize protected areas on the basis of consistent classifications of permitted human activities, which would ensure that IUCN categories better reflect the actual impacts of human activities within protected areas (*24*).

We show that human pressure is prevalent within many protected areas, but our work is subject to three caveats. First, although we explore a scenario in which land under intense human pressure does not contribute toward conservation targets, some aspects of biodiversity can persist in areas of high human pressure [for example, mixed agricultural land (*25*)], and some protected areas are intentionally placed in high-pressure areas. Second, the human footprint does not account for all pressures affecting biodiversity, such as poaching or climate change. This is especially true for developing regions, where activities such as small-scale shifting agriculture and poaching are exerting considerable pressure on biodiversity in many protected areas (*9*). Third, the human footprint measures the pressure humans place on the environment, not the realized state or impact on biodiversity. Further studies investigating how natural systems within protected areas respond to specific human pressures, or assessing the impacts of human pressure on biodiversity within protected areas at a local scale, would provide valuable additional information for measuring progress toward Convention on Biological Diversity commitments.

The Convention on Biological Diversity provides an opportunity to overcome one of society's grandest challenges—halting global biodiversity loss. Many nations report being on track to meet their commitments (*2*), but our analysis suggests that this progress may be undermined by widespread human pressure inside protected areas. As nations continue to expand their protected-area estates, there is clearly an urgent need for them to undertake objective assessments of human pressure and habitat condition within protected areas. These efforts must be combined with better management practices in land beyond protected areas, to ensure that nature conservation goals can be more fully achieved across diverse landscapes in the long term.

REFERENCES AND NOTES

1. A. D. Barnosky *et al.*, *Nature* **471**, 51–57 (2011).
2. UN Environment World Conservation Monitoring Centre, International Union for Conservation of Nature, World Database on Protected Areas (2017); www.protectedplanet.net.
3. Convention on Biological Diversity, "COP 10 decision X/2: strategic plan for biodiversity 2011–2020," 10th Meeting of the Conference of the Parties to the Convention on Biological Diversity, Nagoya, Japan, 18 to 29 October 2010.
4. N. Dudley, S. Stolton, P. Shadie, *Guidelines for Applying Protected Area Management Categories* (International Union for Conservation of Nature, Gland, Switzerland, 2008).

5. J. E. M. Watson *et al.*, *Conserv. Biol.* **30**, 243–248 (2016).
6. C. L. Gray *et al.*, *Nat. Commun.* **7**, 12306 (2016).
7. B. W. T. Coetzee, K. J. Gaston, S. L. Chown, *PLOS ONE* **9**, e105824 (2014).
8. T. Newbold *et al.*, *Nature* **520**, 45–50 (2015).
9. W. F. Laurance *et al.*, *Nature* **489**, 290–294 (2012).
10. J. Geldmann, L. N. Joppa, N. D. Burgess, *Conserv. Biol.* **28**, 1604–1616 (2014).
11. W. F. Laurance, M. Goosem, S. G. W. Laurance, *Trends Ecol. Evol.* **24**, 659–669 (2009).
12. J. B. Kauffman, W. C. Krueger, *J. Range Manage.* **37**, 430–438 (1984).
13. M. F. J. Aronson *et al.*, *Proc. Biol. Sci.* **281**, 20133330 (2014).
14. O. Venter *et al.*, *Nat. Commun.* **7**, 12558 (2016).
15. K. Safi, N. Pettorelli, *Glob. Ecol. Biogeogr.* **19**, 352–362 (2010).
16. M. A. Tucker *et al.*, *Science* **359**, 466–469 (2018).
17. T. H. Ricketts *et al.*, *Proc. Natl. Acad. Sci. U.S.A.* **102**, 18497–18501 (2005).
18. P. Moguel, V. M. Toledo, *Conserv. Biol.* **13**, 11–21 (1999).
19. B. R. Scheffers *et al.*, *Science* **354**, aaf7671 (2016).
20. R. M. Pringle, *Nature* **546**, 91–99 (2017).
21. A. Balmford *et al.*, *Science* **297**, 950–953 (2002).
22. J. E. M. Watson, N. Dudley, D. B. Segan, M. Hockings, *Nature* **515**, 67–73 (2014).
23. P. A. Lindsey *et al.*, *Glob. Ecol. Conserv.* **10**, 243–252 (2017).
24. B. Horta e Costa *et al.*, *Mar. Policy* **72**, 192–198 (2016).
25. B. Phalan, M. Onial, A. Balmford, R. E. Green, *Science* **333**, 1289–1291 (2011).

ACKNOWLEDGMENTS

We are grateful to M. Di Marco, M. Hockings, J. Geldmann, N. Burgess, L. Coad, and the Green Fire Science lab group for providing constructive feedback and discussions around elements of this study. **Funding:** This work was supported by an Australian Government Research Training Program Scholarship. **Author contributions:** K.R.J., O.V., and J.E.M.W. designed the research. K.R.J. performed the analysis. K.R.J., O.V., R.A.F., J.R.A., S.L.M., P.J.N., and J.E.M.W. wrote the manuscript. **Competing interests:** None declared. **Data and materials availability:** The revised human footprint data are available for download from http://datadryad.org/resource/doi:10.5061/dryad.052q5. Protected-area data are available for download from www.protectedplanet.net/. Ecoregional data are available for download from www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world. Country-, ecoregion-, and biome-level protected area–coverage statistics are available for download from www.protectedplanet.net/c/protected-planet-report-2016/protected-planet-report-2016–data–maps-figures. All other data needed to evaluate the conclusions in the paper are present in the paper or the supplementary materials.

SUPPLEMENTARY MATERIALS

www.sciencemag.org/content/360/6390/788/suppl/DC1
Materials and Methods
Figs. S1 to S7
Tables S1 to S2
References (*26*–*36*)

14 September 2017; accepted 29 March 2018
10.1126/science.aap9565

One-third of global protected land is under intense human pressure

Kendall R. Jones, Oscar Venter, Richard A. Fuller, James R. Allan, Sean L. Maxwell, Pablo Jose Negret and James E. M. Watson

Science **360** (6390), 788-791.
DOI: 10.1126/science.aap9565

Protected yet pressured

Protected areas are increasingly recognized as an essential way to safeguard biodiversity. Although the percentage of land included in the global protected area network has increased from 9 to 15%, Jones *et al.* found that a third of this area is influenced by intensive human activity. Thus, even landscapes that are protected are experiencing some human pressure, with only the most remote northern regions remaining almost untouched.

Science, this issue p. 788