

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/337933460>

Pervasive human-driven decline of life on Earth points to the need for transformative change

Article in Science · December 2019

DOI: 10.1126/science.aax3100

CITATIONS

746

READS

5,089

28 authors, including:



Sandra Diaz

National University of Cordoba, Argentina

344 PUBLICATIONS 56,546 CITATIONS

[SEE PROFILE](#)



Josef Settele

Helmholtz-Zentrum für Umweltforschung

666 PUBLICATIONS 29,319 CITATIONS

[SEE PROFILE](#)



Eduardo S. Brondizio

Indiana University Bloomington

257 PUBLICATIONS 17,487 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



SOS * Second-order Science * Sciences (in and) of Society * [View project](#)



Are local range expansions in southerly populations of *Aloidendron dichotomum* early indicators of a future range shift? [View project](#)

REVIEW SUMMARY

GLOBAL CONSERVATION

Pervasive human-driven decline of life on Earth points to the need for transformative change

Sandra Díaz*, Josef Settele, Eduardo S. Brondízio, Hien T. Ngo, John Agard, Almut Arneth, Patricia Balvanera, Kate A. Brauman, Stuart H. M. Butchart, Kai M. A. Chan, Lucas A. Garibaldi, Kazuhito Ichii, Jianguo Liu, Suneetha M. Subramanian, Guy F. Midgley, Patricia Miloslavich, Zsolt Molnár, David Obura, Alexander Pfaff, Stephen Polasky, Andy Purvis, Jona Razzaque, Belinda Reyers, Rinku Roy Chowdhury, Yunne-Jai Shin, Ingrid Visseren-Hamakers, Katherine J. Willis, Cynthia N. Zayas

BACKGROUND: Human actions have long been known to drive declines in nature, and there is growing awareness of how globalization means that these drivers increasingly act at a distance (telecoupling). However, evidence from different disciplines has largely accumulated in parallel, and the global effects of telecouplings have never been addressed comprehensively. Now, the first integrated global-scale intergovernmental assessment of the status, trends, and future of the links between people and nature provides an unprecedented picture of the extent of our mutual dependence, the breadth and depth of the ongoing and impending crisis, and the interconnectedness among sectors and regions.

ADVANCES: Human impacts on life on Earth have increased sharply since the 1970s. The world is increasingly managed to maximize the flow of material contributions from nature to keep up with rising demands for food,

energy, timber, and more, with global trade increasing the geographic separation between supply and demand. This unparalleled appropriation of nature is causing the fabric of life on which humanity depends to fray and unravel: Most indicators of the state of nature, whether monitored by natural and social scientists or by Indigenous Peoples and local communities, are declining. These include the number and population size of wild species, the number of local varieties of domesticated species, the distinctness of ecological communities, and the extent and integrity of many terrestrial and aquatic ecosystems. As a consequence, nature's capacity to provide crucial benefits has also declined, including environmental processes underpinning human health and nonmaterial contributions to human quality of life. The costs are distributed unequally, as are the benefits of an expanding global economy.



Traditional diversity-rich human landscapes, and the livelihoods and identities that depend on them, face global threats. Mosaics of crops, forest, and pasture have been maintained for millennia around the world. Now, they are under increasing threat from climate change and large-scale land use change to accommodate global demands for commodities. So are the livelihoods and cultural identity of the peoples that live in them, such as this woman collecting fodder for her flock in the Checacupe district, Perú.

These trends in nature and its contributions to people are projected to worsen in the coming decades—unevenly so among different regions—unless rapid and integrated action is taken to reduce the direct drivers responsible for most change over the past 50 years: land and sea use change, direct harvesting of many plants and animals, climate change (whose impacts are set to accelerate), pollution, and the spread of invasive alien species. Exploratory scenarios suggest that a world with increased regional barriers—resonating with recent geopolitical trends—will yield more negative global trends in nature, as well as the greatest

ON OUR WEBSITE

Read the full article at <http://dx.doi.org/10.1126/science.aax3100>

disparity in trends across regions, greater than a world with liberal financial markets, and much greater than one that prioritizes and integrates actions toward sustainable development. Evidence from target-seeking scenarios and pathways indicates that a world that achieves many of the global biodiversity targets and sustainability goals related to food, energy, climate, and water is not—yet—beyond reach, but that no single action can get us there.

OUTLOOK: Our comprehensive assessment of status, trends, and possible futures for nature and people suggests that action at the level of direct drivers of nature decline, although necessary, is not sufficient to prevent further deterioration of the fabric of life on Earth. Reversal of recent declines—and a sustainable global future—are only possible with urgent transformative change that tackles the root causes: the interconnected economic, socio-cultural, demographic, political, institutional, and technological indirect drivers behind the direct drivers. As well as a pan-sectoral approach to conserving and restoring the nature that underpins many goals, this transformation will need innovative governance approaches that are adaptive; inclusive; informed by existing and new evidence; and integrative across systems, jurisdictions, and tools. Although the challenge is formidable, every delay will make the task even harder. Crucially, our analysis pinpoints five priority interventions (“levers”) and eight leverage points for intervention in the indirect drivers of global social and economic systems where they can make the biggest difference. ■

The list of author affiliations is available in the full article online.

*Corresponding author. Email: sandra.diaz@unc.edu.ar

Cite this article as S. Díaz et al., *Science* **366**, eaax3100 (2019). DOI: 10.1126/science.aax3100



TOMORROW'S EARTH

Read more articles online at scim.ag/TomorrowsEarth

REVIEW

GLOBAL CONSERVATION

Pervasive human-driven decline of life on Earth points to the need for transformative change

Sandra Díaz^{1,2,*}, Josef Settele^{3,4}, Eduardo S. Brondizio⁵, Hien T. Ngo⁶, John Agard⁷, Almut Arneth⁸, Patricia Balvanera⁹, Kate A. Brauman¹⁰, Stuart H. M. Butchart^{11,12}, Kai M. A. Chan¹³, Lucas A. Garibaldi¹⁴, Kazuhito Ichii^{15,16}, Jianguo Liu¹⁷, Suneetha M. Subramanian^{18,19}, Guy F. Midgley²⁰, Patricia Milosavljević^{21,22}, Zsolt Molnár²³, David Obura^{24,25}, Alexander Pfaff²⁶, Stephen Polasky^{27,28}, Andy Purvis^{29,30}, Jona Razzaque³¹, Belinda Reyers^{32,33}, Rinku Roy Chowdhury³⁴, Yunne-Jai Shin^{35,36}, Ingrid Visseren-Hamakers^{37,38}, Katherine J. Willis^{39,40}, Cynthia N. Zayas⁴¹

The human impact on life on Earth has increased sharply since the 1970s, driven by the demands of a growing population with rising average per capita income. Nature is currently supplying more materials than ever before, but this has come at the high cost of unprecedented global declines in the extent and integrity of ecosystems, distinctness of local ecological communities, abundance and number of wild species, and the number of local domesticated varieties. Such changes reduce vital benefits that people receive from nature and threaten the quality of life of future generations. Both the benefits of an expanding economy and the costs of reducing nature's benefits are unequally distributed. The fabric of life on which we all depend—nature and its contributions to people—is unravelling rapidly. Despite the severity of the threats and lack of enough progress in tackling them to date, opportunities exist to change future trajectories through transformative action. Such action must begin immediately, however, and address the root economic, social, and technological causes of nature's deterioration.

Although previous large-scale environmental assessments have documented how human actions have been driving biodiversity loss and ecosystem deterioration, the recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services Global Assessment (1) has provided an unprecedentedly ambitious, interdisciplinary, and comprehensive synthesis of the evidence. It paints the clearest picture yet of how, despite humanity's profound dependence on nature, we are altering it at a truly planetary

scale, with impacts that are distributed very unequally around the world and among sectors of society. This is the first comprehensive global assessment of nature that followed an intergovernmental process from start to end, covering not only the history of humanity's interactions with nature—with particular focus on the past 50 years—but also how these might change in the future. It was carried out by an independent, interdisciplinary team of experts from more than 50 countries within a framework that fully embraces the interdependence

between people and nature (2–4), using a systematic approach that incorporates indigenous and local knowledge as well as the latest findings of natural and social sciences up to May 2018. Here, we distill the major findings of this report and augment them with more recent evidence.

Taking stock of the fabric of life

The challenges of mitigating and adapting to climate change while achieving food, water, energy, and health security, and overcoming the unequal burdens of environmental deterioration and biodiversity loss, all rest on a common foundation: living nature. Specifically, we consider the fabric of life on Earth that has been “woven” by natural processes over many millions of years and in conjunction with people for many thousands of years. The vital contributions made by living nature to humanity, referred to as nature's contributions to people (4), affect virtually all aspects of human existence and contribute to achieving all the Sustainable Development Goals identified by the United Nations (5, 6). These various contributions are now widely recognized in the scientific literature, but governmental policies and market transactions typically do not reflect their full value (7).

Human actions are causing the fabric of life to unravel, posing serious risks for the quality of life of people. Over the past 50 years, the capacity of nature to support quality of life has declined for 14 of the 18 categories of nature's contributions to people considered by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (Fig. 1). Nature's capacity to provide beneficial regulation of environmental processes—such as modulating air and water quality, sequestering carbon, building healthy soils, pollinating crops, and providing coastal protection from hazards such

¹Consejo Nacional de investigaciones Científicas y Técnicas, Instituto Multidisciplinario de Biología Vegetal (IMBIV), Córdoba, Argentina. ²Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, Casilla de Correo 495, 5000, Córdoba, Argentina. ³Department of Community Ecology, Helmholtz Centre for Environmental Research—UFZ, Halle, Germany. ⁴German Centre for Integrative Biodiversity Research—iDiv, Leipzig, Germany. ⁵Department of Anthropology, Indiana University, Bloomington, IN, USA. ⁶Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) Secretariat, United Nations Campus, Platz der Vereinten Nationen 1, D-53113 Bonn, Germany. ⁷Department of Life Sciences, University of the West Indies, St. Augustine Campus, Trinidad and Tobago. ⁸Atmospheric Environmental Research, Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany. ⁹Instituto de Investigaciones en Ecosistemas y Sustentabilidad, Universidad Nacional Autónoma de México, CP 58190, Morelia, Michoacán, México. ¹⁰Institute on the Environment, University of Minnesota, 325 Learning and Environmental Sciences, 1954 Buford Avenue, St. Paul, MN 55108, USA. ¹¹BirdLife International, David Attenborough Building, Pembroke Street, Cambridge CB2 3QZ, UK. ¹²Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK. ¹³Institute for Resources, Environment, and Sustainability, The University of British Columbia, Vancouver, Canada. ¹⁴Instituto de Investigaciones en Recursos Naturales, Agroecología y Desarrollo Rural, Universidad Nacional de Río Negro, Consejo Nacional de Investigaciones Científicas y Técnicas, Mitre 630, CP 8400, San Carlos de Bariloche, Río Negro, Argentina. ¹⁵Center for Environmental Remote Sensing, Chiba University, 1-33, Yayoi-cho, Inage-ku, Chiba, 263-852, Japan. ¹⁶Center for Global Environmental Research, National Institute for Environmental Studies, 16-2, Onogawa, Tsukuba, 305-0053, Japan. ¹⁷Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, 115 Manly Miles Building, East Lansing, MI 48823, USA. ¹⁸United Nations University (UNU)—Institute for the Advanced Study of Sustainability, Tokyo, Japan. ¹⁹UNU—International Institute for Global Health, Kuala Lumpur, Malaysia. ²⁰Global Change Biology Group, Department of Botany and Zoology, Stellenbosch University, P/Bag X1, Matieland 7602, South Africa. ²¹Institute for Marine and Antarctic Studies, University of Tasmania, and Commonwealth Scientific and Industrial Research Organisation (CSIRO)—Oceans and Atmosphere, Hobart, Tasmania, Australia. ²²Departamento de Estudios Ambientales, Universidad Simón Bolívar, Caracas, Venezuela. ²³Centre for Ecological Research Institute of Ecology and Botany, Magyar Tudományok Akadémia, H-2163 Vácrátót, Hungary. ²⁴Coastal Oceans Research and Development—Indian Ocean (CORDIO) East Africa, Mombasa, Kenya. ²⁵Global Climate Institute, The University of Queensland, QLD 4072, Australia. ²⁶Sanford School of Public Policy, Duke University, Durham, NC 27708, USA. ²⁷Department of Applied Economics, University of Minnesota, 1994 Buford Avenue, St. Paul, MN 55108, USA. ²⁸Department of Ecology, Evolution, and Behavior, University of Minnesota, 1994 Buford Avenue, St. Paul, MN 55108, USA. ²⁹Department of Life Sciences, Natural History Museum, London SW7 5BD, UK. ³⁰Grand Challenges in Ecosystems and the Environment, Imperial College London, Ascot SL5 7PY, UK. ³¹Department of Law, Faculty of Business and Law, University of the West of England, Bristol, Bristol, UK. ³²Stockholm Resilience Centre, Stockholm University, Sweden. ³³Department of Conservation Ecology, Stellenbosch University, Matieland, 7602, South Africa. ³⁴Graduate School of Geography, Clark University, Worcester, MA 01610, USA. ³⁵Marine Biodiversity, Exploitation and Conservation (MARBEC) Research Unit, Institut de Recherche pour le Développement (IRD), Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Centre National de la Recherche Scientifique (CNRS), University of Montpellier, Montpellier, France. ³⁶Department of Biological Sciences, Marine Research Institute, University of Cape Town, 7701 Rondebosch, South Africa. ³⁷Department of Environmental Science and Policy, George Mason University, Fairfax, VA, USA. ³⁸Institute for Management Research, Radboud University, Nijmegen, the Netherlands. ³⁹Royal Botanic Gardens, Kew, Richmond, TW9 3AE, UK. ⁴⁰Long-Term Ecology Laboratory, Department of Zoology, University of Oxford, Oxford OX1 3SZ, UK. ⁴¹Center for International Studies University of the Philippines, Diliman, Philippines.

*Corresponding author. Email: sandra.diaz@unc.edu.ar



Fig. 1. Global trends in the capacity of nature to contribute to good quality of life from 1970 to the present. Fourteen of the 18 categories of nature's contributions to people show a decline. Half of the 18 categories show consistent patterns globally, whereas the other half show declines in some regions and gains in others. For example, forest areas and the nature's contributions to people supported by forests have generally declined in tropical regions while increasing in some temperate areas over the past 50 years. Data supporting global trends and regional variations come from a systematic review of more than 2000 studies (8). Indicators were selected on the basis of availability of global data, prior use in assessments, and alignment with 18 categories. For many categories of nature's contributions, two indicators are included that show different aspects of nature's capacity to contribute to human quality of life within that category. Indicators are defined so that an increase in the indicator is associated with an improvement in nature's contributions. More details and illustrative examples of indicators and references are provided in in table S1. [Modified from (1).]

as storms and storm surges—has decreased globally, although for some benefits, trends vary by region (Fig. 1, third column) (8). For the 100 million to 300 million people who live in coastal areas below the 100-year flood level

(9), the loss of coastal habitats has increased the risk of flooding and storm damage. Loss of animal pollinators affects more than 75% of global food crop types, risking US\$235 billion to 577 billion of global crop output annually

(10). The potential of nature to contribute in nonmaterial ways to human quality of life—through learning and inspiration, physical and psychological experiences, and supporting identities and sense of place—has also declined (Fig. 1). Exceptions to the downward trend of nature's contributions to people come from an increase in many of the material goods provided by nature, including food, energy, timber, and other materials (Fig. 1). For example, the harvest of commercial timber (11) and fish have both increased by almost 50% since 1970, and the value of agricultural crop production (\$2.6 trillion in 2016) has increased approximately threefold. However, even within material contributions, some indicators show a strong decline, such as the abundance of marine fish stocks (12). In addition, the benefits of these increases have not been evenly distributed: Although the prevalence (percentage) of undernourishment has decreased globally in the past two decades, more than 800 million people still face chronic food deprivation (11).

The increase in the global production of consumer goods and the decline in almost all other contributions are directly related. The world is increasingly managed to accelerate the flow of material contributions from nature to keep up with rising demand. Since 1970, global population has doubled (13), per capita consumption has increased by 45%, the value of global economic activity as measured in gross domestic product (GDP) has increased by >300% (14), global trade has increased by ~900% (15), and the extraction of living materials from nature has increased by >200% (16).

The results of this unprecedented appropriation of nature can now be seen much more clearly than even 15 years ago (17), thanks to rapid advances in data and tools for observation, analysis, synthesis, and modeling of marine, freshwater, and especially terrestrial nature. These new data reveal that human actions have directly altered at least 70% of land surface (18, 19); 66% of ocean surface is experiencing increasing cumulative impacts (20); around 85% of wetland area has been lost since the 1700s (21), and 77% of rivers longer than 1000 km no longer flow freely from source to sea (22). Coastal ecosystems show some of the largest and most rapid recent declines. Live coral cover on reefs has nearly halved in the past 150 years and is projected to virtually disappear this century unless there is strong climate change mitigation (23). Seagrass extent is decreasing by more than 10% per decade, while kelp forests have declined in 38% of their biogeographic regions (24).

The biomass of the world's vegetation (25) has halved over human history, and forests now span only 68% of their preindustrial extent

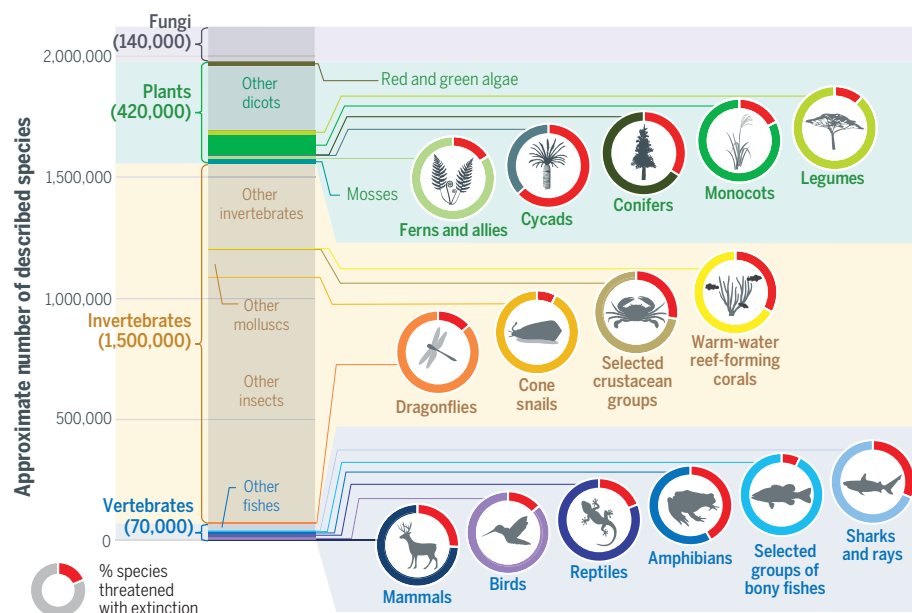


Fig. 2. Extinction risk and diversity in different taxonomic groups. Approximate number of described species of animals, plants, and fungi (bar) and the proportion of species that are threatened with extinction (pie charts) in groups that have been globally assessed for the IUCN Red List (54), either comprehensively or (for legumes, monocots, ferns and allies, dragonflies, and reptiles) through a sampled approach. Proportions assume that data deficient species are equally threatened as non-data deficient species. The proportions of data deficient species in each group are mammals, 15%; birds, 0.5%; reptiles, 21%; amphibians, 23%; bony fishes, 12%; sharks and rays, 42%; dragonflies, 35%; cone snails, 14%; crustaceans, 40%; corals, 17%; ferns, 0.4%; cycads, 1%; conifers, 1.2%; monocots, 12.1%; and legumes, 7.9%. The proportions of data deficient species in each realm are terrestrial, 10.7%; freshwater, 20.8%; and marine, 21.9%. [Sources: (49, 54, 107–113).]

(26). Although the rate of forest loss has slowed globally since the 1980s, it is still rapid in many tropical regions (27), and the increased extent of temperate and boreal forests (28) has been accompanied by increased fragmentation and changes in function [such as carbon storage (29)].

As a result of human impacts, terrestrial ecological communities worldwide are estimated to have lost more than 20% of their original biodiversity on average (30). In the ocean, animal populations and habitat extent have declined in the 20th century (31), with more than 20 described marine species having gone extinct (32). The status of marine fish populations has worsened globally, with one-third of the stocks being currently overfished (32). Illegal, unreported, and unregulated exploitation of fisheries undermine the effectiveness of stock management measures, especially in developing countries, contributing to conflicts (33, 34). Many species that are large, slow-growing, habitat specialist, or carnivorous—such as large cats (35), large sharks (36), primates (37), reef-building corals (38), and woody plants (39)—are declining rapidly in, and being lost from, many places. On average, large terrestrial mammals have been extirpated from 75% of their natural ranges (40), while marine mammals have shown marked declines in abundance

in recent centuries, many to near extinction (41, 42). Endemic species have typically seen larger-than-average changes to their habitats and show faster-than-average population declines. By contrast, ecological generalists and disturbance-adapted species have tended to become more abundant, and some have spread quickly around the world (43). In 21 countries with detailed records, for example, the numbers of invasive alien species have risen by an average of 70% since 1970 (44). This combination of declining endemic species and the spread of already widespread species as humans purposefully or unwittingly transport species around the world drives “biotic homogenization” (45, 46), a convergence of biological communities across regions that blurs the patterns on life’s rich tapestry.

The number of species currently threatened with extinction is unprecedented in human history: an estimated 1 million species of animals and plants. This figure is derived from assessments for many terrestrial, freshwater, and marine vertebrate, invertebrate, and plant groups that have applied the International Union for the Conservation of Nature (IUCN) Red List categories and criteria (the global standard for assessing the relative extinction risk of each species) (47). On average across these groups, ~25% of species are threatened

(classified as Critically Endangered, Endangered, or Vulnerable), although for insects—by far the most species-rich group—the proportion might be as low as 10% (Fig. 2) (48, 49). Uncertainties in the numbers of animal and plant species and the percentage of them (particularly insects) that are threatened make any estimate necessarily approximate (50, 51). Moving from species to populations, wild animal populations are continuing to decline on land and in the sea. The global biomass of wild mammals is now less than 25% of that before the late Pleistocene megafaunal extinction—and less than 10% that of the world’s current human population (52). The global biomass of large predatory fish targeted by fisheries has fallen by two-thirds over the past 100 years (53). The outlook is worsening rapidly, with extinction risk increasing for all groups with known trends (5). A total of 705 vertebrate species are confirmed or presumed to have been driven extinct since 1500 (54), as have 571 plant species (39)—evidence that human actions have increased the global rate of species extinction by at least tens to hundreds of times over background rates before human intervention (39, 55, 56).

Domesticated species and varieties are also being lost. Fewer varieties of plants and animals are being maintained because of changes and standardization in farming practices, market preferences, large-scale trade, and loss of indigenous and local knowledge. Around 560 (~10%) of domesticated breeds of mammals had gone extinct by 2016, and at least 1000 more are threatened (57). Many hotspots of agrobiodiversity and of crop wild relatives are also under threat or lack formal protection (58), jeopardizing the pool of genetic variation that underpins the long-term resilience of agricultural production and food systems in the face of environmental change (59).

Declining trends are also documented in a worldwide evaluation of 321 indicators of nature important for quality of life developed by Indigenous Peoples and local communities. Although the decline in nature is lower in areas managed by Indigenous Peoples than in other lands (60), ~72% of the indicators assessed show deterioration (51).

In addition, rapid evolutionary responses to human drivers are now seen in all major taxonomic groups (61). This includes the evolution of resistance to pesticides and herbicides in insects and plants (62), smaller size and earlier maturation in marine fishes and invertebrates subject to fishing and global warming (63), changes in freeze tolerance in urban plants (64), and phenological shifts in a wide range of taxa in response to climate change (65).

Direct and indirect drivers of change

The direct causes of changes observed in the fabric of life are (in decreasing order of relative impact worldwide) land and sea use change,

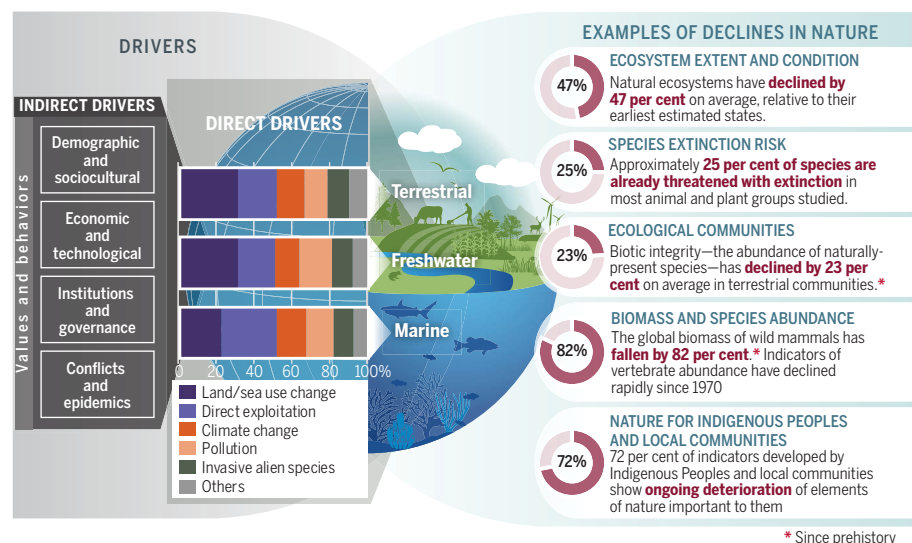


Fig. 3. Examples of global declines in nature that have been and are being caused by direct and indirect drivers of change. Each of the direct drivers of changes (land or sea use change; direct exploitation of organisms; climate change; pollution, including plastics, heavy metals, and direct effects of elevated CO₂ on, for example, terrestrial photosynthesis and seawater pH; and invasive alien species) represents the aggregation of many consequences from sectors such as crop production; animal husbandry; fishing; logging; hunting; mining for minerals, ores, and fossil fuels; development of cities and infrastructure for electricity and transport; and the transport of people and goods itself. The direct drivers result from an array of underlying societal causes. These causes can be demographic (for example, human population dynamics); sociocultural (for example, consumption patterns); economic (for example, trade); technological; or relating to institutions, governance, conflicts, and epidemics. These are called indirect drivers and are underpinned by societal values and behaviors (3, 114). The color bands represent the relative global impact of direct drivers on (from top to bottom) terrestrial, freshwater, and marine nature as estimated from a global systematic review of studies published since 2005 (51). Land and sea use change and direct exploitation account for more than 50% of the global impact on land, in fresh water, and in the sea, but each driver is dominant in certain systems or places. The circles illustrate the magnitude of the negative human impacts on a diverse selection of aspects of nature over a range of different time scales, selected from a global synthesis of indicators; ecosystem extent, extinction risk, and biomass and species abundance include terrestrial, freshwater, and marine species and ecosystems, although most is known about life on land. Biotic integrity refers to the terrestrial realm only, and nature indicators for Indigenous Peoples and local communities are predominately terrestrial. [Reproduced from (1).]

exploitation of organisms, climate change, pollution, and invasive alien species (Fig. 3). Within terrestrial and freshwater ecosystems, the driver with the highest relative impact is land use change, mainly land conversion for cultivation, livestock raising, and plantations. The main driver in the ocean is direct exploitation through biomass extraction (mostly fishing). Although climate change is already a substantial driver of changes to nature and its contributions to people in many places (Fig. 3), even causing extinction in some cases [for example, (66)], it is not yet globally the most important.

The vast area of the world managed by Indigenous Peoples (at least 25 to 28% of land surface) (Fig. 4) under various property regimes is no exception to these trends. Because of their large extent, the fact that nature is overall better preserved within them (60), and because of the diverse stewardship practices carried within them around the world (Fig. 4,

A to I), the fate of nature in these lands has important consequences for wider society as well as for local livelihoods, health, and knowledge transmission (67).

Indirect drivers of change—including demographic, economic, political, and institutional arrangements, and underpinned by societal values—underlie the observed direct drivers (Fig. 3). Indirect drivers interact with one another; for example, economic development choices could cause less deterioration in the presence of environmental policy, whereas the lack of publicly enforced rights could undermine resource management and conservation practices by Indigenous Peoples and local communities (68).

Over the past five decades, global socioeconomic trends have followed highly divergent pathways for countries with contrasting levels of income (Fig. 5) (69). With the dramatic increase in global trade, and more generally economic and social globalization,

nature is ever more influenced by distant consumers (70). Trade has shifted where goods are produced and used, contributing to new economic opportunities but also generating or exacerbating inequities in both economic development and environmental burdens. The demand for material goods is predominantly from higher- and middle-income countries, and it is often satisfied by production in middle- and lower-income countries (Fig. 5, A, B, and C). For example, the European Union, the United States, and Japan together accounted for ~64% of the world imports of fish products in value, whereas developing countries accounted for 59% of the total volume of traded fish (12). These exchanges are often negotiated between actors and institutions of unequal power, which affects the distribution of the benefits and long-term social and ecological costs (Fig. 5F). A handful of transnational corporations control large (>50%) shares of supply chains in agriculture, fishing, logging, and mining (71, 72), whereas funds channeled through tax havens support most illegal, unreported, and unregulated fishing (71, 73), creating governance challenges. Many economic incentives are harmful to nature, including direct and indirect subsidies to fisheries (74), agriculture (including fertilizers and pesticides) (75), livestock raising, forestry, mining, and energy production (including fossil fuels and biofuels) (76). However, conservation policies (including incentives) could also play out unequally. For example, higher-income countries might contribute to the financing of environmental protection in lower-income countries but only to secure global benefits—such as the preservation of particular species and ecosystems, or carbon storage—whereas such policies can sometimes lower welfare locally (77, 78).

Progress toward internationally agreed goals

In view of the trends summarized above, it is not surprising that progress in meeting internationally agreed goals has been generally poor. Progress toward the 20 “Aichi Targets” in the Strategic Plan on Biodiversity 2011–2020 of the Convention on Biological Diversity has been mixed (Fig. 6A). Of the 54 elements comprising the 20 targets, good progress has been made toward five (9%), moderate progress toward 19 (35%), and poor progress or movement away from the target for 21 (39%). Progress is unknown for nine elements (17%). Overall, it is clear that the majority of Aichi Targets will not be met. More progress has been made in adopting and/or implementing policy responses and actions to conserve and use nature more sustainably than has been achieved in addressing the drivers of biodiversity loss. The strongest progress has been toward increasing protected area coverage

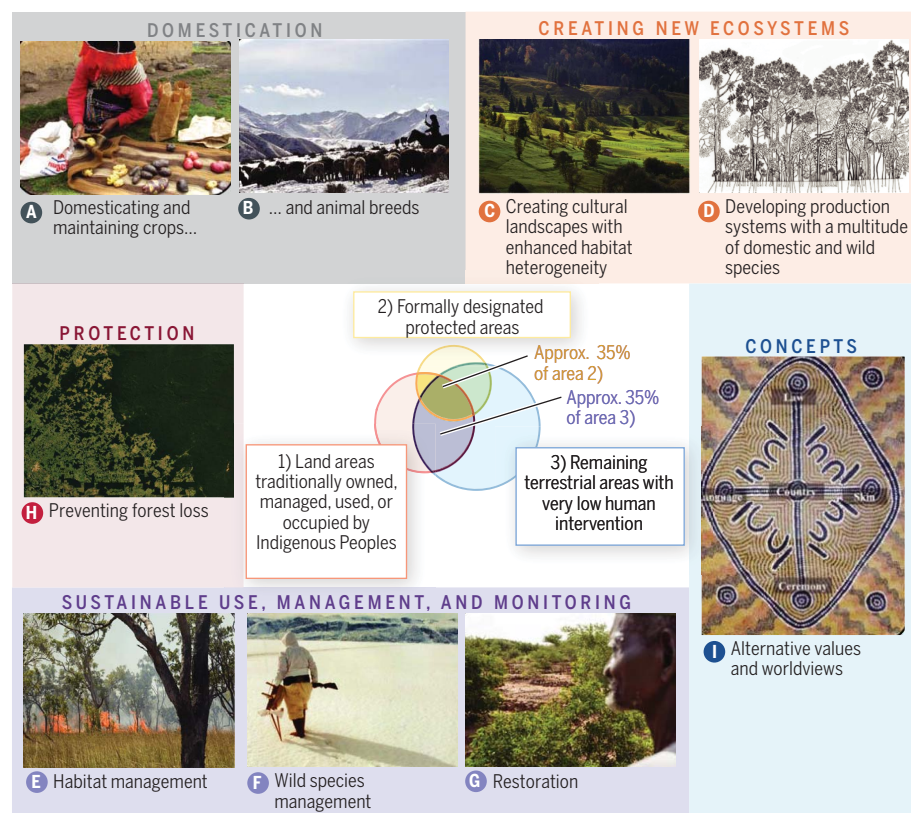


Fig. 4. Contribution of Indigenous Peoples and local communities to biodiversity. A wide range of practices of Indigenous Peoples and local communities maintain and enhance wild and domestic biodiversity. (A and B) Domestication and maintenance of locally adapted crop and fruit varieties and animal breeds (potatoes, Peru; rider and sheep, Kyrgyzstan) (57). (C) Creation of species-rich habitats and fine-grain habitat mosaics (hay meadows, Central Europe) (115). (D) Identification of useful plants and their cultivation in high-diversity agroecosystems (multispecies forest garden, Indonesia) (116). (E and F) Management and monitoring of wild species, habitats, and landscapes and (G) restoration of degraded lands (Australia, Alaska, and Niger) (116, 117). (H) Prevention of deforestation in recognized Indigenous territories (Amazon basin, Brazil) (68). (I) Generation of alternative concepts of relations between humanity and nature (Northern Australia) (118). (Middle) Worldwide, the area traditionally owned, managed, used, or occupied by Indigenous Peoples (red circle), representing ~8 million km² in 87 countries, overlaps with at least 35 to 40% of the area that is formally protected (yellow circle), and a similar proportion of all remaining terrestrial areas with very low human intervention (blue circle) [<4 Human Footprint Index (18)] [based on (60)]. Circles and intersections are proportional in area. [Modified from (1).] [Photos credits: (A) FAO/Sandro Cespolti; (B) FAO/Vyacheslav Oseledko; (C) Daniel Babai; (D) (118); (E) Shutterstock_S. Todd; (F) Vadeve; (G) Rodrigo Ordonez/GLF; (H) Google Maps; (I) Daniel Rockman Jupurrurla.] The image in (I) represents Ngurra-kurlu, the Warlpiri people's understanding of how country contributes to people and vice versa. [Painting by Daniel Rockman Jupurrurla, from (119) and reproduced under the Creative Commons license.]

(Target 11) and developing national biodiversity strategy and action plans (Target 17). However, although protected areas now cover 14.9% of terrestrial and freshwater environments and 7.44% of the marine realm, they only partly cover areas of importance for biodiversity and are not yet fully ecologically representative, well-connected, and effectively and equitably managed. Although some species have been brought back from the brink of extinction (contributing toward Target 12 on preventing extinctions), the species in taxonomic groups with quantified trends are moving toward extinction at an increasing

rate, meaning that this Target will not be met. Few data are available to quantify what the trends would have been in the absence of conservation action and policy responses to the Aichi Targets, although species' extinction risk trends would have been worse (79), and many island ecosystems that are recovering after eradications of invasive mammals would not have done so (80).

Nature and its contributions to people were found to underpin the achievement of all the United Nations Sustainable Development Goals (SDGs), either directly for goals on water, climate, oceans, and biodiversity (SDGs

6, 13, 14, and 15, respectively) or through more complex interactions for goals on poverty, hunger, health, cities, education, gender equality, reduced inequalities, and peace (SDGs 1, 2, 3, 4, 5, 10, 11, and 16, respectively). For SDGs on energy, economic growth, industry and infrastructure, and consumption and production (SDGs 7, 8, 9, and 12, respectively), important feedbacks between these goals and nature and its contributions to people were found with consequences for the achievement of all SDGs.

Declines in nature and its contributions to people therefore compromise our ability to meet the SDGs. At the target level, progress to 35 SDG targets that could be quantitatively assessed—on poverty, hunger, health, water, cities, climate, and biodiversity (SDGs 1, 2, 3, 6, 11, 13, 14, and 15, respectively)—are being undermined by current trends in aspects of nature and its contributions to people relevant to these targets (Fig. 6B). However, current goal and target articulation omit or obscure the links to nature, preventing an assessment of other targets under these goals as well as targets in other goals linked to education, gender equality, reduced inequalities, and peace.

Possible futures

We comprehensively reviewed both exploratory and target-seeking scenarios (81) of future change in direct and indirect drivers. These scenarios resulted in starkly different impacts on nature and its contributions to people and, in combination, enabled synthetic conclusions about the need for transformative change. We considered a wide range of exploratory scenarios on the basis of future plausible changes in direct and indirect drivers. A subset of the scenarios was based on Shared Socioeconomic Pathway (SSP) scenarios and Representative greenhouse gas Concentration Pathways (RCPs) developed in support of Intergovernmental Panel on Climate Change assessments (82). These combined scenarios ranged from “Global sustainability” [combining proactive environmental policy and sustainable production and consumption with low greenhouse gas emissions (SSP1 and RCP2.6)] to “Regional competition” [combining strong trade and other barriers and a growing gap between rich and poor with high emissions (SSP3 and RCP6.0)] to “Economic optimism” [combining rapid economic growth and low environmental regulation with very high greenhouse emissions (SSP5 and RCP8.5)]. Scenarios of a world with increased regional political and trade barriers tend to result in the greatest divergence across regions, scenarios that emphasize liberal financial markets result in intermediate levels of disparity, whereas scenarios that integrate actions toward sustainable development result in more modest differences between regions (83). Under business-as-usual future scenarios—meaning

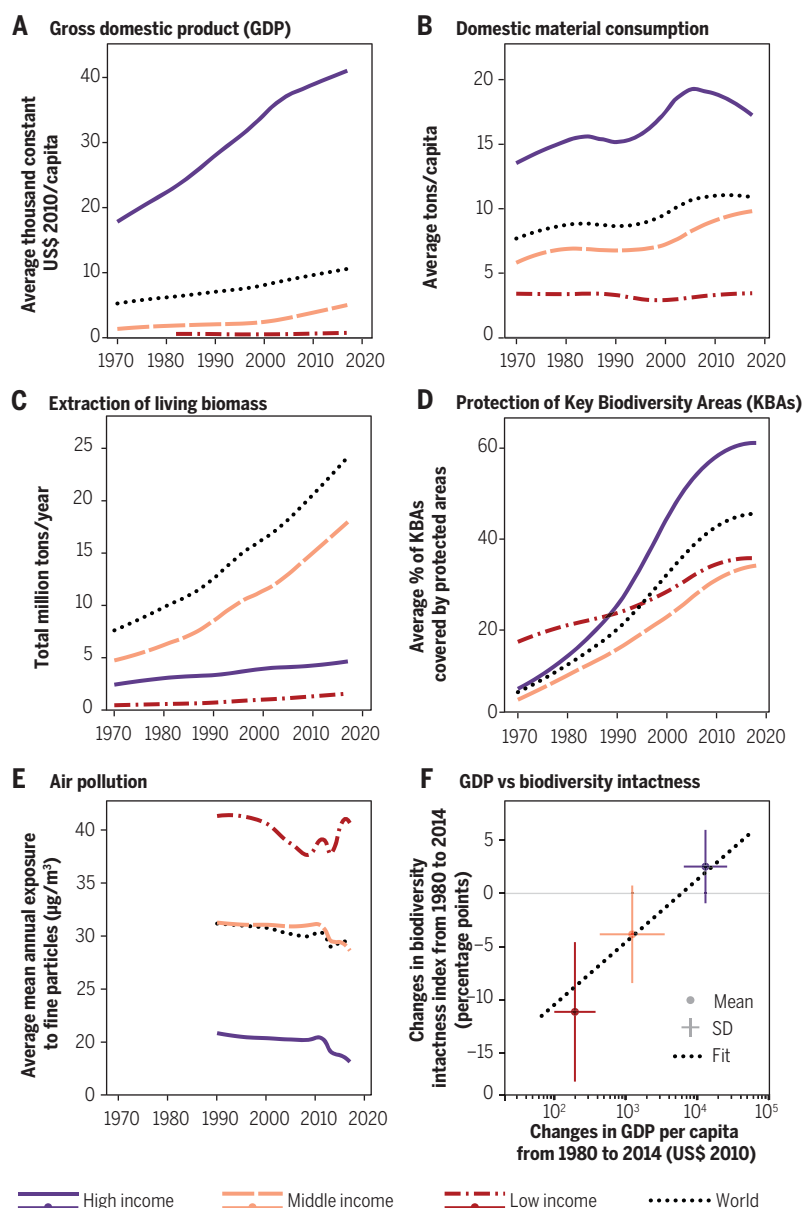


Fig. 5. Development pathways since 1970 have featured unequal impacts on people and nature across countries. (A, B, and C) Increased trade between countries has shifted the tradeoffs between environmental and other goals, with the footprints of increasing consumption in higher-income countries being exported to both middle-income and lower-income countries, who increased extraction of living materials. (D) Protection of key biodiversity areas has been highest in high-income countries, although international financing supported the protection of global public goods in low-income countries, which (E) have experienced much higher local air pollution given less support for local regulation and (F) not only the lowest increases in GDP but also the largest declines in some elements of nature. Countries are classified according to World Bank income categories. Data sources are (A) and (E), www.data.worldbank.org; (B) and (C), www.materialflows.net; (D), www.keybiodiversityareas.org and www.protectedplanet.net; and (F), www.data.worldbank.org and (30). [Modified from (1) and (69)]

that drivers of change do not deviate from the current socioeconomic and governance trajectory—nature in terrestrial, freshwater, and marine realms and most of its contributions to people will continue to decline sharply. Recent modeling of natural regulation of water quality, reduction of coastal

risk, and crop pollination worldwide (84) found convergent conclusions.

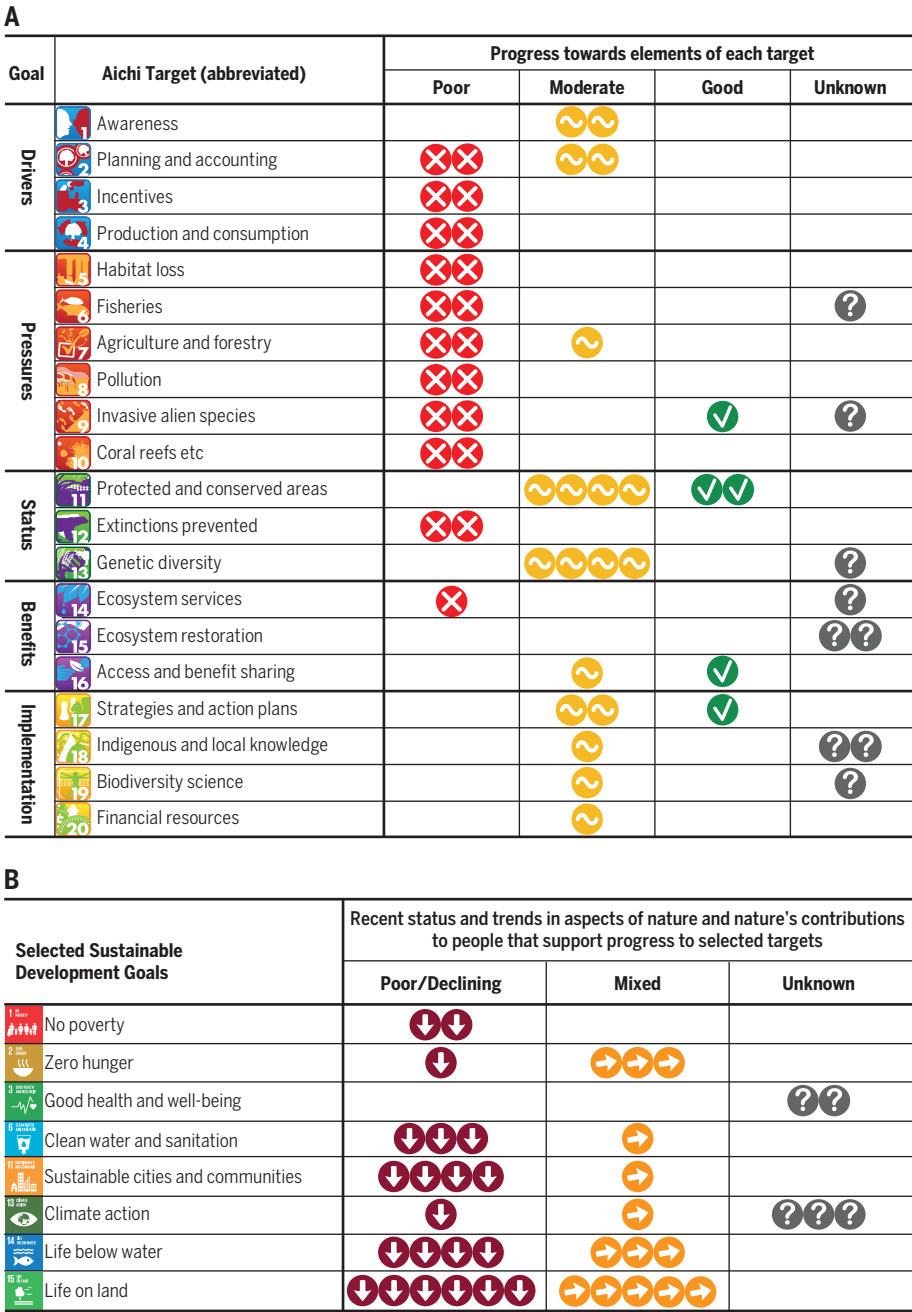
Direct drivers of change that have predominated in the past 50 years (Fig. 3) will continue to play an important role (19, 83, 85), with climate change increasingly driving further biodiversity and ecosystem decline (19, 83, 86).

These projections come with important uncertainties as to the degree of change or to the geographical differentiation of the impacts, depending on the underlying socioeconomic scenario. Given the interconnectedness of the world regions, future scenarios need to better address the impacts of telecouplings [socioeconomic and environmental interactions over distances (70)], such as trade, foreign direct investment, migrations, biological invasions, and pollutant flows (87). Projections also omit interconnections among species, which may cause domino effects that amplify the loss of diversity (88).

A different picture emerges from “target-seeking” scenarios (81), which start with a desirable target set in the future and then evaluate different pathways allowing to achieve it, including the innovations and policy interventions that are needed to reach such a target. Our analysis suggests that it is possible to achieve many of the global biodiversity targets and sustainability goals related to food, energy, climate, and water at local and global scales. The complexity of the challenges calls for an integrative (nexus) approach (89) that simultaneously examines interactions among multiple sectors along with synergies and tradeoffs among goals. An example of a key nexus are the simultaneous needs to mitigate climate change, arrest biodiversity loss, and ensure that all people have adequate nutrition on one hand, and the potentially negative consequences of large-scale land-based climate change mitigation on the other. Even moderate warming will likely be detrimental for biodiversity (90) and associated benefits to people (91). However, most scenarios projected to limit warming to 1.5°C or 2°C by the end of the 21st century rely on large-scale mitigation measures on land, in the form of bioenergy crops, reforestation, and/or afforestation, negatively affecting biodiversity and also food production and water demand (19, 92). At the same time, expanding the amount of land devoted to agriculture to ensure that all people have adequate nutrition would negatively affect biodiversity as well (93) and would further exacerbate climate change (19, 92). Both land-based climate change mitigation and agricultural expansion, when deployed at the large scale, can undermine local livelihoods, create access problems, and intensify social conflict (94). A suite of possible actions could be effective in navigating these tradeoffs (19, 95)—for example, focusing on regeneration and restoration of high-carbon ecosystems (as well as reducing waste and overconsumption) rather than massive bioenergy monoculture plantations—to achieve climate change mitigation (19, 96, 97). Similarly, the increasing demands for food could be met without expanding agriculture’s footprint by sustainably increasing yields, changing dietary choices, and

Fig. 6. Summary of progress toward major internationally agreed goals. (A) Progress toward the Aichi Biodiversity Targets contained in the Strategic Plan on Biodiversity 2011–2020 of the Convention on Biological Diversity. **(B)** Recent status of, and trends in, aspects of nature and nature's contributions to people that support progress toward achieving selected targets of the Sustainable Development Goals adopted through the United Nations in 2015. Scores in (A) for each of the 54 elements of the 20 targets are based on quantitative analysis of indicators, a systematic review of the literature, fifth National Reports to the Convention on Biological Diversity, and available information on countries' stated intentions to implement additional actions by 2020. Progress toward target elements is scored as "Good" (substantial positive trends at a global scale relating to most aspects of the element), "Moderate" (the overall global trend is positive but insubstantial or insufficient, or there may be substantial positive trends for some aspects of the element but little or no progress for others, or the trends are positive in some geographic regions but not in others), "Poor" (little or no progress toward the element or movement away from it; although there may be local, national, or case-specific successes and positive trends for some aspects, the overall global trend shows little or negative progress), or "Unknown" (insufficient information to score progress). In (B), selected targets are those for which current evidence and target wording enable assessment of the consequences for target achievement of trends in nature and nature's contribution to people. Scores for targets are based on systematic assessments of the literature and quantitative analysis of indicators where possible (5). "Poor/Negative" indicates poor status or substantial negative trends at a global scale; "Mixed" indicates the overall global status and trends are good or positive but insubstantial or insufficient, or there may be substantial positive trends for some relevant aspects but negative trends for others, or the trends are positive in some geographic regions but negative in others; "Unknown" indicates insufficient information to score the status and trends. An additional two targets under Goal 1 and two targets under Goal 3 were found to have evidence-based links to nature; however, because of the uncertain and complex relationships between nature and the target, they could not be assessed. [Data redrawn from (1) and (5).]

reducing waste, among other measures (19, 98, 99). More generally, solutions are needed that simultaneously address a nexus of relevant goals, such as feeding humanity, resourcing growing cities, mitigating climate change, protecting nature on land and at sea, maintaining freshwater, and ensuring animal welfare (Fig. 7). The futures that successfully address this suite of sustainability goals require rapid transition toward clean energy, a continued ramping up of biological conservation, large-scale restoration of degraded



ecosystems, and transformation of supply chains to reduce resource extraction and environmental impacts. However, such comprehensive changes to direct drivers also require reform of indirect drivers, including innovations in economic and political structures and societal norms. **Levers and leverage points for transformative change** Our assessment—the most comprehensive carried out to date, including the nexus analysis of scenarios and an expert input process with

literature reviews—revealed clearly that reversing nature's ongoing decline (100) while also addressing inequality will require transformative change, namely a fundamental, system-wide reorganization across technological, economic, and social factors, making sustainability the norm rather than the altruistic exception. Achieving such a transformation for the broader current and future public good will have to overcome resistance from vested interests, including some powerful actors (101). One important avenue to transformation is the improved implementation and enforcement

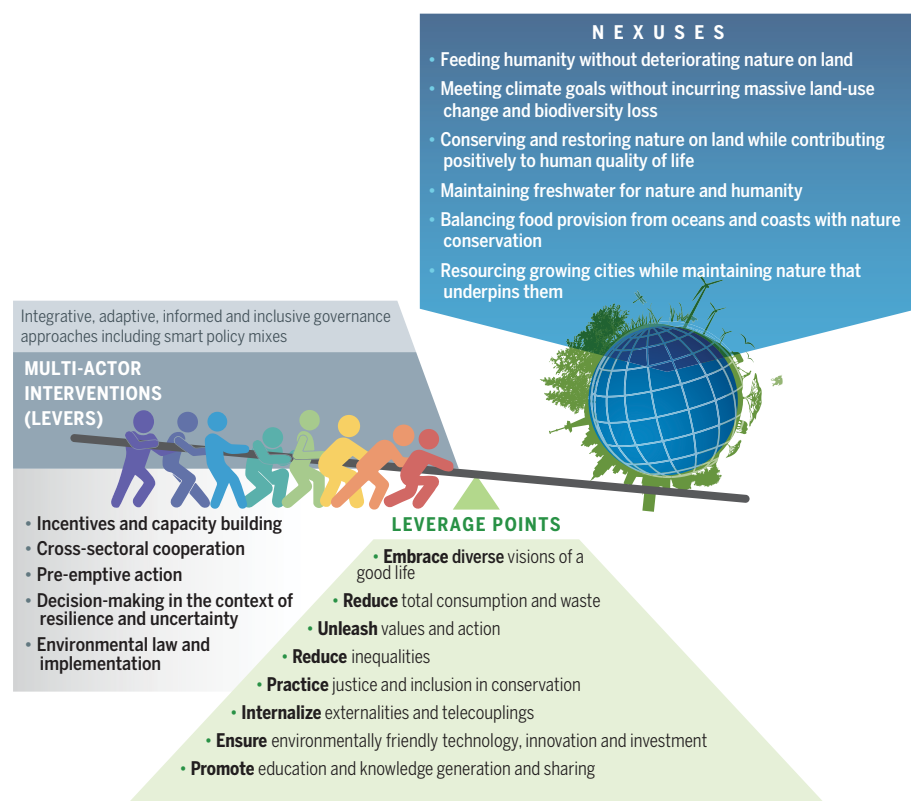


Fig. 7. Enabling transformative change. Collaborative implementation of priority interventions (levers) targeting key points of intervention (leverage points representing major indirect drivers) could enable transformative change from current trends toward more sustainable ones. Effectively addressing these levers and leverage points requires innovative governance approaches and organizing the process around nexuses, representing closely interdependent and complementary goals (1, 94). [Modified from (1).]

of existing environmental policies and regulations and the removal and reform of harmful policies, such as subsidies for energy use or resource harvest (102). Another important step involves reforming global financial and economic systems, steering away from the current limited paradigm of economic growth to reward sustainability and penalize actions, resulting in the deterioration of the fabric of life (103, 104). Such transformative change can be enabled, strengthened, and accelerated with the collaborative application of priority interventions (levers) to key points of intervention (leverage points) through innovative governance approaches (Fig. 7).

A comprehensive set of five levers (95) for this transformative change emerged from our unprecedentedly broad and rigorous analysis of the many possible levers that have been proposed previously: (i) developing incentives and widespread capacity for environmental responsibility and eliminating perverse incentives; (ii) reforming sectoral and segmented decision-making to promote integration across sectors and jurisdictions; (iii) taking preemptive and precautionary actions in regulatory and management institutions and businesses to

avoid, mitigate, and remedy the deterioration of nature, and monitoring their outcomes; (iv) managing for resilient social and ecological systems in the face of uncertainty and complexity to deliver decisions that are robust in a wide range of scenarios; and (v) strengthening environmental laws and policies and their implementation, and the rule of law more generally.

The scenarios analysis and expert-input process further found that efforts focused on the following eight leverage points yield disproportionately large effects: (i) enabling visions of a good quality of life that do not entail ever-increasing material consumption; (ii) lowering total consumption and waste, including by addressing both population growth and per capita consumption differently in different contexts; (iii) unleashing existing, widely held values of responsibility to effect new social norms for sustainability, especially by extending notions of responsibility to include the impacts associated with consumption; (iv) addressing inequalities, especially regarding income and gender, that undermine the capacity for sustainability; (v) ensuring inclusive decision-

making and the fair and equitable sharing of benefits arising from the use of and adherence to human rights in conservation decisions; (vi) accounting for nature's deterioration from both local economic activities and telecouplings (70), including, for example, international trade; (vii) ensuring environmentally friendly technological and social innovation, taking into account potential rebound effects and investment regimes; and (viii) promoting education, knowledge generation, and the maintenance of different knowledge systems, including in the sciences and indigenous and local knowledge, especially regarding nature, conservation, and nature's sustainable use. Although change at some of these levers and leverage points may encounter resistance individually, action at other levers and leverage points can enable such changes.

The review also revealed that innovative governance approaches that are integrative, inclusive, informed, and adaptive (105, 106) are needed to effectively apply these levers to leverage points. Integrative approaches focus on the relationships between sectors and policies and ensure policy coherence and effectiveness, and inclusive approaches, including rights-based ones, reflect a plurality of values and thus promote equity. Informed governance entails new strategies for knowledge production and coproduction that are inclusive of diverse values and knowledge systems. Last, adaptive approaches—including learning, monitoring and feedback loops—help coping with inevitable uncertainties and complexities.

Conclusions and outlook

The most comprehensive global review to date of the interrelationship between people and nature makes it evident that the challenges posed by biodiversity loss, climate change, and achieving a good quality of life for all are deeply interconnected and need to be addressed in an integrative manner—and urgently—from local to global levels. Maintaining a life-sustaining and life-fulfilling planet for humans and other species are thus one and the same challenge—a challenge that cannot be met by business as usual. However, a rich array of approaches and instruments are available that can, together, achieve sustainability. The transformations in economies, politics, and social systems that will be needed in order to deploy these changes in time and at scale can be triggered by a series of targeted interventions, especially at key points of leverage in indirect drivers. In this way, it is still possible to achieve a full suite of goals associated with feeding and resourcing humanity while maintaining and restoring the fabric of life that supports us all.

REFERENCES AND NOTES

1. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), *Summary for Policymakers of the Global Assessment Report of the Intergovernmental*

- Science-Policy Platform on Biodiversity and Ecosystem Services. S. Díaz *et al.*, Eds. (IPBES Secretariat, 2019).
2. G. M. Mace, Ecology. Whose conservation? *Science* **345**, 1558–1560 (2014). doi: [10.1126/science.1254704](https://doi.org/10.1126/science.1254704); pmid: [25258063](https://pubmed.ncbi.nlm.nih.gov/25258063/)
 3. S. Díaz *et al.*, The IPBES Conceptual Framework - connecting nature and people. *Curr. Opin. Environ. Sustain.* **14**, 1–16 (2015). doi: [10.1016/j.cosust.2014.11.002](https://doi.org/10.1016/j.cosust.2014.11.002)
 4. S. Díaz *et al.*, Assessing nature's contributions to people. *Science* **359**, 270–272 (2018). doi: [10.1126/science.aap8826](https://doi.org/10.1126/science.aap8826); pmid: [29348221](https://pubmed.ncbi.nlm.nih.gov/29348221/)
 5. S. H. M. Butchart *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
 6. With the exception of SDG 17 (strengthen the means of implementation and revitalize the global partnership for sustainable development).
 7. A. D. Guerry *et al.*, Natural capital and ecosystem services informing decisions: From promise to practice. *Proc. Natl. Acad. Sci. U.S.A.* **112**, 7348–7355 (2015). doi: [10.1073/pnas.1503751112](https://doi.org/10.1073/pnas.1503751112); pmid: [26082539](https://pubmed.ncbi.nlm.nih.gov/26082539/)
 8. K. A. Brauman *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
 9. J. Hinkel *et al.*, Coastal flood damage and adaptation costs under 21st century sea-level rise. *Proc. Natl. Acad. Sci. U.S.A.* **111**, 3292–3297 (2014). doi: [10.1073/pnas.1222469111](https://doi.org/10.1073/pnas.1222469111); pmid: [24596428](https://pubmed.ncbi.nlm.nih.gov/24596428/)
 10. S. G. Potts *et al.*, Safeguarding pollinators and their values to human well-being. *Nature* **540**, 220–229 (2016). doi: [10.1038/nature20588](https://doi.org/10.1038/nature20588); pmid: [27894123](https://pubmed.ncbi.nlm.nih.gov/27894123/)
 11. Food and Agriculture Organization of the United Nations (FAO), *FAOSTAT Statistical Database* (FAO, 2019).
 12. FAO, *The State of World's Fisheries and Aquaculture 2018. Meeting the Sustainable Development Goals* (Food and Agriculture Organization of the United Nations, Rome, 2018). <https://data.worldbank.org/indicator/SP.POP.TOTL>
 13. <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD>
 14. <https://data.worldbank.org/indicator/NE.EXP.GNFS.KD>
 15. www.materialflows.net
 16. Millennium Ecosystem Assessment, *Ecosystems and Human Well-being* (Island Press, 2005).
 17. J. E. M. Watson *et al.*, Catastrophic declines in wilderness areas undermine global environment targets. *Curr. Biol.* **26**, 2929–2934 (2016). doi: [10.1016/j.cub.2016.08.049](https://doi.org/10.1016/j.cub.2016.08.049); pmid: [27618267](https://pubmed.ncbi.nlm.nih.gov/27618267/)
 18. Intergovernmental Panel on Climate Change (IPCC), *IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, A. Arneth *et al.*, Eds. (IPCC, 2019).
 19. B. S. Halpern *et al.*, Patterns and emerging trends in global ocean health. *PLOS ONE* **10**, e0117863 (2015). doi: [10.1371/journal.pone.0117863](https://doi.org/10.1371/journal.pone.0117863); pmid: [25774678](https://pubmed.ncbi.nlm.nih.gov/25774678/)
 20. N. C. Davidson, How much wetland has the world lost? Long-term and recent trends in global wetland area. *Mar. Freshw. Res.* **65**, 934 (2014). doi: [10.1071/MF14173](https://doi.org/10.1071/MF14173)
 21. G. Grill *et al.*, Mapping the world's free-flowing rivers. *Nature* **569**, 215–221 (2019). doi: [10.1038/s41586-019-1111-9](https://doi.org/10.1038/s41586-019-1111-9); pmid: [31068722](https://pubmed.ncbi.nlm.nih.gov/31068722/)
 22. K. Frieler *et al.*, Limiting global warming to 2 C is unlikely to save most coral reefs. *Nat. Clim. Chang.* **3**, 165–170 (2013). doi: [10.1038/nclimate1674](https://doi.org/10.1038/nclimate1674)
 23. K. A. Krumhansl *et al.*, Global patterns of kelp forest change over the past half-century. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 13785–13790 (2016). doi: [10.1073/pnas.1606102113](https://doi.org/10.1073/pnas.1606102113); pmid: [27849580](https://pubmed.ncbi.nlm.nih.gov/27849580/)
 24. K.-H. Erb *et al.*, Unexpectedly large impact of forest management and grazing on global vegetation biomass. *Nature* **553**, 73–76 (2018). doi: [10.1038/nature25138](https://doi.org/10.1038/nature25138); pmid: [29258288](https://pubmed.ncbi.nlm.nih.gov/29258288/)
 25. Food and Agriculture Organization of the United Nations (FAO), *Global Forest Resources Assessment 2010* (FAO, 2010).
 26. X.-P. Song *et al.*, Global land change from 1982 to 2016. *Nature* **560**, 639–643 (2018). doi: [10.1038/s41586-018-0411-9](https://doi.org/10.1038/s41586-018-0411-9); pmid: [30089903](https://pubmed.ncbi.nlm.nih.gov/30089903/)
 27. R. J. Keenan *et al.*, Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. *For. Ecol. Manage.* **352**, 9–20 (2015). doi: [10.1016/j.foreco.2015.06.014](https://doi.org/10.1016/j.foreco.2015.06.014)
 28. J. Gauthier, P. Bernier, T. Kuuluvainen, A. Z. Shvidenko, D. G. Schepaschenko, Boreal forest health and global change. *Science* **349**, 819–822 (2015). doi: [10.1126/science.aaa9092](https://doi.org/10.1126/science.aaa9092); pmid: [26293953](https://pubmed.ncbi.nlm.nih.gov/26293953/)
 29. S. L. L. Hill *et al.*, Worldwide impacts of past and projected future land-use change on local species richness and the Biodiversity Intactness Index. *bioRxiv* 311787 [Preprint]. 1 May 2018.
 30. J. Rice, in *The First Global Integrated Marine Assessment: World Ocean Assessment I*, United Nations (Cambridge Univ. Press, 2017).
 31. E. Sala, N. Knowlton, Global marine biodiversity trends. *Annu. Rev. Environ. Resour.* **31**, 93–122 (2006). doi: [10.1146/annurev.energy.31.020105.100235](https://doi.org/10.1146/annurev.energy.31.020105.100235)
 32. D. J. Agnew *et al.*, Estimating the worldwide extent of illegal fishing. *PLOS ONE* **4**, e4570 (2009). doi: [10.1371/journal.pone.0004570](https://doi.org/10.1371/journal.pone.0004570); pmid: [19240812](https://pubmed.ncbi.nlm.nih.gov/19240812/)
 33. J. Spijkers *et al.*, Global patterns of fisheries conflict: Forty years of data. *Glob. Environ. Change* **57**, 101921 (2019). doi: [10.1016/j.gloenvcha.2019.05.005](https://doi.org/10.1016/j.gloenvcha.2019.05.005)
 34. W. J. Ripple *et al.*, Status and ecological effects of the world's largest carnivores. *Science* **343**, 1241484 (2014). doi: [10.1126/science.1241484](https://doi.org/10.1126/science.1241484); pmid: [24408439](https://pubmed.ncbi.nlm.nih.gov/24408439/)
 35. N. K. Duly *et al.*, Extinction risk and conservation of the world's sharks and rays. *eLife* **3**, e00590 (2014). doi: [10.7554/eLife.00590](https://doi.org/10.7554/eLife.00590); pmid: [24448405](https://pubmed.ncbi.nlm.nih.gov/24448405/)
 36. A. Estrada *et al.*, Impending extinction crisis of the world's primates: Why primates matter. *Sci. Adv.* **3**, e005946 (2017). doi: [10.1126/sciadv.1600946](https://doi.org/10.1126/sciadv.1600946); pmid: [28116351](https://pubmed.ncbi.nlm.nih.gov/28116351/)
 37. C. Wilkinson *et al.*, in *The First Global Integrated Marine Assessment: World Ocean Assessment I*, United Nations (Cambridge Univ. Press, 2017).
 38. A. M. Humphreys, R. Govaerts, S. Z. Ficiniski, E. Nic Lughadha, M. S. Vorontsova, Global dataset shows geography and life form predict modern plant extinction and rediscovery. *Nat. Ecol. Evol.* **3**, 1043–1047 (2019). doi: [10.1038/s41559-019-0906-2](https://doi.org/10.1038/s41559-019-0906-2); pmid: [31182811](https://pubmed.ncbi.nlm.nih.gov/31182811/)
 39. S. Faurby, J. C. Svenning, Historic and prehistoric human-driven extinctions have reshaped global mammal diversity patterns. *Divers. Distrib.* **21**, 1155–1166 (2015). doi: [10.1111/ddi.12369](https://doi.org/10.1111/ddi.12369)
 40. J. Schipper *et al.*, The status of the world's land and marine mammals: Diversity, threat, and knowledge. *Science* **322**, 225–230 (2008). doi: [10.1126/science.1165115](https://doi.org/10.1126/science.1165115); pmid: [18845749](https://pubmed.ncbi.nlm.nih.gov/18845749/)
 41. M. Magera, J. E. Mills Flemming, K. Kaschner, L. B. Christensen, H. K. Lotze, Recovery trends in marine mammal populations. *PLOS ONE* **8**, e77908 (2013). doi: [10.1371/journal.pone.0077908](https://doi.org/10.1371/journal.pone.0077908); pmid: [24205025](https://pubmed.ncbi.nlm.nih.gov/24205025/)
 42. M. Tabarelli, C. A. Peres, F. P. L. Melo, The 'few winners and many losers' paradigm revisited: Emerging prospects for tropical forest biodiversity. *Biol. Conserv.* **155**, 136–140 (2012). doi: [10.1016/j.biocon.2012.06.020](https://doi.org/10.1016/j.biocon.2012.06.020)
 43. S. Pagad *et al.*, IUCN SSC Invasive Species Specialist Group, Invasive alien species information management supporting practitioners, policy makers and decision takers. *Int. J. Appl. Res. Biologic. Invasions* **6**, 127 (2015).
 44. T. Newbold *et al.*, Widespread winners and narrow-ranged losers: Land use homogenizes biodiversity in local assemblages worldwide. *PLOS Biol.* **16**, e2006841 (2018). doi: [10.1371/journal.pbio.2006841](https://doi.org/10.1371/journal.pbio.2006841); pmid: [30513079](https://pubmed.ncbi.nlm.nih.gov/30513079/)
 45. W. D. Pearse *et al.*, Homogenization of plant diversity, composition, and structure in North American urban yards. *Ecosphere* **9**, e02105 (2018). doi: [10.1002/ecs2.2105](https://doi.org/10.1002/ecs2.2105)
 46. International Union for the Conservation of Nature (IUCN), *IUCN Red List Categories and Criteria. Version 3.1* (Gland, Switzerland, 2012). www.iucn.org/content/european-red-list
 47. V. Clausen *et al.*, Odonata enter the biodiversity crisis debate: The first global assessment of an insect group. *Biol. Conserv.* **142**, 1864–1869 (2009). doi: [10.1016/j.biocon.2009.03.028](https://doi.org/10.1016/j.biocon.2009.03.028)
 48. M. J. Caley, R. Fisher, K. Mengersen, Global species richness estimates have not converged. *Trends Ecol. Evol.* **29**, 187–188 (2014). doi: [10.1016/j.tree.2014.02.002](https://doi.org/10.1016/j.tree.2014.02.002); pmid: [24569101](https://pubmed.ncbi.nlm.nih.gov/24569101/)
 49. A. Purvis *et al.*, in *Global Assessment Report on Biodiversity and Ecosystem Services: The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
 50. Y. M. Bar-On, R. Phillips, R. Milo, The biomass distribution on Earth. *Proc. Natl. Acad. Sci. U.S.A.* **115**, 6506–6511 (2018). doi: [10.1073/pnas.1711842115](https://doi.org/10.1073/pnas.1711842115); pmid: [29784790](https://pubmed.ncbi.nlm.nih.gov/29784790/)
 51. V. Christensen *et al.*, A century of fish biomass decline in the ocean. *Mar. Ecol. Prog. Ser.* **512**, 155–166 (2014). doi: [10.3354/meps10946](https://doi.org/10.3354/meps10946)
 52. IUCN, *The IUCN Red List of Threatened Species. Version 2019-2. Downloaded on 18 July 2019* (IUCN, 2019); www.iucnredlist.org
 53. S. L. Pimm *et al.*, The biodiversity of species and their rates of extinction, distribution, and protection. *Science* **344**, 1246752 (2014). doi: [10.1126/science.1246752](https://doi.org/10.1126/science.1246752); pmid: [24876501](https://pubmed.ncbi.nlm.nih.gov/24876501/)
 54. G. Ceballos *et al.*, Accelerated modern human-induced species losses: Entering the sixth mass extinction. *Sci. Adv.* **1**, e1400253 (2015). doi: [10.1126/sciadv.1400253](https://doi.org/10.1126/sciadv.1400253); pmid: [26601195](https://pubmed.ncbi.nlm.nih.gov/26601195/)
 55. FAO, *The State of the World's Animal Genetic Resources for Food and Agriculture*. B. Rischkowsky, D. Pilling, Eds. (FAO, 2016).
 56. S. Pironon *et al.*, Potential adaptive strategies for 29 sub-Saharan crops under future climate change. *Nat. Clim. Chang.* **9**, 758–763 (2019). doi: [10.1038/s41558-019-0585-7](https://doi.org/10.1038/s41558-019-0585-7)
 57. N. P. Castañeda-Álvarez *et al.*, Global conservation priorities for crop wild relatives. *Nat. Plants* **2**, 16022 (2016). doi: [10.1038/nplants.2016.22](https://doi.org/10.1038/nplants.2016.22); pmid: [27249561](https://pubmed.ncbi.nlm.nih.gov/27249561/)
 58. S. T. Garnett *et al.*, A spatial overview of the global importance of Indigenous lands for conservation. *Nat. Sustainabil.* **1**, 369–374 (2018). doi: [10.1038/s41893-018-0100-6](https://doi.org/10.1038/s41893-018-0100-6)
 59. A. P. Hendry, K. M. Gotanda, E. I. Svensson, Human influences on evolution, and the ecological and societal consequences. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **372**, 20160028 (2017). doi: [10.1098/rstb.2016.0028](https://doi.org/10.1098/rstb.2016.0028); pmid: [27920373](https://pubmed.ncbi.nlm.nih.gov/27920373/)
 60. F. Gould, Z. S. Brown, J. Kuzma, Wicked evolution: Can we address the sociobiological dilemma of pesticide resistance? *Science* **360**, 728–732 (2018). doi: [10.1126/science.aar3780](https://doi.org/10.1126/science.aar3780); pmid: [29773742](https://pubmed.ncbi.nlm.nih.gov/29773742/)
 61. A. Audzijonyte *et al.*, Trends and management implications of human-influenced life-history changes in marine ectotherms. *Fish Fish.* **17**, 1005–1028 (2016). doi: [10.1111/taf.12156](https://doi.org/10.1111/taf.12156)
 62. K. A. Thompson, M. Renaudin, M. T. J. Johnson, Urbanization drives the evolution of parallel clines in plant populations. *Proc. Biol. Sci.* **283**, 20162180 (2016). doi: [10.1098/rspb.2016.2180](https://doi.org/10.1098/rspb.2016.2180); pmid: [28003451](https://pubmed.ncbi.nlm.nih.gov/28003451/)
 63. J. Merilä, A. P. Hendry, Climate change, adaptation, and phenotypic plasticity: The problem and the evidence. *Evol. Appl.* **7**, 1–14 (2014). doi: [10.1111/eva.12137](https://doi.org/10.1111/eva.12137); pmid: [24454544](https://pubmed.ncbi.nlm.nih.gov/24454544/)
 64. J. C. Z. Woinarski, S. T. Garnett, S. M. Legge, D. B. Lindenmayer, The contribution of policy, law, management, research, and advocacy failings to the recent extinctions of three Australian vertebrate species. *Conserv. Biol.* **31**, 13–23 (2017). doi: [10.1111/cobi.12852](https://doi.org/10.1111/cobi.12852); pmid: [27704619](https://pubmed.ncbi.nlm.nih.gov/27704619/)
 65. UNEP, *Cultural and Spiritual Values of Biodiversity* (Intermediate Technology, 1999).
 66. L. Porter-Bolland *et al.*, Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. *For. Ecol. Manage.* **268**, 6–17 (2012). doi: [10.1016/j.foreco.2011.05.034](https://doi.org/10.1016/j.foreco.2011.05.034)
 67. P. Balvanera *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
 68. J. Liu *et al.*, Framing sustainability in a telecoupled world. *Ecol. Soc.* **18**, art26 (2013). doi: [10.5751/ES-05873-180226](https://doi.org/10.5751/ES-05873-180226)
 69. H. Osterblom *et al.*, Transnational corporations as 'keystone actors' in marine ecosystems. *PLOS ONE* **10**, e0127533 (2015). doi: [10.1371/journal.pone.0127533](https://doi.org/10.1371/journal.pone.0127533); pmid: [26017777](https://pubmed.ncbi.nlm.nih.gov/26017777/)
 70. C. Folke *et al.*, Transnational corporations and the challenge of biosphere stewardship. *Nat. Ecol. Evol.* **3**, 1396–1403 (2019). doi: [10.1038/s41559-019-0978-z](https://doi.org/10.1038/s41559-019-0978-z); pmid: [31527729](https://pubmed.ncbi.nlm.nih.gov/31527729/)
 71. V. Galaz *et al.*, Tax havens and global environmental degradation. *Nat. Ecol. Evol.* **2**, 1352–1357 (2018). doi: [10.1038/s41559-018-0497-3](https://doi.org/10.1038/s41559-018-0497-3); pmid: [30104749](https://pubmed.ncbi.nlm.nih.gov/30104749/)
 72. U. R. Sumaila, V. Lam, F. Le Manach, W. Swartz, D. Pauly, Global fisheries subsidies: An updated estimate. *Mar. Policy* **69**, 189–193 (2016). doi: [10.1016/j.marpol.2015.12.026](https://doi.org/10.1016/j.marpol.2015.12.026)
 73. F. H. Oosterhuis, P. Ten Brink, Eds., *Paying the Polluter: Environmentally Harmful Subsidies and their Reform* (Edward Elgar, 2014).

76. P. Ten Brink, *The Economics of Ecosystems and Biodiversity in National and International Policy Making* (Routledge, 2012).
77. A. S. Pullin et al., Human well-being impacts of terrestrial protected areas. *Environ. Evid.* **2**, 19 (2013). doi: [10.1186/2047-2382-2-19](https://doi.org/10.1186/2047-2382-2-19)
78. M. M. Bayrak, M. L. Marafa, Ten years of REDD+: A critical review of the impact of REDD+ on forest-dependent communities. *Sustainability* **8**, 620 (2016). doi: [10.3390/su8070620](https://doi.org/10.3390/su8070620)
79. M. Hoffmann et al., The impact of conservation on the status of the world's vertebrates. *Science* **330**, 1503–1509 (2010). doi: [10.1126/science.1194442](https://doi.org/10.1126/science.1194442); pmid: [20978281](https://pubmed.ncbi.nlm.nih.gov/20978281/)
80. H. P. Jones et al., Invasive mammal eradication on islands results in substantial conservation gains. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 4033–4038 (2016). doi: [10.1073/pnas.1521179113](https://doi.org/10.1073/pnas.1521179113); pmid: [27001852](https://pubmed.ncbi.nlm.nih.gov/27001852/)
81. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), *The Methodological Assessment on Scenarios and Models of Biodiversity and Ecosystem Services*, S. Ferrier et al., Eds. (Secretariat of the Intergovernmental Platform for Biodiversity and Ecosystem Services, 2016).
82. B. C. O'Neill et al., A new scenario framework for climate change research: The concept of shared socioeconomic pathways. *Clim. Change* **122**, 387–400 (2014). doi: [10.1007/s10584-013-0905-2](https://doi.org/10.1007/s10584-013-0905-2)
83. Y. J. Shin et al., in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio et al., Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
84. R. Chaplin-Kramer et al., Global modeling of nature's contributions to people. *Science* **366**, 255–258 (2019). doi: [10.1126/science.aaw3372](https://doi.org/10.1126/science.aaw3372); pmid: [31601772](https://pubmed.ncbi.nlm.nih.gov/31601772/)
85. N. Titeux et al., Biodiversity scenarios neglect future land-use changes. *Glob. Chang. Biol.* **22**, 2505–2515 (2016). doi: [10.1111/gcb.13272](https://doi.org/10.1111/gcb.13272); pmid: [26950650](https://pubmed.ncbi.nlm.nih.gov/26950650/)
86. M. C. Urban, Climate change. Accelerating extinction risk from climate change. *Science* **348**, 571–573 (2015). doi: [10.1126/science.aaa4984](https://doi.org/10.1126/science.aaa4984); pmid: [25931559](https://pubmed.ncbi.nlm.nih.gov/25931559/)
87. E. K. Kapsar et al., Telecoupling research: The first five years. *Sustainability* **11**, 1033 (2019). doi: [10.3390/su11041033](https://doi.org/10.3390/su11041033)
88. G. Strona, C. J. A. Bradshaw, Co-extinctions annihilate planetary life during extreme environmental change. *Sci. Rep.* **8**, 16724 (2018). doi: [10.1038/s41598-018-35068-1](https://doi.org/10.1038/s41598-018-35068-1); pmid: [30425270](https://pubmed.ncbi.nlm.nih.gov/30425270/)
89. J. Liu et al., Nexus approaches to global sustainable development. *Nat. Sustainability* **1**, 466–476 (2018). doi: [10.1038/s41893-018-0135-8](https://doi.org/10.1038/s41893-018-0135-8)
90. G. T. Pecl et al., Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science* **355**, eaai9214 (2017). doi: [10.1126/science.aa9214](https://doi.org/10.1126/science.aa9214); pmid: [28360268](https://pubmed.ncbi.nlm.nih.gov/28360268/)
91. O. Hoegh-Guldberg et al., in *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, V. Masson-Delmotte et al., Eds. (World Meteorological Organization, 2018).
92. Intergovernmental Panel on Climate Change (IPCC), *Summary for Policymakers in Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, Masson-Delmotte et al., Eds. (World Meteorological Organization, 2018).
93. D. Tilman et al., Future threats to biodiversity and pathways to their prevention. *Nature* **546**, 73–81 (2017). doi: [10.1038/nature22900](https://doi.org/10.1038/nature22900); pmid: [28569796](https://pubmed.ncbi.nlm.nih.gov/28569796/)
94. D. M. Cáceres, Accumulation by Dispossession and Socio-Environmental Conflicts Caused by the Expansion of Agribusiness in Argentina. *J. Agrar. Change* **15**, 116–147 (2015). doi: [10.1111/joac.12057](https://doi.org/10.1111/joac.12057)
95. K. M. A. Chan et al., in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio et al., Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
96. J.-F. Bastin et al., The global tree restoration potential. *Science* **365**, 76–79 (2019). doi: [10.1126/science.aax0848](https://doi.org/10.1126/science.aax0848); pmid: [31273120](https://pubmed.ncbi.nlm.nih.gov/31273120/)
97. S. L. Lewis, C. E. Wheeler, E. T. A. Mitchard, A. Koch, Restoring natural forests is the best way to remove atmospheric carbon. *Nature* **568**, 25–28 (2019). doi: [10.1038/d41586-019-01026-8](https://doi.org/10.1038/d41586-019-01026-8); pmid: [30940972](https://pubmed.ncbi.nlm.nih.gov/30940972/)
98. J. Poore, T. Nemecek, Reducing food's environmental impacts through producers and consumers. *Science* **360**, 987–992 (2018). doi: [10.1126/science.aag0216](https://doi.org/10.1126/science.aag0216); pmid: [29853680](https://pubmed.ncbi.nlm.nih.gov/29853680/)
99. H. M. Tallis et al., An attainable global vision for conservation and human well-being. *Front. Ecol. Environ.* **16**, 563–570 (2018). doi: [10.1002/fee.1965](https://doi.org/10.1002/fee.1965)
100. G. M. Mace et al., Aiming higher to bend the curve of biodiversity loss. *Nat. Sustainability* **1**, 448–451 (2018). doi: [10.1038/s41893-018-0130-0](https://doi.org/10.1038/s41893-018-0130-0)
101. L. Raymond, S. L. Weldon, D. Kelly, X. B. Arriaga, A. M. Clark, Making change: Norm-based strategies for institutional change to address intractable problems. *Polit. Res. Q.* **67**, 197–211 (2014). doi: [10.1177/1065912913510786](https://doi.org/10.1177/1065912913510786)
102. Organization for Economic Cooperation (OECD), *Environmentally Harmful Subsidies: Challenges for Reform* (OECD, 2005).
103. D. O'Rourke, N. Lollo, Transforming consumption: From decoupling, to behavior change, to system changes for sustainable consumption. *Annu. Rev. Environ. Resour.* **40**, 233–259 (2015). doi: [10.1146/annurev-environ-102014-021224](https://doi.org/10.1146/annurev-environ-102014-021224)
104. G. Kallis et al., Research on degrowth. *Annu. Rev. Environ. Resour.* **43**, 291–316 (2018). doi: [10.1146/annurev-environ-102017-025941](https://doi.org/10.1146/annurev-environ-102017-025941)
105. S. Sith, P. M. Cox, W. J. Collins, C. Huntingford, Indirect radiative forcing of climate change through ozone effects on the land-carbon sink. *Nature* **448**, 791–794 (2007). doi: [10.1038/nature06059](https://doi.org/10.1038/nature06059); pmid: [17653194](https://pubmed.ncbi.nlm.nih.gov/17653194/)
106. J. Razzaque et al., in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio et al., Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
107. Z. Q. Zhang, Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness (Addenda 2013). *Zootaxa* **3703**, 1–82 (2013). doi: [10.11646/zootaxa.3148.1.1](https://doi.org/10.11646/zootaxa.3148.1.1); pmid: [26146682](https://pubmed.ncbi.nlm.nih.gov/26146682/)
108. M. Böhm et al., The conservation status of the world's reptiles. *Biol. Conserv.* **157**, 372–385 (2013). doi: [10.1016/j.biocon.2012.07.015](https://doi.org/10.1016/j.biocon.2012.07.015)
109. N. A. Brummitt et al., Green plants in the red: A baseline global assessment for the IUCN sampled Red List Index for plants. *PLOS ONE* **10**, e0135152 (2015). doi: [10.1371/journal.pone.0135152](https://doi.org/10.1371/journal.pone.0135152); pmid: [26252495](https://pubmed.ncbi.nlm.nih.gov/26252495/)
110. E. N. Lughadha et al., Counting counts: Revised estimates of numbers of accepted species of flowering plants, seed plants, vascular plants and land plants with a review of other recent estimates. *Phytotaxa* **272**, 82 (2016). doi: [10.11646/phytotaxa.272.1.5](https://doi.org/10.11646/phytotaxa.272.1.5)
111. M. J. M. Christenhusz, J. W. Byng, The number of known plants species in the world and its annual increase. *Phytotaxa* **261**, 201 (2016). doi: [10.11646/phytotaxa.261.3.1](https://doi.org/10.11646/phytotaxa.261.3.1)
112. *State of the World's Plants 2017*, K. J. Willis, Ed. (Royal Botanical Gardens, 2017).
113. *State of the World's Fungi 2018*, K. J. Willis, Ed. (Royal Botanical Gardens, 2018).
114. E. S. Brondizio et al., in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio et al., Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
115. Z. Molnár, F. Berkes, in *Reconnecting Natural and Cultural Capital: Contributions from Science and Policy*, M. L. Paracchini et al., Eds. (Joint Research Centre, 2018).
116. F. Berkes, *Sacred Ecology* (Routledge, 2017).
117. V. Reyes-García et al., The contributions of Indigenous Peoples and local communities to ecological restoration. *Restor. Ecol.* **27**, 3–8 (2019). doi: [10.1111/rec.12894](https://doi.org/10.1111/rec.12894)
118. G. Michon, H. De Foresta, P. Levang, F. Verdeaux, Domestic forests: A new paradigm for integrating local communities' forestry into tropical forest science. *Ecol. Soc.* **12**, 1 (2007).
119. W. J. Pawu-Kurluplurnu et al., "Ngurra-kurlu: A way of working with Warlpiri people" (Desert Knowledge, 2008).

ACKNOWLEDGMENTS

We thank the reviewers who provided thoughtful and constructive feedback on this manuscript, which resulted in considerable improvement to the manuscript. We are grateful to the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) Global Assessment Management Committee, review editors and numerous contributing authors, to the IPBES Secretariat and its Technical Support Units, and all the governments and organizations that supported author meetings. We are especially grateful to A. Larigauderie (IPBES executive secretary) and R. T. Watson (IPBES chair 2016–2019), for their strategic vision and continued advice, and to I. Baste (IPBES Bureau) and M. Stenseke, S. Demissew, and L. Dziba (MEP co-chairs) for their continued advice. We also acknowledge the contributions of D. Cooper, M. Guéze (GA Technical Support Unit); Y. O. Estrada (data visualization); and R. González, S. Hill, C. Hilton-Taylor, and M. Rivers (data and discussions for this paper).

Funding: The authors received no specific funding for this work; all authors involved in IPBES assessments and deliverables are involved on a voluntary basis. The IPBES global assessment was made possible thanks to many generous contributions, including nonearmarked contributions to the IPBES trust fund from governments (Australia, Belgium, Bulgaria, Canada, Chile, China, Denmark, Estonia, European Union, Finland, France, Germany, India, Japan, Latvia, Luxembourg, Malaysia, Monaco, Netherlands, New Zealand, Norway, Republic of Korea, South Africa, Sweden, Switzerland, the United Kingdom, and the United States); earmarked contributions to the IPBES trust fund toward the global assessment [Germany, Canada, France (Agence Française pour la Biodiversité), Norway, the United Kingdom, and the United States]; and in-kind contributions targeted at the global assessment. All donors are listed on the IPBES web site: www.ipbes.net/donors.

Author contributions: All authors volunteered and contributed their time in producing this publication and components of the underlying assessment report (5, 8, 51, 69, 83, 95, 106, 114) and its summary for policymakers (1). We are grateful to the following lead authors, fellows, and chapter scientists of the IPBES Global Assessment: C. Adams, A. P. D. Aguiar, D. Armenteras, Y. Aumeeruddy-Thomas, X. Bai, L. Balint, Z. Basher, T. Bekele Gode, E. Bennett, Y. A. Bofo, A. K. Boedhihartono, P. Brancalion, E. Bukvareva, I. Chan, N. Chettri, W. L. Cheung, B. Czúcz, F. DeClerck, E. Dulloo, A. Fernandez-Llamazares, B. Gabrielyan, L. Galletto, K. Galvin, E. García Frapolli, A. P. Gautam, L. R. Gerber, A. Geschke, J. Gutt, S. Hashimoto, A. Heinemann, A. Hendry, G. C. Hernández Pedraza, T. Hickler, A. I. Horcea-Milcu, S. A. Hussain, M. Israr, U. Jacob, W. Jetz, J. Jetzkowitz, P. Jaureguiberry, M. S. Karim, E. Kelemen, E. Keskin, P. Kindlmann, M. Kok, M. Kolb, Z. Krenova, R. Krug, P. Leadley, M. Lim, J. Liu, G. Lui, A. J. Lynch, M. Mastrangelo, P. McElwee, L. Merino, P. A. Minang, A. Mohamed, A. Mohammed, I. B. Mphahwe Kosamu, E. Mungatana, R. Muradian, M. Murray-Hudson, T. H. Mwampamba, N. Nagabhatla, A. Niamir, N. Nkongolo, P. O'Farrell, T. Oberdorff, P. Osano, B. Öztürk, H. Palang, M. G. Palomo, I. Palomo, M. Panahi, U. Pascual, R. Pichs Madruga, P. Plissock, V. Reyes-García, C. Rondinini, G. M. Rusch, O. Saito, R. Salimov, J. A. Samakov, J. Sathyapalan, T. Satterfield, A. K. Saydel, E. R. Selig, O. Selomane, R. Seppelt, L. Shannon, A. U. B. Shrestha, A. Sidorovich, A. Simcock, G. S. Singh, B., J. Spangenberg, B. Strassburg, E. Strombom, D. Tarkhishvili, N. Titeux, E. Turnhout, M. Verma, A. Viña, M. Wiemers, M. J. Williams H. Xu, D. Xue, T. Yue, and D. Zaleski.

Competing interests: The authors declare no competing interests. **Data and materials availability:** All data are available in the manuscript or the supplementary materials.

SUPPLEMENTARY MATERIALS

science.sciencemag.org/content/366/6471/eaax3100/suppl/DC1
Table S1

References (120–163)

10.1126/science.aax3100

Pervasive human-driven decline of life on Earth points to the need for transformative change

Sandra Díaz, Josef Settele, Eduardo S. Brondízio, Hien T. Ngo, John Agard, Almut Arneth, Patricia Balvanera, Kate A. Brauman, Stuart H. M. Butchart, Kai M. A. Chan, Lucas A. Garibaldi, Kazuhito Ichii, Jianguo Liu, Suneetha M. Subramanian, Guy F. Midgley, Patricia Miloslavich, Zsolt Molnár, David Obura, Alexander Pfaff, Stephen Polasky, Andy Purvis, Jona Razzaque, Belinda Reyers, Rinku Roy Chowdhury, Yunne-Jai Shin, Ingrid Visseren-Hamakers, Katherine J. Willis and Cynthia N. Zayas

Science **366** (6471), eaax3100.
DOI: 10.1126/science.aax3100

The time is now

For decades, scientists have been raising calls for societal changes that will reduce our impacts on nature. Though much conservation has occurred, our natural environment continues to decline under the weight of our consumption. Humanity depends directly on the output of nature; thus, this decline will affect us, just as it does the other species with which we share this world. Díaz *et al.* review the findings of the largest assessment of the state of nature conducted as of yet. They report that the state of nature, and the state of the equitable distribution of nature's support, is in serious decline. Only immediate transformation of global business-as-usual economies and operations will sustain nature as we know it, and us, into the future.

Science, this issue p. eaax3100

ARTICLE TOOLS

<http://science.sciencemag.org/content/366/6471/eaax3100>

SUPPLEMENTARY MATERIALS

<http://science.sciencemag.org/content/suppl/2019/12/11/366.6471.eaax3100.DC1>

RELATED CONTENT

<http://science.sciencemag.org/content/sci/366/6471/eaay3038.full>
<http://science.sciencemag.org/content/sci/366/6471/eaaw9256.full>

REFERENCES

This article cites 141 articles, 36 of which you can access for free
<http://science.sciencemag.org/content/366/6471/eaax3100#BIBL>

PERMISSIONS

<http://www.sciencemag.org/help/reprints-and-permissions>

Use of this article is subject to the [Terms of Service](#)

Science (print ISSN 0036-8075; online ISSN 1095-9203) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. The title *Science* is a registered trademark of AAAS.

Copyright © 2019 The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. No claim to original U.S. Government Works



Supplementary Material for

Pervasive human-driven decline of life on Earth points to the need for transformative change

Sandra Díaz*, Josef Settele, Eduardo S. Brondízio, Hien T. Ngo, John Agard, Almut Arneth, Patricia Balvanera, Kate A. Brauman, Stuart H. M. Butchart, Kai M. A. Chan, Lucas A. Garibaldi, Kazuhito Ichii, Jianguo Liu, Suneetha M. Subramanian, Guy F. Midgley, Patricia Miloslavich, Zsolt Molnár, David Obura, Alexander Pfaff, Stephen Polasky, Andy Purvis, Jona Razzaque, Belinda Reyers, Rinku Roy Chowdhury, Yunne-Jai Shin, Ingrid Visseren-Hamakers, Katherine J. Willis, Cynthia N. Zayas

*Corresponding author. E-mail: sandra.diaz@unc.edu.ar

Published 13 December 2019, *Science* **366**, eaax3100 (2019)
DOI: 10.1126/science.aax3100

This PDF file includes:

Table S1
References

Table S1. Brief explanation of the 18 categories of nature's contributions to people distinguished by IPBES (1), and some illustrative indicators and references used in the systematic review of their global trends from the 1970s, summarized in Figure 1. See (1) for fuller description of the 18 categories and (8) for details on indicators and methods and complete list of references.

Natures contribution to people	Brief explanation	Examples of trends in selected indicators since the 1970s	Realms assessed in cited examples
1. Habitat creation and maintenance	The formation and continued production, by ecosystems or organisms within them, of ecological conditions necessary or favorable for living beings of direct or indirect importance to humans.	Significant global habitat declines (5) with differing magnitudes across regions.	Terrestrial
2. Pollination and dispersal of seeds and other propagules	Facilitation by animals of movement of pollen among flowers, and dispersal of seeds, larvae or spores of organisms beneficial or harmful to humans.	Global decrease in pollinator diversity (10, 120, 121), most of them in industrialized regions; little evidence elsewhere (122-126). Habitat destruction indicates decrease (10, 127)	Terrestrial
3. Regulation of air quality	Regulation by ecosystems, of CO ₂ / O ₂ balance, O ₃ , sulphur oxide, nitrogen oxides, volatile organic compounds, particulates, aerosols, allergens. Filtration, fixation, degradation or storage of pollutants that directly affect human health or infrastructure.	Increase in air pollutants from biomass burning, deforestation, and agriculture, but increase in plant leaf area increases pollution retention and vegetation protects soils and prevents dust (128). Unresolved urban impact (129).	Terrestrial
4. Regulation of climate	Climate regulation by ecosystems (including regulation of global warming) through: (a) effects on emissions of greenhouse gases, (b) effects on biophysical feedbacks from vegetation cover to atmosphere, such as those involving albedo, surface roughness, long-wave radiation, evapotranspiration (including moisture-recycling) and cloud formation, (c) processes involving biogenic volatile organic compounds, and regulation of aerosols and aerosol precursors by terrestrial plants and phytoplankton.	Stable but spatially variable terrestrial sequestration of carbon in biomass and emissions from land use change, substantial interannual variation (27,28, 130). Precise contributions of ecosystems incomplete.	Terrestrial
5. Regulation of ocean acidification	Regulation, by photosynthetic organisms (on land or in water), of atmospheric CO ₂ concentrations and therefore seawater pH; this affects associated calcification processes by many marine organisms important to humans (such as corals)	Stable terrestrial greenhouse gas emissions from land use change and sequestration in biomass (130). Increase in ocean carbon sequestration (130). Warming of upper ocean increases area of nitrogen-fixing phytoplankton, increasing ocean net primary productivity (131, 132).	Terrestrial and marine

6. Regulation of freshwater quantity, location and timing	Regulation, by ecosystems, of the quantity, location and timing of the flow of surface and groundwater used for drinking, irrigation, transport, hydropower, and as the support of non-material contributions.	Increased runoff quantity and flow speed due to deforestation, expanding (un-irrigated) cropland, and urbanization (133, 134). Ecosystem change impact on water regulation established but incomplete (135).	Terrestrial
7. Regulation of freshwater and coastal water quality	Regulation (through filtration of particles, pathogens, excess nutrients and other chemicals) by ecosystems or particular organisms, of the quality of water used directly (e.g. drinking, swimming) or indirectly (e.g. aquatic foods, irrigated food and fiber crops, freshwater and coastal habitats of heritage value).	Decreased filtration potential due to increased impervious surfaces and vegetation removal (136, 137), though varies globally (138). Mechanisms well understood but filtration effectiveness varies widely among studies (136, 137).	Terrestrial
8. Formation, protection and decontamination of soils and sediments	Formation and long-term maintenance of soil structure and processes by plants and soil organisms. Includes: physical protection of soil and sediments from erosion, and supply of organic matter and nutrients by vegetation; processes that underlie the continued fertility of soils important to humans (e.g. decomposition and nutrient cycling) filtration, fixation, attenuation or storage of chemical and biological pollutants in soils and sediments.	Global decline in soil organic carbon, regional variation (139-143).	Terrestrial
9. Regulation of hazards and extreme events	Amelioration, by ecosystems, of the impacts on humans or their infrastructure caused by e.g. floods, wind, storms, hurricanes, heat waves, tsunamis, high noise levels, fires, seawater intrusion, tidal waves. Reduction or increase, by ecosystems or particular organisms, of hazards like landslides, avalanches	Decreased natural hazard regulation from land use change including shoreline hardening, floodplain development, and detrimental forest management (144). Reduced in most cases, but there have been positive changes (144, 145). Mechanisms understood but poorly studied <i>in situ</i> (144).	Terrestrial, marine
10. Regulation of detrimental organisms and biological processes	Regulation, by organisms, of pests, pathogens, predators or competitors that affect humans or plants or animals of importance for humans. Also the direct detrimental effect of organisms on humans or their plants, animals or infrastructure.	Decline in natural enemies of pests, and in competent hosts of vector-borne and zoonotic diseases in all regions, with larger declines in the tropics and sub-tropics (146, 147). Decreased natural habitat in agriculture to support pest predators (148).	Terrestrial
11. Energy	Production of biomass-based fuels, such as biofuel crops, animal waste, fuelwood, agricultural residue pellets, peat.	Increasing extent of agricultural land, with regional variation (149). Global decrease in forested area to provide fuelwood, with regional variation (27, 28).	Terrestrial
12. Food and feed	Production of food from wild, managed, or domesticated organisms. Production of feed (forage and fodder) for domesticated animals or for aquaculture, from the same sources.	Increase in harvested area, yields, and meat and milk production, with regional variation (149). Decrease in fish catch potential (150), but increase in aquaculture, with regional variation (151).	Terrestrial, freshwater, marine

13. Materials, companionship and labor	Production of materials derived from organisms in cultivated or wild ecosystems, for construction, clothing, printing, ornamental purposes. Live organisms being directly used for decoration, transport, and labor.	Increasing extent of agricultural land, with regional variations (149), and area of cotton remained stable. Global decline in forest area; much spatial variation (27, 28).	Terrestrial
14. Medicinal, biochemical and genetic resources	Production of materials derived from organisms used for medicinal, veterinary and pharmacological purposes. Production of genes and genetic information used for plant and animal breeding and biotechnology.	Declining fraction of known medicinal species due to decline in indigenous and local knowledge, including access to customary territories; this reduces capacity to identify new drugs from nature (152). Declining measures of phylogenetic diversity (153).	Terrestrial
15. Learning and inspiration	Provision, by landscapes, seascapes, habitats or organisms, of opportunities for the development of the capabilities that allow humans to prosper through education, acquisition of knowledge and development of skills for wellbeing, information, and inspiration for art and technological design (e.g. biomimicry)	Declining population living in direct proximity to nature due to urbanization and migration (154, 155). Reduced human-nature interactions (156). Declining diversity of life from which to learn, measured as phylogenetic diversity (153).	Terrestrial
16. Physical and psychological experiences	Provision, by landscapes, seascapes, habitats or organisms, of opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, tourism and aesthetic enjoyment based on the close contact with nature	Declining area of natural intact and traditional landscapes and seascapes due to urbanization and land use change (157, 158).	Terrestrial
17. Supporting identities	Landscapes, seascapes, habitats or organisms being the basis for religious, spiritual, and social-cohesion experiences.	Stable human environments provide culture with the possibility to attribute value to it and form identities (159-161). Increased globalization, urbanization, and environmental degradation deterioration had leads to decreased stability of land use and land cover (161, 162).	Terrestrial
18. Maintenance of options	Capacity of ecosystems, habitats, species or genotypes to keep options open in order to support a good quality of life.	Increasing species extinction rates; major regional variation (55, 163). Decreasing phylogenetic diversity (153). Trends based on data but the places and species for highest diversity loss are not well established.	Terrestrial

References and Notes

1. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), *Summary for Policymakers of the Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. S. Díaz *et al.*, Eds. (IPBES Secretariat, 2019).
2. G. M. Mace, Ecology. Whose conservation? *Science* **345**, 1558–1560 (2014).
[doi:10.1126/science.1254704](https://doi.org/10.1126/science.1254704) [Medline](#)
3. S. Díaz, S. Demissew, J. Carabias, C. Joly, M. Lonsdale, N. Ash, A. Larigauderie, J. R. Adhikari, S. Arico, A. Báldi, A. Bartuska, I. A. Baste, A. Bilgin, E. Brondizio, K. M. A. Chan, V. E. Figueroa, A. Duraiappah, M. Fischer, R. Hill, T. Koetz, P. Leadley, P. Lyver, G. M. Mace, B. Martin-Lopez, M. Okumura, D. Pacheco, U. Pascual, E. S. Pérez, B. Reyers, E. Roth, O. Saito, R. J. Scholes, N. Sharma, H. Tallis, R. Thaman, R. Watson, T. Yahara, Z. A. Hamid, C. Akosim, Y. Al-Hafedh, R. Allahverdiyev, E. Amankwah, S. T. Asah, Z. Asfaw, G. Bartus, L. A. Brooks, J. Caillaux, G. Dalle, D. Darnaedi, A. Driver, G. Erpul, P. Escobar-Eyzaguirre, P. Failler, A. M. M. Fouda, B. Fu, H. Gundimeda, S. Hashimoto, F. Homer, S. Lavorel, G. Lichtenstein, W. A. Mala, W. Mandivenyi, P. Matczak, C. Mbizvo, M. Mehrdadi, J. P. Metzger, J. B. Mikissa, H. Moller, H. A. Mooney, P. Mumby, H. Nagendra, C. Nesshover, A. A. Oteng-Yeboah, G. Pataki, M. Roué, J. Rubis, M. Schultz, P. Smith, R. Sumaila, K. Takeuchi, S. Thomas, M. Verma, Y. Yeo-Chang, D. Zlatanova, The IPBES Conceptual Framework - connecting nature and people. *Curr. Opin. Environ. Sustain.* **14**, 1–16 (2015). [doi:10.1016/j.cosust.2014.11.002](https://doi.org/10.1016/j.cosust.2014.11.002)
4. S. Díaz, U. Pascual, M. Stenseke, B. Martín-López, R. T. Watson, Z. Molnár, R. Hill, K. M. A. Chan, I. A. Baste, K. A. Brauman, S. Polasky, A. Church, M. Lonsdale, A. Larigauderie, P. W. Leadley, A. P. E. van Oudenhoven, F. van der Plaats, M. Schröter, S. Lavorel, Y. Aumeeruddy-Thomas, E. Bukvareva, K. Davies, S. Demissew, G. Erpul, P. Failler, C. A. Guerra, C. L. Hewitt, H. Keune, S. Lindley, Y. Shirayama, Assessing nature's contributions to people. *Science* **359**, 270–272 (2018).
[doi:10.1126/science.aap8826](https://doi.org/10.1126/science.aap8826) [Medline](#)
5. S. H. M. Butchart *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
6. With the exception of SDG 17 (strengthen the means of implementation and revitalize the global partnership for sustainable development).
7. A. D. Guerry, S. Polasky, J. Lubchenco, R. Chaplin-Kramer, G. C. Daily, R. Griffin, M. Ruckelshaus, I. J. Bateman, A. Duraiappah, T. Elmqvist, M. W. Feldman, C. Folke, J. Hoekstra, P. M. Kareiva, B. L. Keeler, S. Li, E. McKenzie, Z. Ouyang, B. Reyers, T. H. Ricketts, J. Rockström, H. Tallis, B. Vira, Natural capital and ecosystem services informing decisions: From promise to practice. *Proc. Natl. Acad. Sci. U.S.A.* **112**, 7348–7355 (2015). [doi:10.1073/pnas.1503751112](https://doi.org/10.1073/pnas.1503751112) [Medline](#)
8. K. A. Brauman *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat

of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).

9. J. Hinkel, D. Lincke, A. T. Vafeidis, M. Perrette, R. J. Nicholls, R. S. J. Tol, B. Marzeion, X. Fettweis, C. Ionescu, A. Levermann, Coastal flood damage and adaptation costs under 21st century sea-level rise. *Proc. Natl. Acad. Sci. U.S.A.* **111**, 3292–3297 (2014). [doi:10.1073/pnas.1222469111](https://doi.org/10.1073/pnas.1222469111) [Medline](#)
10. S. G. Potts, V. Imperatriz-Fonseca, H. T. Ngo, M. A. Aizen, J. C. Biesmeijer, T. D. Breeze, L. V. Dicks, L. A. Garibaldi, R. Hill, J. Settele, A. J. Vanbergen, Safeguarding pollinators and their values to human well-being. *Nature* **540**, 220–229 (2016). [doi:10.1038/nature20588](https://doi.org/10.1038/nature20588) [Medline](#)
11. Food and Agriculture Organization of the United Nations (FAO), *FAOSTAT Statistical Database* (FAO, 2019).
12. FAO, *The State of World's Fisheries and Aquaculture 2018. Meeting the Sustainable Development Goals* (Food and Agriculture Organization of the United Nations, Rome, 2018).
13. <https://data.worldbank.org/indicator/SP.POP.TOTL>
14. <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD>
15. <https://data.worldbank.org/indicator/NE.EXP.GNFS.KD>
16. www.materialflows.net
17. Millennium Ecosystem Assessment, *Ecosystems and Human Well-being* (Island Press, 2005).
18. J. E. M. Watson, D. F. Shanahan, M. Di Marco, J. Allan, W. F. Laurance, E. W. Sanderson, B. Mackey, O. Venter, Catastrophic declines in wilderness areas undermine global environment targets. *Curr. Biol.* **26**, 2929–2934 (2016). [doi:10.1016/j.cub.2016.08.049](https://doi.org/10.1016/j.cub.2016.08.049) [Medline](#)
19. Intergovernmental Panel on Climate Change (IPCC), *IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, A. Arneth *et al.*, Eds. (IPCC, 2019).
20. B. S. Halpern, C. Longo, J. S. S. Lowndes, B. D. Best, M. Frazier, S. K. Katona, K. M. Kleisner, A. A. Rosenberg, C. Scarborough, E. R. Selig, Patterns and emerging trends in global ocean health. *PLOS ONE* **10**, e0117863 (2015). [doi:10.1371/journal.pone.0117863](https://doi.org/10.1371/journal.pone.0117863) [Medline](#)
21. N. C. Davidson, How much wetland has the world lost? Long-term and recent trends in global wetland area. *Mar. Freshw. Res.* **65**, 934 (2014). [doi:10.1071/MF14173](https://doi.org/10.1071/MF14173)
22. G. Grill, B. Lehner, M. Thieme, B. Geenen, D. Tickner, F. Antonelli, S. Babu, P. Borrelli, L. Cheng, H. Crochetiere, H. Ehalt Macedo, R. Filgueiras, M. Goichot, J. Higgins, Z. Hogan, B. Lip, M. E. McClain, J. Meng, M. Mulligan, C. Nilsson, J. D. Olden, J. J. Opperman, P. Petry, C. Reidy Liermann, L. Sáenz, S. Salinas-Rodríguez, P. Schelle, R. J. P. Schmitt, J. Snider, F. Tan, K. Tockner, P. H. Valdujo, A. van Soesbergen, C. Zarfl,

- Mapping the world's free-flowing rivers. *Nature* **569**, 215–221 (2019).
[doi:10.1038/s41586-019-1111-9](https://doi.org/10.1038/s41586-019-1111-9) [Medline](#)
23. K. Frieler, M. Meinshausen, A. Golly, M. Mengel, K. Lebek, S. D. Donner, O. Hoegh-Guldberg, Limiting global warming to 2 C is unlikely to save most coral reefs. *Nat. Clim. Chang.* **3**, 165–170 (2013). [doi:10.1038/nclimate1674](https://doi.org/10.1038/nclimate1674)
24. K. A. Krumhansl, D. K. Okamoto, A. Rassweiler, M. Novak, J. J. Bolton, K. C. Cavanaugh, S. D. Connell, C. R. Johnson, B. Konar, S. D. Ling, F. Micheli, K. M. Norderhaug, A. Pérez-Matus, I. Sousa-Pinto, D. C. Reed, A. K. Salomon, N. T. Shears, T. Wernberg, R. J. Anderson, N. S. Barrett, A. H. Buschmann, M. H. Carr, J. E. Caselle, S. Derrien-Courtet, G. J. Edgar, M. Edwards, J. A. Estes, C. Goodwin, M. C. Kenner, D. J. Kushner, F. E. Moy, J. Nunn, R. S. Steneck, J. Vásquez, J. Watson, J. D. Witman, J. E. K. Byrnes, Global patterns of kelp forest change over the past half-century. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 13785–13790 (2016). [doi:10.1073/pnas.1606102113](https://doi.org/10.1073/pnas.1606102113) [Medline](#)
25. K.-H. Erb, T. Kastner, C. Plutzer, A. L. S. Bais, N. Carvalhais, T. Fetzl, S. Gingrich, H. Haberl, C. Lauk, M. Niedertscheider, J. Pongratz, M. Thurner, S. Luyssaert, Unexpectedly large impact of forest management and grazing on global vegetation biomass. *Nature* **553**, 73–76 (2018). [doi:10.1038/nature25138](https://doi.org/10.1038/nature25138) [Medline](#)
26. Food and Agriculture Organization of the United Nations (FAO), *Global Forest Resources Assessment 2010* (FAO, 2010).
27. X.-P. Song, M. C. Hansen, S. V. Stehman, P. V. Potapov, A. Tyukavina, E. F. Vermote, J. R. Townshend, Global land change from 1982 to 2016. *Nature* **560**, 639–643 (2018).
[doi:10.1038/s41586-018-0411-9](https://doi.org/10.1038/s41586-018-0411-9) [Medline](#)
28. R. J. Keenan, G. A. Reams, F. Achard, J. V. de Freitas, A. Grainger, E. Lindquist, Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. *For. Ecol. Manage.* **352**, 9–20 (2015). [doi:10.1016/j.foreco.2015.06.014](https://doi.org/10.1016/j.foreco.2015.06.014)
29. S. Gauthier, P. Bernier, T. Kuuluvainen, A. Z. Shvidenko, D. G. Schepaschenko, Boreal forest health and global change. *Science* **349**, 819–822 (2015).
[doi:10.1126/science.aaa9092](https://doi.org/10.1126/science.aaa9092) [Medline](#)
30. S. L. L. Hill *et al.*, Worldwide impacts of past and projected future land-use change on local species richness and the Biodiversity Intactness Index. bioRxiv 311787 [Preprint]. 1 May 2018.
31. J. Rice, in *The First Global Integrated Marine Assessment: World Ocean Assessment I*, United Nations (Cambridge Univ. Press, 2017).
32. E. Sala, N. Knowlton, Global marine biodiversity trends. *Annu. Rev. Environ. Resour.* **31**, 93–122 (2006). [doi:10.1146/annurev.energy.31.020105.100235](https://doi.org/10.1146/annurev.energy.31.020105.100235)
33. D. J. Agnew, J. Pearce, G. Pramod, T. Peatman, R. Watson, J. R. Beddington, T. J. Pitcher, Estimating the worldwide extent of illegal fishing. *PLOS ONE* **4**, e4570 (2009).
[doi:10.1371/journal.pone.0004570](https://doi.org/10.1371/journal.pone.0004570) [Medline](#)
34. J. Spijkers, G. Singh, R. Blasiak, T. H. Morrison, P. Le Billon, H. Österblom, Global patterns of fisheries conflict: Forty years of data. *Glob. Environ. Change* **57**, 101921 (2019).
[doi:10.1016/j.gloenvcha.2019.05.005](https://doi.org/10.1016/j.gloenvcha.2019.05.005)

35. W. J. Ripple, J. A. Estes, R. L. Beschta, C. C. Wilmers, E. G. Ritchie, M. Hebblewhite, J. Berger, B. Elmhagen, M. Letnic, M. P. Nelson, O. J. Schmitz, D. W. Smith, A. D. Wallach, A. J. Wirsing, Status and ecological effects of the world's largest carnivores. *Science* **343**, 1241484 (2014). [doi:10.1126/science.1241484](https://doi.org/10.1126/science.1241484) [Medline](#)
36. N. K. Dulvy, S. L. Fowler, J. A. Musick, R. D. Cavanagh, P. M. Kyne, L. R. Harrison, J. K. Carlson, L. N. K. Davidson, S. V. Fordham, M. P. Francis, C. M. Pollock, C. A. Simpfendorfer, G. H. Burgess, K. E. Carpenter, L. J. V. Compagno, D. A. Ebert, C. Gibson, M. R. Heupel, S. R. Livingstone, J. C. Sanciangco, J. D. Stevens, S. Valenti, W. T. White, Extinction risk and conservation of the world's sharks and rays. *eLife* **3**, e00590 (2014). [doi:10.7554/eLife.00590](https://doi.org/10.7554/eLife.00590) [Medline](#)
37. A. Estrada, P. A. Garber, A. B. Rylands, C. Roos, E. Fernandez-Duque, A. Di Fiore, K. A.-I. Nekaris, V. Nijman, E. W. Heymann, J. E. Lambert, F. Rovero, C. Barelli, J. M. Setchell, T. R. Gillespie, R. A. Mittermeier, L. V. Arregoitia, M. de Guinea, S. Gouveia, R. Dobrovolski, S. Shanee, N. Shanee, S. A. Boyle, A. Fuentes, K. C. MacKinnon, K. R. Amato, A. L. S. Meyer, S. Wich, R. W. Sussman, R. Pan, I. Kone, B. Li, Impending extinction crisis of the world's primates: Why primates matter. *Sci. Adv.* **3**, e1600946 (2017). [doi:10.1126/sciadv.1600946](https://doi.org/10.1126/sciadv.1600946) [Medline](#)
38. C. Wilkinson *et al.*, in *The First Global Integrated Marine Assessment: World Ocean Assessment I*, United Nations (Cambridge Univ. Press, 2017).
39. A. M. Humphreys, R. Govaerts, S. Z. Ficinski, E. Nic Lughadha, M. S. Vorontsova, Global dataset shows geography and life form predict modern plant extinction and rediscovery. *Nat. Ecol. Evol.* **3**, 1043–1047 (2019). [doi:10.1038/s41559-019-0906-2](https://doi.org/10.1038/s41559-019-0906-2) [Medline](#)
40. S. Faurby, J. C. Svenning, Historic and prehistoric human-driven extinctions have reshaped global mammal diversity patterns. *Divers. Distrib.* **21**, 1155–1166 (2015). [doi:10.1111/ddi.12369](https://doi.org/10.1111/ddi.12369)
41. J. Schipper, J. S. Chanson, F. Chiozza, N. A. Cox, M. Hoffmann, V. Katariya, J. Lamoreux, A. S. L. Rodrigues, S. N. Stuart, H. J. Temple, J. Baillie, L. Boitani, T. E. Lacher Jr., R. A. Mittermeier, A. T. Smith, D. Absolon, J. M. Aguiar, G. Amori, N. Bakkour, R. Baldi, R. J. Berridge, J. Bielby, P. A. Black, J. J. Blanc, T. M. Brooks, J. A. Burton, T. M. Butynski, G. Catullo, R. Chapman, Z. Cokeliss, B. Collen, J. Conroy, J. G. Cooke, G. A. B. da Fonseca, A. E. Derocher, H. T. Dublin, J. W. Duckworth, L. Emmons, R. H. Emslie, M. Festa-Bianchet, M. Foster, S. Foster, D. L. Garshelis, C. Gates, M. Gimenez-Dixon, S. Gonzalez, J. F. Gonzalez-Maya, T. C. Good, G. Hammerson, P. S. Hammond, D. Happold, M. Happold, J. Hare, R. B. Harris, C. E. Hawkins, M. Haywood, L. R. Heaney, S. Hedges, K. M. Helgen, C. Hilton-Taylor, S. A. Hussain, N. Ishii, T. A. Jefferson, R. K. B. Jenkins, C. H. Johnston, M. Keith, J. Kingdon, D. H. Knox, K. M. Kovacs, P. Langhammer, K. Leus, R. Lewison, G. Lichtenstein, L. F. Lowry, Z. Macavoy, G. M. Mace, D. P. Mallon, M. Masi, M. W. McKnight, R. A. Medellín, P. Medici, G. Mills, P. D. Moehlman, S. Molur, A. Mora, K. Nowell, J. F. Oates, W. Olech, W. R. L. Oliver, M. Oprea, B. D. Patterson, W. F. Perrin, B. A. Polidoro, C. Pollock, A. Powel, Y. Protas, P. Racey, J. Ragle, P. Ramani, G. Rathbun, R. R. Reeves, S. B. Reilly, J. E. Reynolds 3rd, C. Rondinini, R. G. Rosell-Ambal, M. Rulli, A. B. Rylands, S. Savini, C. J. Schank, W. Sechrest, C. Self-Sullivan, A. Shoemaker, C. Sillero-Zubiri, N. De Silva, D. E. Smith, C. Srinivasulu, P. J. Stephenson, N. van Strien, B. K. Talukdar, B. L.

- Taylor, R. Timmins, D. G. Tirira, M. F. Tognelli, K. Tsytulina, L. M. Veiga, J.-C. Vié, E. A. Williamson, S. A. Wyatt, Y. Xie, B. E. Young, The status of the world's land and marine mammals: Diversity, threat, and knowledge. *Science* **322**, 225–230 (2008). [doi:10.1126/science.1165115](https://doi.org/10.1126/science.1165115) [Medline](#)
42. A. M. Magera, J. E. Mills Flemming, K. Kaschner, L. B. Christensen, H. K. Lotze, Recovery trends in marine mammal populations. *PLOS ONE* **8**, e77908 (2013). [doi:10.1371/journal.pone.0077908](https://doi.org/10.1371/journal.pone.0077908) [Medline](#)
43. M. Tabarelli, C. A. Peres, F. P. L. Melo, The ‘few winners and many losers’ paradigm revisited: Emerging prospects for tropical forest biodiversity. *Biol. Conserv.* **155**, 136–140 (2012). [doi:10.1016/j.biocon.2012.06.020](https://doi.org/10.1016/j.biocon.2012.06.020)
44. S. Pagad *et al.*, IUCN SSC Invasive Species Specialist Group, Invasive alien species information management supporting practitioners, policy makers and decision takers. *Int. J. Appl. Res. Biologic. Invasions* **6**, 127 (2015).
45. T. Newbold, L. N. Hudson, S. Contu, S. L. L. Hill, J. Beck, Y. Liu, C. Meyer, H. R. P. Phillips, J. P. W. Scharlemann, A. Purvis, Widespread winners and narrow-ranged losers: Land use homogenizes biodiversity in local assemblages worldwide. *PLOS Biol.* **16**, e2006841 (2018). [doi:10.1371/journal.pbio.2006841](https://doi.org/10.1371/journal.pbio.2006841) [Medline](#)
46. W. D. Pearse, J. Cavender-Bares, S. E. Hobbie, M. L. Avolio, N. Bettez, R. Roy Chowdhury, L. E. Darling, P. M. Groffman, J. M. Grove, S. J. Hall, J. B. Heffernan, J. Learned, C. Neill, K. C. Nelson, D. E. Pataki, B. L. Ruddell, M. K. Steele, T. L. E. Trammell, Homogenization of plant diversity, composition, and structure in North American urban yards. *Ecosphere* **9**, e02105 (2018). [doi:10.1002/ecs2.2105](https://doi.org/10.1002/ecs2.2105)
47. International Union for the Conservation of Nature (IUCN), IUCN Red List Categories and Criteria. Version 3.1 (Gland, Switzerland, 2012).
48. www.iucn.org/content/european-red-list
49. V. Clausnitzer, V. J. Kalkman, M. Ram, B. Collen, J. E. M. Baillie, M. Bedjanič, W. R. T. Darwall, K.-D. B. Dijkstra, R. Dow, J. Hawking, H. Karube, E. Malikova, D. Paulson, K. Schütte, F. Suhling, R. J. Villanueva, N. von Ellenrieder, K. Wilson, Odonata enter the biodiversity crisis debate: The first global assessment of an insect group. *Biol. Conserv.* **142**, 1864–1869 (2009). [doi:10.1016/j.biocon.2009.03.028](https://doi.org/10.1016/j.biocon.2009.03.028)
50. M. J. Caley, R. Fisher, K. Mengersen, Global species richness estimates have not converged. *Trends Ecol. Evol.* **29**, 187–188 (2014). [doi:10.1016/j.tree.2014.02.002](https://doi.org/10.1016/j.tree.2014.02.002) [Medline](#)
51. A. Purvis *et al.*, in *Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondízio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
52. Y. M. Bar-On, R. Phillips, R. Milo, The biomass distribution on Earth. *Proc. Natl. Acad. Sci. U.S.A.* **115**, 6506–6511 (2018). [doi:10.1073/pnas.1711842115](https://doi.org/10.1073/pnas.1711842115) [Medline](#)
53. V. Christensen, M. Coll, C. Piroddi, J. Steenbeek, J. Buszowski, D. Pauly, A century of fish biomass decline in the ocean. *Mar. Ecol. Prog. Ser.* **512**, 155–166 (2014). [doi:10.3354/meps10946](https://doi.org/10.3354/meps10946)

54. IUCN, *The IUCN Red List of Threatened Species. Version 2019-2*. Downloaded on 18 July 2019 (IUCN, 2019); www.iucnredlist.org.
55. S. L. Pimm, C. N. Jenkins, R. Abell, T. M. Brooks, J. L. Gittleman, L. N. Joppa, P. H. Raven, C. M. Roberts, J. O. Sexton, The biodiversity of species and their rates of extinction, distribution, and protection. *Science* **344**, 1246752 (2014). [doi:10.1126/science.1246752](https://doi.org/10.1126/science.1246752) [Medline](#)
56. G. Ceballos, P. R. Ehrlich, A. D. Barnosky, A. García, R. M. Pringle, T. M. Palmer, Accelerated modern human-induced species losses: Entering the sixth mass extinction. *Sci. Adv.* **1**, e1400253 (2015). [doi:10.1126/sciadv.1400253](https://doi.org/10.1126/sciadv.1400253) [Medline](#)
57. FAO, *The State of the World's Animal Genetic Resources for Food and Agriculture*. B. Rischkowsky, D. Pilling, Eds. (FAO, 2016).
58. S. Pironon, T. R. Etherington, J. S. Borrell, N. Kühn, M. Macias-Fauria, I. Ondo, C. Tovar, P. Wilkin, K. J. Willis, Potential adaptive strategies for 29 sub-Saharan crops under future climate change. *Nat. Clim. Chang.* **9**, 758–763 (2019). [doi:10.1038/s41558-019-0585-7](https://doi.org/10.1038/s41558-019-0585-7)
59. N. P. Castañeda-Álvarez, C. K. Khoury, H. A. Achicanoy, V. Bernau, H. Dempewolf, R. J. Eastwood, L. Guarino, R. H. Harker, A. Jarvis, N. Maxted, J. V. Müller, J. Ramirez-Villegas, C. C. Sosa, P. C. Struik, H. Vincent, J. Toll, Global conservation priorities for crop wild relatives. *Nat. Plants* **2**, 16022 (2016). [doi:10.1038/nplants.2016.22](https://doi.org/10.1038/nplants.2016.22) [Medline](#)
60. S. T. Garnett, N. D. Burgess, J. E. Fa, Á. Fernández-Llamazares, Z. Molnár, C. J. Robinson, J. E. M. Watson, K. K. Zander, B. Austin, E. S. Brondizio, N. F. Collier, T. Duncan, E. Ellis, H. Geyle, M. V. Jackson, H. Jonas, P. Malmer, B. McGowan, A. Sivongxay, I. Leiper, A spatial overview of the global importance of Indigenous lands for conservation. *Nat. Sustainabil.* **1**, 369–374 (2018). [doi:10.1038/s41893-018-0100-6](https://doi.org/10.1038/s41893-018-0100-6)
61. A. P. Hendry, K. M. Gotanda, E. I. Svensson, Human influences on evolution, and the ecological and societal consequences. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **372**, 20160028 (2017). [doi:10.1098/rstb.2016.0028](https://doi.org/10.1098/rstb.2016.0028) [Medline](#)
62. F. Gould, Z. S. Brown, J. Kuzma, Wicked evolution: Can we address the sociobiological dilemma of pesticide resistance? *Science* **360**, 728–732 (2018). [doi:10.1126/science.aar3780](https://doi.org/10.1126/science.aar3780) [Medline](#)
63. A. Audzijonyte, E. Fulton, M. Haddon, F. Helidoniotis, A. J. Hobday, A. Kuparinen, J. Morrongiello, A. D. M. Smith, J. Upston, R. S. Waples, Trends and management implications of human-influenced life-history changes in marine ectotherms. *Fish Fish.* **17**, 1005–1028 (2016). [doi:10.1111/faf.12156](https://doi.org/10.1111/faf.12156)
64. K. A. Thompson, M. Renaudin, M. T. J. Johnson, Urbanization drives the evolution of parallel clines in plant populations. *Proc. Biol. Sci.* **283**, 20162180 (2016). [doi:10.1098/rspb.2016.2180](https://doi.org/10.1098/rspb.2016.2180) [Medline](#)
65. J. Merilä, A. P. Hendry, Climate change, adaptation, and phenotypic plasticity: The problem and the evidence. *Evol. Appl.* **7**, 1–14 (2014). [doi:10.1111/eva.12137](https://doi.org/10.1111/eva.12137) [Medline](#)
66. J. C. Z. Woinarski, S. T. Garnett, S. M. Legge, D. B. Lindenmayer, The contribution of policy, law, management, research, and advocacy failings to the recent extinctions of

- three Australian vertebrate species. *Conserv. Biol.* **31**, 13–23 (2017).
[doi:10.1111/cobi.12852](https://doi.org/10.1111/cobi.12852) [Medline](#)
67. UNEP, *Cultural and Spiritual Values of Biodiversity* (Intermediate Technology, 1999).
 68. L. Porter-Bolland, E. A. Ellis, M. R. Guariguata, I. Ruiz-Mallén, S. Negrete-Yankelevich, V. Reyes-García, Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. *For. Ecol. Manage.* **268**, 6–17 (2012).
[doi:10.1016/j.foreco.2011.05.034](https://doi.org/10.1016/j.foreco.2011.05.034)
 69. P. Balvanera *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
 70. J. Liu, V. Hull, M. Batistella, R. DeFries, T. Dietz, F. Fu, T. W. Hertel, R. C. Izaurralde, E. F. Lambin, S. Li, L. A. Martinelli, W. J. McConnell, E. F. Moran, R. Naylor, Z. Ouyang, K. R. Polenske, A. Reenberg, G. de Miranda Rocha, C. S. Simmons, P. H. Verburg, P. M. Vitousek, F. Zhang, C. Zhu, Framing sustainability in a telecoupled world. *Ecol. Soc.* **18**, art26 (2013). [doi:10.5751/ES-05873-180226](https://doi.org/10.5751/ES-05873-180226)
 71. H. Österblom, J.-B. Jouffray, C. Folke, B. Crona, M. Troell, A. Merrie, J. Rockström, Transnational corporations as ‘keystone actors’ in marine ecosystems. *PLOS ONE* **10**, e0127533 (2015). [doi:10.1371/journal.pone.0127533](https://doi.org/10.1371/journal.pone.0127533) [Medline](#)
 72. C. Folke, H. Österblom, J.-B. Jouffray, E. F. Lambin, W. N. Adger, M. Scheffer, B. I. Crona, M. Nyström, S. A. Levin, S. R. Carpenter, J. M. Anderies, S. Chapin 3rd, A.-S. Crépin, A. Dauriach, V. Galaz, L. J. Gordon, N. Kautsky, B. H. Walker, J. R. Watson, J. Wilen, A. de Zeeuw, Transnational corporations and the challenge of biosphere stewardship. *Nat. Ecol. Evol.* **3**, 1396–1403 (2019). [doi:10.1038/s41559-019-0978-z](https://doi.org/10.1038/s41559-019-0978-z) [Medline](#)
 73. V. Galaz, B. Crona, A. Dauriach, J.-B. Jouffray, H. Österblom, J. Fichtner, Tax havens and global environmental degradation. *Nat. Ecol. Evol.* **2**, 1352–1357 (2018).
[doi:10.1038/s41559-018-0497-3](https://doi.org/10.1038/s41559-018-0497-3) [Medline](#)
 74. U. R. Sumaila, V. Lam, F. Le Manach, W. Swartz, D. Pauly, Global fisheries subsidies: An updated estimate. *Mar. Policy* **69**, 189–193 (2016). [doi:10.1016/j.marpol.2015.12.026](https://doi.org/10.1016/j.marpol.2015.12.026)
 75. F. H. Oosterhuis, P. Ten Brink, Eds., *Paying the Polluter: Environmentally Harmful Subsidies and their Reform* (Edward Elgar, 2014).
 76. P. Ten Brink, *The Economics of Ecosystems and Biodiversity in National and International Policy Making* (Routledge, 2012).
 77. A. S. Pullin, M. Bangpan, S. Dalrymple, K. Dickson, N. R. Haddaway, J. R. Healey, H. Hauari, N. Hockley, J. P. G. Jones, T. Knight, C. Vigurs, S. Oliver, Human well-being impacts of terrestrial protected areas. *Environ. Evid.* **2**, 19 (2013). [doi:10.1186/2047-2382-2-19](https://doi.org/10.1186/2047-2382-2-19)
 78. M. M. Bayrak, M. L. Marafa, Ten years of REDD+: A critical review of the impact of REDD+ on forest-dependent communities. *Sustainability* **8**, 620 (2016).
[doi:10.3390/su8070620](https://doi.org/10.3390/su8070620)

79. M. Hoffmann, C. Hilton-Taylor, A. Angulo, M. Böhm, T. M. Brooks, S. H. M. Butchart, K. E. Carpenter, J. Chanson, B. Collen, N. A. Cox, W. R. T. Darwall, N. K. Dulvy, L. R. Harrison, V. Katariya, C. M. Pollock, S. Quader, N. I. Richman, A. S. L. Rodrigues, M. F. Tognelli, J.-C. Vié, J. M. Aguiar, D. J. Allen, G. R. Allen, G. Amori, N. B. Ananjeva, F. Andreone, P. Andrew, A. L. Aquino Ortiz, J. E. M. Baillie, R. Baldi, B. D. Bell, S. D. Biju, J. P. Bird, P. Black-Decima, J. J. Blanc, F. Bolaños, W. Bolivar-G, I. J. Burfield, J. A. Burton, D. R. Capper, F. Castro, G. Catullo, R. D. Cavanagh, A. Channing, N. L. Chao, A. M. Chenery, F. Chiozza, V. Clausnitzer, N. J. Collar, L. C. Collett, B. B. Collette, C. F. Cortez Fernandez, M. T. Craig, M. J. Crosby, N. Cumberlidge, A. Cuttelod, A. E. Derocher, A. C. Diesmos, J. S. Donaldson, J. W. Duckworth, G. Dutson, S. K. Dutta, R. H. Emslie, A. Farjon, S. Fowler, J. Freyhof, D. L. Garshelis, J. Gerlach, D. J. Gower, T. D. Grant, G. A. Hammerson, R. B. Harris, L. R. Heaney, S. B. Hedges, J.-M. Hero, B. Hughes, S. A. Hussain, J. Icochea M, R. F. Inger, N. Ishii, D. T. Iskandar, R. K. B. Jenkins, Y. Kaneko, M. Kottelat, K. M. Kovacs, S. L. Kuzmin, E. La Marca, J. F. Lamoreux, M. W. N. Lau, E. O. Lavilla, K. Leus, R. L. Lewison, G. Lichtenstein, S. R. Livingstone, V. Lukoschek, D. P. Mallon, P. J. K. McGowan, A. McIvor, P. D. Moehlman, S. Molur, A. Muñoz Alonso, J. A. Musick, K. Nowell, R. A. Nussbaum, W. Olech, N. L. Orlov, T. J. Papenfuss, G. Parra-Olea, W. F. Perrin, B. A. Polidoro, M. Pourkazemi, P. A. Racey, J. S. Ragle, M. Ram, G. Rathbun, R. P. Reynolds, A. G. J. Rhodin, S. J. Richards, L. O. Rodríguez, S. R. Ron, C. Rondinini, A. B. Rylands, Y. Sadovy de Mitcheson, J. C. Sanciango, K. L. Sanders, G. Santos-Barrera, J. Schipper, C. Self-Sullivan, Y. Shi, A. Shoemaker, F. T. Short, C. Sillero-Zubiri, D. L. Silvano, K. G. Smith, A. T. Smith, J. Snoeks, A. J. Stattersfield, A. J. Symes, A. B. Taber, B. K. Talukdar, H. J. Temple, R. Timmins, J. A. Tobias, K. Tsytulina, D. Tweddle, C. Ubeda, S. V. Valenti, P. P. van Dijk, L. M. Veiga, A. Veloso, D. C. Wege, M. Wilkinson, E. A. Williamson, F. Xie, B. E. Young, H. R. Akçakaya, L. Bennun, T. M. Blackburn, L. Boitani, H. T. Dublin, G. A. B. da Fonseca, C. Gascon, T. E. Lacher Jr., G. M. Mace, S. A. Mainka, J. A. McNeely, R. A. Mittermeier, G. M. G. Reid, J. P. Rodriguez, A. A. Rosenberg, M. J. Samways, J. Smart, B. A. Stein, S. N. Stuart, The impact of conservation on the status of the world's vertebrates. *Science* **330**, 1503–1509 (2010). [doi:10.1126/science.1194442](https://doi.org/10.1126/science.1194442) [Medline](#)
80. H. P. Jones, N. D. Holmes, S. H. M. Butchart, B. R. Tershy, P. J. Kappes, I. Corkery, A. Aguirre-Muñoz, D. P. Armstrong, E. Bonnaud, A. A. Burbidge, K. Campbell, F. Courchamp, P. E. Cowan, R. J. Cuthbert, S. Ebbert, P. Genovesi, G. R. Howald, B. S. Keitt, S. W. Kress, C. M. Miskelly, S. Oppel, S. Poncet, M. J. Rauzon, G. Rocamora, J. C. Russell, A. Samaniego-Herrera, P. J. Seddon, D. R. Spatz, D. R. Towns, D. A. Croll, Invasive mammal eradication on islands results in substantial conservation gains. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 4033–4038 (2016). [doi:10.1073/pnas.1521179113](https://doi.org/10.1073/pnas.1521179113) [Medline](#)
81. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), *The Methodological Assessment on Scenarios and Models of Biodiversity and Ecosystem Services*, S. Ferrier *et al.*, Eds. (Secretariat of the Intergovernmental Platform for Biodiversity and Ecosystem Services, 2016).
82. B. C. O'Neill, E. Kriegler, K. Riahi, K. L. Ebi, S. Hallegatte, T. R. Carter, R. Mathur, D. P. van Vuuren, A new scenario framework for climate change research: The concept of

- shared socioeconomic pathways. *Clim. Change* **122**, 387–400 (2014). [doi:10.1007/s10584-013-0905-2](https://doi.org/10.1007/s10584-013-0905-2)
83. Y. J. Shin *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
 84. R. Chaplin-Kramer, R. P. Sharp, C. Weil, E. M. Bennett, U. Pascual, K. K. Arkema, K. A. Brauman, B. P. Bryant, A. D. Guerry, N. M. Haddad, M. Hamann, P. Hamel, J. A. Johnson, L. Mandle, H. M. Pereira, S. Polasky, M. Ruckelshaus, M. R. Shaw, J. M. Silver, A. L. Vogl, G. C. Daily, Global modeling of nature's contributions to people. *Science* **366**, 255–258 (2019). [doi:10.1126/science.aaw3372](https://doi.org/10.1126/science.aaw3372) [Medline](#)
 85. N. Titeux, K. Henle, J.-B. Mihoub, A. Regos, I. R. Geijzenborffer, W. Cramer, P. H. Verburg, L. Brotons, Biodiversity scenarios neglect future land-use changes. *Glob. Chang. Biol.* **22**, 2505–2515 (2016). [doi:10.1111/gcb.13272](https://doi.org/10.1111/gcb.13272) [Medline](#)
 86. M. C. Urban, Climate change. Accelerating extinction risk from climate change. *Science* **348**, 571–573 (2015). [doi:10.1126/science.aaa4984](https://doi.org/10.1126/science.aaa4984) [Medline](#)
 87. E. K. Kapsar, C. Hovis, R. Bicudo da Silva, E. Buchholtz, A. Carlson, Y. Dou, Y. Du, P. Furumo, Y. Li, A. Torres, D. Yang, H. Wan, J. Zaehring, J. Liu, Telecoupling research: The first five years. *Sustainability* **11**, 1033 (2019). [doi:10.3390/su11041033](https://doi.org/10.3390/su11041033)
 88. G. Strona, C. J. A. Bradshaw, Co-extinctions annihilate planetary life during extreme environmental change. *Sci. Rep.* **8**, 16724 (2018). [doi:10.1038/s41598-018-35068-1](https://doi.org/10.1038/s41598-018-35068-1) [Medline](#)
 89. J. Liu, V. Hull, H. C. J. Godfray, D. Tilman, P. Gleick, H. Hoff, C. Pahl-Wostl, Z. Xu, M. G. Chung, J. Sun, S. Li, Nexus approaches to global sustainable development. *Nat. Sustainabil.* **1**, 466–476 (2018). [doi:10.1038/s41893-018-0135-8](https://doi.org/10.1038/s41893-018-0135-8)
 90. G. T. Pecl, M. B. Araújo, J. D. Bell, J. Blanchard, T. C. Bonebrake, I.-C. Chen, T. D. Clark, R. K. Colwell, F. Danielsen, B. Evengård, L. Falconi, S. Ferrier, S. Frusher, R. A. Garcia, R. B. Griffiths, A. J. Hobday, C. Janion-Scheepers, M. A. Jarzyna, S. Jennings, J. Lenoir, H. I. Linnetved, V. Y. Martin, P. C. McCormack, J. McDonald, N. J. Mitchell, T. Mustonen, J. M. Pandolfi, N. Pettorelli, E. Popova, S. A. Robinson, B. R. Scheffers, J. D. Shaw, C. J. B. Sorte, J. M. Strugnell, J. M. Sunday, M.-N. Tuanmu, A. Vergés, C. Villanueva, T. Wernberg, E. Wapstra, S. E. Williams, Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science* **355**, eaai9214 (2017). [doi:10.1126/science.aai9214](https://doi.org/10.1126/science.aai9214) [Medline](#)
 91. O. Hoegh-Guldberg *et al.*, in *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, V. Masson-Delmotte *et al.*, Eds. (World Meteorological Organization, 2018).
 92. Intergovernmental Panel on Climate Change (IPCC), *Summary for Policymakers in Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the*

context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, Masson-Delmotte *et al.*, Eds. (World Meteorological Organization, 2018).

93. D. Tilman, M. Clark, D. R. Williams, K. Kimmel, S. Polasky, C. Packer, Future threats to biodiversity and pathways to their prevention. *Nature* **546**, 73–81 (2017).
[doi:10.1038/nature22900](https://doi.org/10.1038/nature22900) [Medline](#)
94. D. M. Cáceres, Accumulation by Dispossession and Socio-Environmental Conflicts Caused by the Expansion of Agribusiness in Argentina. *J. Agrar. Change* **15**, 116–147 (2015).
[doi:10.1111/joac.12057](https://doi.org/10.1111/joac.12057)
95. K. M. A. Chan *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondízio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
96. J.-F. Bastin, Y. Finegold, C. Garcia, D. Mollicone, M. Rezende, D. Routh, C. M. Zohner, T. W. Crowther, The global tree restoration potential. *Science* **365**, 76–79 (2019).
[doi:10.1126/science.aax0848](https://doi.org/10.1126/science.aax0848) [Medline](#)
97. S. L. Lewis, C. E. Wheeler, E. T. A. Mitchard, A. Koch, Restoring natural forests is the best way to remove atmospheric carbon. *Nature* **568**, 25–28 (2019). [doi:10.1038/d41586-019-01026-8](https://doi.org/10.1038/d41586-019-01026-8) [Medline](#)
98. J. Poore, T. Nemecek, Reducing food’s environmental impacts through producers and consumers. *Science* **360**, 987–992 (2018). [doi:10.1126/science.aaq0216](https://doi.org/10.1126/science.aaq0216) [Medline](#)
99. H. M. Tallis, P. L. Hawthorne, S. Polasky, J. Reid, M. W. Beck, K. Brauman, J. M. Bielicki, S. Binder, M. G. Burgess, E. Cassidy, A. Clark, J. Fargione, E. T. Game, J. Gerber, F. Isbell, J. Kiesecker, R. McDonald, M. Metian, J. L. Molnar, N. D. Mueller, C. O’Connell, D. Ovando, M. Troell, T. M. Boucher, B. McPeck, An attainable global vision for conservation and human well-being. *Front. Ecol. Environ.* **16**, 563–570 (2018).
[doi:10.1002/fee.1965](https://doi.org/10.1002/fee.1965)
100. G. M. Mace, M. Barrett, N. D. Burgess, S. E. Cornell, R. Freeman, M. Grooten, A. Purvis, Aiming higher to bend the curve of biodiversity loss. *Nat. Sustainabil.* **1**, 448–451 (2018). [doi:10.1038/s41893-018-0130-0](https://doi.org/10.1038/s41893-018-0130-0)
101. L. Raymond, S. L. Weldon, D. Kelly, X. B. Arriaga, A. M. Clark, Making change: Norm-based strategies for institutional change to address intractable problems. *Polit. Res. Q.* **67**, 197–211 (2014). [doi:10.1177/1065912913510786](https://doi.org/10.1177/1065912913510786)
102. Organization for Economic Cooperation (OECD), *Environmentally Harmful Subsidies: Challenges for Reform* (OECD, 2005).
103. D. O’Rourke, N. Lollo, Transforming consumption: From decoupling, to behavior change, to system changes for sustainable consumption. *Annu. Rev. Environ. Resour.* **40**, 233–259 (2015). [doi:10.1146/annurev-environ-102014-021224](https://doi.org/10.1146/annurev-environ-102014-021224)
104. G. Kallis, V. Kostakis, S. Lange, B. Muraca, S. Paulson, M. Schmelzer, Research on degrowth. *Annu. Rev. Environ. Resour.* **43**, 291–316 (2018). [doi:10.1146/annurev-environ-102017-025941](https://doi.org/10.1146/annurev-environ-102017-025941)

105. S. Sitch, P. M. Cox, W. J. Collins, C. Huntingford, Indirect radiative forcing of climate change through ozone effects on the land-carbon sink. *Nature* **448**, 791–794 (2007).
[doi:10.1038/nature06059](https://doi.org/10.1038/nature06059) [Medline](#)
106. J. Razzaque *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondizio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
107. Z. Q. Zhang, Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness (Addenda 2013). *Zootaxa* **3703**, 1–82 (2013).
[doi:10.11646/zootaxa.3148.1.1](https://doi.org/10.11646/zootaxa.3148.1.1) [Medline](#)
108. M. Böhm, B. Collen, J. E. M. Baillie, P. Bowles, J. Chanson, N. Cox, G. Hammerson, M. Hoffmann, S. R. Livingstone, M. Ram, A. G. J. Rhodin, S. N. Stuart, P. P. van Dijk, B. E. Young, L. E. Afuang, A. Aghasyan, A. García, C. Aguilar, R. Ajtic, F. Akarsu, L. R. V. Alencar, A. Allison, N. Ananjeva, S. Anderson, C. Andrén, D. Ariano-Sánchez, J. C. Arredondo, M. Auliya, C. C. Austin, A. Avci, P. J. Baker, A. F. Barreto-Lima, C. L. Barrio-Amorós, D. Basu, M. F. Bates, A. Batistella, A. Bauer, D. Bennett, W. Böhme, D. Broadley, R. Brown, J. Burgess, A. Captain, S. Carreira, M. R. Castañeda, F. Castro, A. Catenazzi, J. R. Cedeño-Vázquez, D. G. Chapple, M. Cheylan, D. F. Cisneros-Heredia, D. Cogalniceanu, H. Cogger, C. Corti, G. C. Costa, P. J. Couper, T. Courtney, J. Crnobrnja-Isailovic, P.-A. Crochet, B. Crother, F. Cruz, J. C. Daltry, R. J. R. Daniels, I. Das, A. de Silva, A. C. Diesmos, L. Dirksen, T. M. Doan, C. K. Dodd Jr., J. S. Doody, M. E. Dorcas, J. Duarte de Barros Filho, V. T. Egan, E. H. El Mouden, D. Embert, R. E. Espinoza, A. Fallabrino, X. Feng, Z.-J. Feng, L. Fitzgerald, O. Flores-Villela, F. G. R. França, D. Frost, H. Gadsden, T. Gamble, S. R. Ganesh, M. A. Garcia, J. E. García-Pérez, J. Gatus, M. Gaulke, P. Geniez, A. Georges, J. Gerlach, S. Goldberg, J.-C. T. Gonzalez, D. J. Gower, T. Grant, E. Greenbaum, C. Grieco, P. Guo, A. M. Hamilton, K. Hare, S. B. Hedges, N. Heideman, C. Hilton-Taylor, R. Hitchmough, B. Hollingsworth, M. Hutchinson, I. Ineich, J. Iverson, F. M. Jaksic, R. Jenkins, U. Joger, R. Jose, Y. Kaska, U. Kaya, J. S. Keogh, G. Köhler, G. Kuchling, Y. Kumlutaş, A. Kwet, E. La Marca, W. Lamar, A. Lane, B. Lardner, C. Latta, G. Latta, M. Lau, P. Lavin, D. Lawson, M. LeBreton, E. Lehr, D. Limpus, N. Lipczynski, A. S. Lobo, M. A. López-Luna, L. Luiselli, V. Lukoschek, M. Lundberg, P. Lymberakis, R. Macey, W. E. Magnusson, D. L. Mahler, A. Malhotra, J. Mariaux, B. Maritz, O. A. V. Marques, R. Márquez, M. Martins, G. Masterson, J. A. Mateo, R. Mathew, N. Mathews, G. Mayer, J. R. McCranie, G. J. Measey, F. Mendoza-Quijano, M. Menegon, S. Métrailler, D. A. Milton, C. Montgomery, S. A. A. Morato, T. Mott, A. Muñoz-Alonso, J. Murphy, T. Q. Nguyen, G. Nilson, C. Nogueira, H. Núñez, N. Orlov, H. Ota, J. Ottenwalder, T. Papenfuss, S. Pasachnik, P. Passos, O. S. G. Pauwels, N. Pérez-Buitrago, V. Pérez-Mellado, E. R. Pianka, J. Pleguezuelos, C. Pollock, P. Ponce-Campos, R. Powell, F. Pupin, G. E. Quintero Díaz, R. Radder, J. Ramer, A. R. Rasmussen, C. Raxworthy, R. Reynolds, N. Richman, E. L. Rico, E. Riservato, G. Rivas, P. L. B. da Rocha, M.-O. Rödel, L. Rodríguez Schettino, W. M. Roosenburg, J. P. Ross, R. Sadek, K. Sanders, G. Santos-Barrera, H. H. Schleich, B. R. Schmidt, A. Schmitz, M. Sharifi, G. Shea, H.-T. Shi, R. Shine, R. Sindaco, T. Slimani, R. Somaweera, S. Spawls, P. Stafford, R. Stuebing, S. Sweet, E. Sy, H. J. Temple, M. F. Tognelli, K. Tolley, P. J. Tolson, B. Tuniyev, S. Tuniyev, N. Üzümlü, G. van Buurt, M.

- Van Sluys, A. Velasco, M. Vences, M. Veselý, S. Vinke, T. Vinke, G. Vogel, M. Vogrin, R. C. Vogt, O. R. Wearn, Y. L. Werner, M. J. Whiting, T. Wiewandt, J. Wilkinson, B. Wilson, S. Wren, T. Zamin, K. Zhou, G. Zug, The conservation status of the world's reptiles. *Biol. Conserv.* **157**, 372–385 (2013). [doi:10.1016/j.biocon.2012.07.015](https://doi.org/10.1016/j.biocon.2012.07.015)
109. N. A. Brummitt, S. P. Bachman, J. Griffiths-Lee, M. Lutz, J. F. Moat, A. Farjon, J. S. Donaldson, C. Hilton-Taylor, T. R. Meagher, S. Albuquerque, E. Aletrari, A. K. Andrews, G. Atchison, E. Baloch, B. Barlozzini, A. Brunazzi, J. Carretero, M. Celesti, H. Chadburn, E. Cianfoni, C. Cockel, V. Coldwell, B. Concetti, S. Contu, V. Crook, P. Dyson, L. Gardiner, N. Ghanim, H. Greene, A. Groom, R. Harker, D. Hopkins, S. Khela, P. Lakeman-Fraser, H. Lindon, H. Lockwood, C. Loftus, D. Lombrici, L. Lopez-Poveda, J. Lyon, P. Malcolm-Tompkins, K. McGregor, L. Moreno, L. Murray, K. Nazar, E. Power, M. Quiton Tuijtelaars, R. Salter, R. Segrott, H. Thacker, L. J. Thomas, S. Tingvoll, G. Watkinson, K. Wojtaszekova, E. M. Nic Lughadha, Green plants in the red: A baseline global assessment for the IUCN sampled Red List Index for plants. *PLOS ONE* **10**, e0135152 (2015). [doi:10.1371/journal.pone.0135152](https://doi.org/10.1371/journal.pone.0135152) [Medline](#)
 110. E. N. Lughadha, R. Govaerts, I. Belyaeva, N. Black, H. Lindon, R. Allkin, R. Magill, N. Nicolson, Counting counts: Revised estimates of numbers of accepted species of flowering plants, seed plants, vascular plants and land plants with a review of other recent estimates. *Phytotaxa* **272**, 82 (2016). [doi:10.11646/phytotaxa.272.1.5](https://doi.org/10.11646/phytotaxa.272.1.5)
 111. M. J. M. Christenhusz, J. W. Byng, The number of known plants species in the world and its annual increase. *Phytotaxa* **261**, 201 (2016). [doi:10.11646/phytotaxa.261.3.1](https://doi.org/10.11646/phytotaxa.261.3.1)
 112. *State of the World's Plants 2017*, K. J. Willis, Ed. (Royal Botanical Gardens, 2017).
 113. *State of the World's Fungi 2018*, K. J. Willis, Ed. (Royal Botanical Gardens, 2018).
 114. E. S. Brondízio *et al.*, in *Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, E. S. Brondízio *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services, 2019).
 115. Z. Molnár, F. Berkes, in *Reconnecting Natural and Cultural Capital: Contributions from Science and Policy*, M. L. Paracchini *et al.*, Eds. (Joint Research Centre, 2018).
 116. F. Berkes, *Sacred Ecology* (Routledge, 2017).
 117. V. Reyes-García, Á. Fernández-Llamazares, P. McElwee, Z. Molnár, K. Öllerer, S. J. Wilson, E. S. Brondizio, The contributions of Indigenous Peoples and local communities to ecological restoration. *Restor. Ecol.* **27**, 3–8 (2019). [doi:10.1111/rec.12894](https://doi.org/10.1111/rec.12894)
 118. G. Michon, H. De Foresta, P. Levang, F. Verdeaux, Domestic forests: A new paradigm for integrating local communities' forestry into tropical forest science. *Ecol. Soc.* **12**, 1 (2007).
 119. W. J. Pawu-Kurlpurlurnu *et al.*, “Ngurra-kurlu: A way of working with Warlpiri people” (Desert Knowledge, 2008).
 120. E. C. Regan, L. Santini, L. Ingwall-King, M. Hoffmann, C. Rondinini, A. Symes, J. Taylor, S. H. M. Butchart, Global trends in the status of bird and mammal pollinators. *Conserv. Lett.* **8**, 397–403 (2015). [doi:10.1111/conl.12162](https://doi.org/10.1111/conl.12162)

121. IPBES, *Summary for policymakers of the assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on Pollinators, Pollination and Food Production*, S. G. Potts *et al.*, Eds. (Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2016).
122. J. C. Biesmeijer, S. P. Roberts, M. Reemer, R. Ohlemüller, M. Edwards, T. Peeters, A. P. Schaffers, S. G. Potts, R. Kleukers, C. D. Thomas, J. Settele, W. E. Kunin, Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* **313**, 351–354 (2006). [doi:10.1126/science.1127863](https://doi.org/10.1126/science.1127863) [Medline](#)
123. S. A. Cameron, J. D. Lozier, J. P. Strange, J. B. Koch, N. Cordes, L. F. Solter, T. L. Griswold, Patterns of widespread decline in North American bumble bees. *Proc. Natl. Acad. Sci. U.S.A.* **108**, 662–667 (2011). [doi:10.1073/pnas.1014743108](https://doi.org/10.1073/pnas.1014743108) [Medline](#)
124. I. Bartomeus, J. S. Ascher, J. Gibbs, B. N. Danforth, D. L. Wagner, S. M. Hedtke, R. Winfree, Historical changes in northeastern US bee pollinators related to shared ecological traits. *Proc. Natl. Acad. Sci. U.S.A.* **110**, 4656–4660 (2013). [doi:10.1073/pnas.1218503110](https://doi.org/10.1073/pnas.1218503110) [Medline](#)
125. L. G. Carnevali, W. E. Kunin, P. Keil, J. Aguirre-Gutiérrez, W. N. Ellis, R. Fox, Q. Groom, S. Hennekens, W. Van Landuyt, D. Maes, F. Van de Meutter, D. Michez, P. Rasmont, B. Ode, S. G. Potts, M. Reemer, S. P. M. Roberts, J. Schaminée, M. F. WallisDeVries, J. C. Biesmeijer, Species richness declines and biotic homogenisation have slowed down for NW-European pollinators and plants. *Ecol. Lett.* **16**, 870–878 (2013). [doi:10.1111/ele.12121](https://doi.org/10.1111/ele.12121) [Medline](#)
126. I. Koh, E. V. Lonsdorf, N. M. Williams, C. Brittain, R. Isaacs, J. Gibbs, T. H. Ricketts, Modeling the status, trends, and impacts of wild bee abundance in the United States. *Proc. Natl. Acad. Sci. U.S.A.* **113**, 140–145 (2016). [doi:10.1073/pnas.1517685113](https://doi.org/10.1073/pnas.1517685113) [Medline](#)
127. L. A. Garibaldi, M. A. Aizen, A. M. Klein, S. A. Cunningham, L. D. Harder, Global growth and stability of agricultural yield decrease with pollinator dependence. *Proc. Natl. Acad. Sci. U.S.A.* **108**, 5909–5914 (2011). [doi:10.1073/pnas.1012431108](https://doi.org/10.1073/pnas.1012431108) [Medline](#)
128. J. Lelieveld, J. S. Evans, M. Fnais, D. Giannadaki, A. Pozzer, The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature* **525**, 367–371 (2015). [doi:10.1038/nature15371](https://doi.org/10.1038/nature15371) [Medline](#)
129. B. L. Keeler, P. Hamel, T. McPhearson, M. H. Hamann, M. L. Donahue, K. A. Meza Prado, K. K. Arkema, G. N. Bratman, K. A. Brauman, J. C. Finlay, A. D. Guerry, S. E. Hobbie, J. A. Johnson, G. K. MacDonald, R. I. McDonald, N. Neverisky, S. A. Wood, Social-ecological and technological factors moderate the value of urban nature. *Nat. Sustainabil.* **2**, 29–38 (2019). [doi:10.1038/s41893-018-0202-1](https://doi.org/10.1038/s41893-018-0202-1)
130. C. Le Quéré, R. M. Andrew, P. Friedlingstein, S. Sitch, J. Pongratz, A. C. Manning, J. I. Korsbakken, G. P. Peters, J. G. Canadell, R. B. Jackson, T. A. Boden, P. P. Tans, O. D. Andrews, V. K. Arora, D. C. E. Bakker, L. Barbero, M. Becker, R. A. Betts, L. Bopp, F. Chevallier, L. P. Chini, P. Ciais, C. E. Cosca, J. Cross, K. Currie, T. Gasser, I. Harris, J. Hauck, V. Haverd, R. A. Houghton, C. W. Hunt, G. Hurtt, T. Ilyina, A. K. Jain, E. Kato, M. Kautz, R. F. Keeling, K. Klein Goldewijk, A. Körtzinger, P. Landschützer, N.

- Lefèvre, A. Lenton, S. Lienert, I. Lima, D. Lombardozzi, N. Metzl, F. Millero, P. M. S. Monteiro, D. R. Munro, J. E. M. S. Nabel, S. Nakaoka, Y. Nojiri, X. A. Padin, A. Peregon, B. Pfeil, D. Pierrot, B. Poulter, G. Rehder, J. Reimer, C. Rödenbeck, J. Schwinger, R. Séférian, I. Skjelvan, B. D. Stocker, H. Tian, B. Tilbrook, F. N. Tubiello, I. T. van der Laan-Luijkx, G. R. van der Werf, S. van Heuven, N. Viovy, N. Vuichard, A. P. Walker, A. J. Watson, A. J. Wiltshire, S. Zaehle, D. Zhu, Global Carbon Budget 2017. *Earth Syst. Sci. Data* **10**, 405–448 (2018). [doi:10.5194/essd-10-405-2018](https://doi.org/10.5194/essd-10-405-2018)
131. X. A. G. Morán, Á. López-Urrutia, A. Calvo-Díaz, W. K. W. Li, Increasing importance of small phytoplankton in a warmer ocean. *Glob. Change Biol.* **16**, 1137–1144 (2010). [doi:10.1111/j.1365-2486.2009.01960.x](https://doi.org/10.1111/j.1365-2486.2009.01960.x)
 132. C. M. Duarte, Reviews and syntheses: Hidden forests, the role of vegetated coastal habitats in the ocean carbon budget. *Biogeosciences* **14**, 301–310 (2017). [doi:10.5194/bg-14-301-2017](https://doi.org/10.5194/bg-14-301-2017)
 133. S. M. Sterling, A. Ducharne, J. Polcher, The impact of global land-cover change on the terrestrial water cycle. *Nat. Clim. Chang.* **3**, 385–390 (2012). [doi:10.1038/nclimate1690](https://doi.org/10.1038/nclimate1690)
 134. A. Trabucco, R. J. Zomer, D. A. Bossio, O. van Straaten, L. V. Verchot, Climate change mitigation through afforestation/reforestation: A global analysis of hydrologic impacts with four case studies. *Agric. Ecosyst. Environ.* **126**, 81–97 (2008). [doi:10.1016/j.agee.2008.01.015](https://doi.org/10.1016/j.agee.2008.01.015)
 135. A. van Dijk, R. J. Keenan, Planted forests and water in perspective. *For. Ecol. Manage.* **251**, 1–9 (2007). [doi:10.1016/j.foreco.2007.06.010](https://doi.org/10.1016/j.foreco.2007.06.010)
 136. P. M. Mayer, S. K. Reynolds Jr., M. D. McCutchen, T. J. Canfield, Meta-analysis of nitrogen removal in riparian buffers. *J. Environ. Qual.* **36**, 1172–1180 (2007). [doi:10.2134/jeq2006.0462](https://doi.org/10.2134/jeq2006.0462) [Medline](#)
 137. B. W. Sweeney, J. D. Newbold, Streamside forest buffer width needed to protect stream water quality, habitat, and organisms: A literature review. *J. Am. Water Resour. Assoc.* **50**, 560–584 (2014). [doi:10.1111/jawr.12203](https://doi.org/10.1111/jawr.12203)
 138. K. C. Seto, B. Güneralp, L. R. Hutyrá, Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc. Natl. Acad. Sci. U.S.A.* **109**, 16083–16088 (2012). [doi:10.1073/pnas.1211658109](https://doi.org/10.1073/pnas.1211658109) [Medline](#)
 139. IPBES, *Summary for Policymakers of the Assessment Report on Land Degradation and Restoration of the Intergovernmental SciencePolicy Platform on Biodiversity and Ecosystem Services*, R. Scholes *et al.*, Eds. (IPBES Secretariat, 2018).
 140. FAO, ITPS, Status of the World's Soil Resources (SWSR)—Main Report, 978-92-5-109004-6 (FAO, 2015); www.fao.org/publications.
 141. R. Lal, Sequestering carbon and increasing productivity by conservation agriculture. *J. Soil Water Conserv.* **70**, 55A–62A (2015). [doi:10.2489/jswc.70.3.55A](https://doi.org/10.2489/jswc.70.3.55A)
 142. R. Lal, Restoring soil quality to mitigate soil degradation. *Sustainability* **7**, 5875–5895 (2015). [doi:10.3390/su7055875](https://doi.org/10.3390/su7055875)
 143. G. Pierzynski, Brajendra, Threats to Soils: Global Trends and Perspectives. A Contribution from the Intergovernmental Technical Panel on Soils, Global Soil Partnership. Food and

- Agriculture Organization of the United Nations, *Global Land Outlook Working Paper* (United Nations Convention to Combat Desertification, 2017); <https://knowledge.unccd.int/publication/threats-soils-global-trends-and-perspectives-contribution-intergovernmental-technical>.
144. F. G. Renaud, K. *et al.*, *The Role of Ecosystems in Disaster Risk Reduction* (United Nations University Press, 2013); <https://collections.unu.edu/view/UNU:1995#overview>.
 145. K. K. Arkema, R. Griffin, S. Maldonado, J. Silver, J. Suckale, A. D. Guerry, Linking social, ecological, and physical science to advance natural and nature-based protection for coastal communities. *Ann. N. Y. Acad. Sci.* **1399**, 5–26 (2017). [doi:10.1111/nyas.13322](https://doi.org/10.1111/nyas.13322) [Medline](#)
 146. G. M. Gurr, S. D. Wratten, D. A. Landis, M. You, Habitat management to suppress pest populations: Progress and prospects. *Annu. Rev. Entomol.* **62**, 91–109 (2017). [doi:10.1146/annurev-ento-031616-035050](https://doi.org/10.1146/annurev-ento-031616-035050) [Medline](#)
 147. K. E. Jones, N. G. Patel, M. A. Levy, A. Storeygard, D. Balk, J. L. Gittleman, P. Daszak, Global trends in emerging infectious diseases. *Nature* **451**, 990–993 (2008). [doi:10.1038/nature06536](https://doi.org/10.1038/nature06536) [Medline](#)
 148. D. K. Letourneau, J. A. Jedlicka, S. G. Bothwell, C. R. Moreno, Effects of natural enemy biodiversity on the suppression of arthropod herbivores in terrestrial ecosystems. *Annu. Rev. Ecol. Evol. Syst.* **40**, 573–592 (2009). [doi:10.1146/annurev.ecolsys.110308.120320](https://doi.org/10.1146/annurev.ecolsys.110308.120320)
 149. N. Alexandratos, J. Bruinsma, *World Agriculture Towards 2030/2050: The 2012 Revision* (FAO, 2012); www.fao.org/docrep/016/ap106e/ap106e.pdf.
 150. W. W. L. Cheung, V. W. Lam, J. L. Sarmiento, K. Kearney, R. Watson, D. Zeller, D. Pauly, Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Glob. Change Biol.* **16**, 24–35 (2010). [doi:10.1111/j.1365-2486.2009.01995.x](https://doi.org/10.1111/j.1365-2486.2009.01995.x)
 151. U. T. Srinivasan, W. W. L. Cheung, R. Watson, U. R. Sumaila, Food security implications of global marine catch losses due to overfishing. *J. Bioeconomics* **12**, 183–200 (2010). [doi:10.1007/s10818-010-9090-9](https://doi.org/10.1007/s10818-010-9090-9)
 152. C. Richerzhagen, *Protecting Biological Diversity - The Effectiveness of Access and Benefit-sharing Regimes* (Routledge, 2010); www.ecolex.org/details/literature/protecting-biological-diversity-the-effectiveness-of-access-and-benefit-sharing-regimes-mon-083811.
 153. D. P. Faith *et al.*, in *Phylogenetic Diversity: Applications and Challenges in Biodiversity Science*, R. A. Scherson, D. P. Faith, Eds. (Springer International Publishing, 2018), pp. 73–91; https://doi.org/10.1007/978-3-319-93145-6_4.
 154. United Nations, Department of Economic and Social Affairs, Population Division, “World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352)” Report (United Nations Department of Economic and Social Affairs, 2014); <https://population.un.org/wup/Publications/Files/WUP2014-Highlights.pdf>.
 155. WHO, Urban population growth, Global Health Observatory data (2016); www.who.int/gho/urban_health/situation_trends/urban_population_growth/en.

156. M. Soga, K. J. Gaston, Extinction of experience: The loss of human-nature interactions. *Front. Ecol. Environ.* **14**, 94–101 (2016). [doi:10.1002/fee.1225](https://doi.org/10.1002/fee.1225)
157. K. C. Seto, J. M. Shepherd, Global urban land-use trends and climate impacts. *Curr. Opin. Environ. Sustain.* **1**, 89–95 (2009). [doi:10.1016/j.cosust.2009.07.012](https://doi.org/10.1016/j.cosust.2009.07.012)
158. K. C. Seto, M. Fragkias, B. Güneralp, M. K. Reilly, A meta-analysis of global urban land expansion. *PLOS ONE* **6**, e23777 (2011). [doi:10.1371/journal.pone.0023777](https://doi.org/10.1371/journal.pone.0023777) [Medline](#)
159. T. C. Daniel, A. Muhar, A. Arnberger, O. Aznar, J. W. Boyd, K. M. A. Chan, R. Costanza, T. Elmqvist, C. G. Flint, P. H. Gobster, A. Grêt-Regamey, R. Lave, S. Muhar, M. Penker, R. G. Ribe, T. Schauppenlehner, T. Sikor, I. Soloviy, M. Spierenburg, K. Taczanowska, J. Tam, A. von der Dunk, Contributions of cultural services to the ecosystem services agenda. *Proc. Natl. Acad. Sci. U.S.A.* **109**, 8812–8819 (2012). [doi:10.1073/pnas.1114773109](https://doi.org/10.1073/pnas.1114773109) [Medline](#)
160. J. Stephenson, The Cultural Values Model: An integrated approach to values in landscapes. *Landsc. Urban Plan.* **84**, 127–139 (2008). [doi:10.1016/j.landurbplan.2007.07.003](https://doi.org/10.1016/j.landurbplan.2007.07.003)
161. T. Plieninger, C. Bieling, N. Fagerholm, A. Byg, T. Hartel, P. Hurley, C. A. López-Santiago, N. Nagabhatla, E. Oteros-Rozas, C. M. Raymond, D. van der Horst, L. Huntsinger, The role of cultural ecosystem services in landscape management and planning. *Curr. Opin. Environ. Sustain.* **14**, 28–33 (2015). [doi:10.1016/j.cosust.2015.02.006](https://doi.org/10.1016/j.cosust.2015.02.006)
162. A. I. Milcu, J. Hanspach, D. Abson, J. Fischer, Cultural Ecosystem Services: A literature review and prospects for future research. *Ecol. Soc.* **18**, art44 (2013). [doi:10.5751/ES-05790-180344](https://doi.org/10.5751/ES-05790-180344)
163. G. Ceballos, P. R. Ehrlich, R. Dirzo, Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proc. Natl. Acad. Sci. U.S.A.* **114**, E6089–E6096 (2017). [doi:10.1073/pnas.1704949114](https://doi.org/10.1073/pnas.1704949114) [Medline](#)