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.

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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 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.

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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, sociocultural, 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. ■

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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. Brondízio[5], Hien T. Ngo[6], John Agard[7], Almut Arneth[8], Patricia Balvanera[9], Kate A. Brauman[10], Stuart H. M. Butchart[11,12], Kai M. A. Chan[13], Lucas A. Garibaldi[14], Kazuhito Ichii[15,16], Jianguo Liu[17], Suneetha M. Subramanian[18,19], Guy F. Midgley[20], Patricia Miloslavich[21,22], Zsolt Molnár[23], David Obura[24,25], Alexander Pfaff[26], Stephen Polasky[27,28], Andy Purvis[29,30], Jona Razzaque[31], Belinda Reyers[32,33], Rinku Roy Chowdhury[34], Yunne-Jai Shin[35,36], Ingrid Visseren-Hamakers[37,38], Katherine J. Willis[39,40], Cynthia N. Zayas[41]

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

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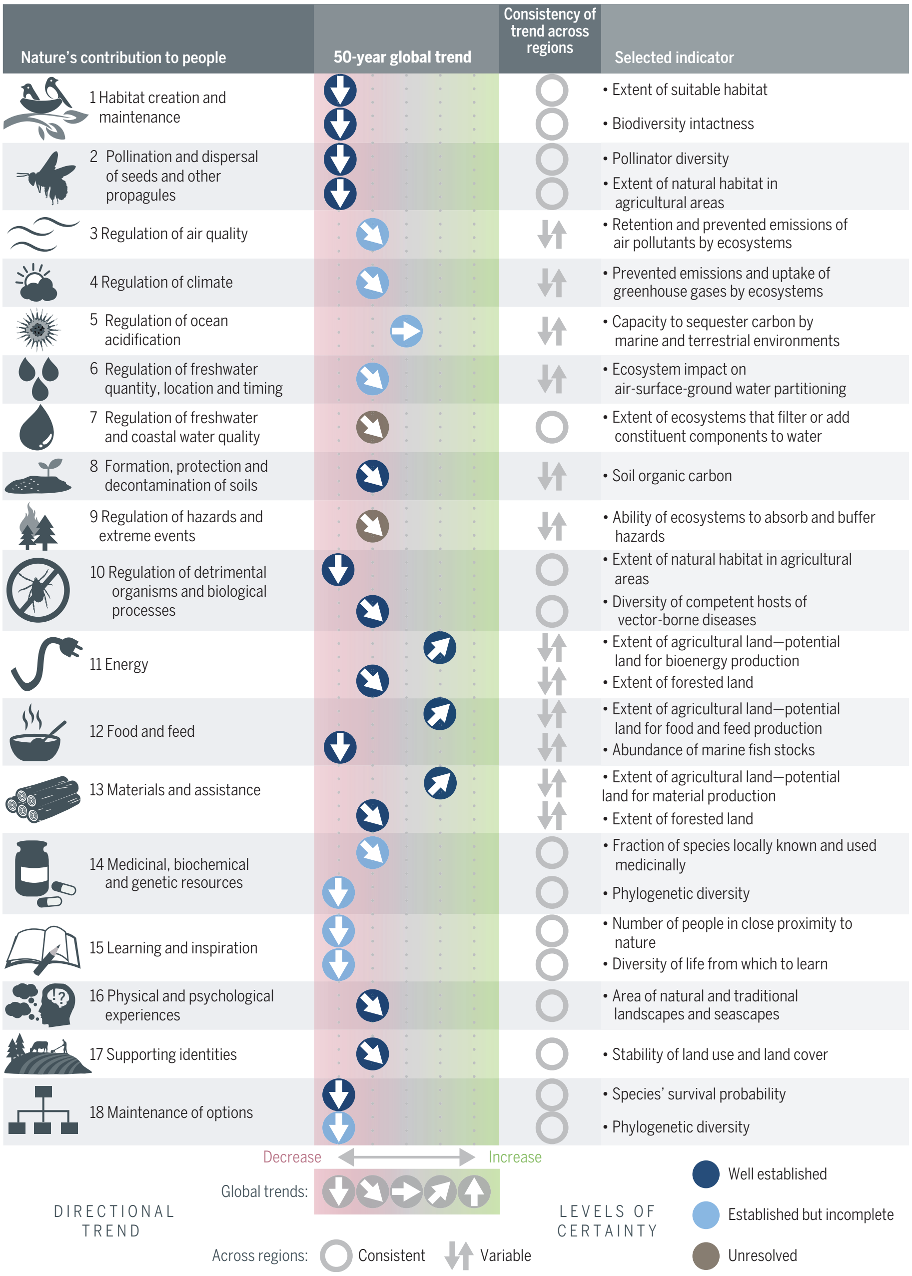

Fig. 1. Global trends in the capacity of nature to contribute to good quality of life from 1970 to the present. Fourteen of the 18 categories of nature's contributions to people show a decline. Half of the 18 categories show consistent patterns globally, whereas the other half show declines in some regions 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

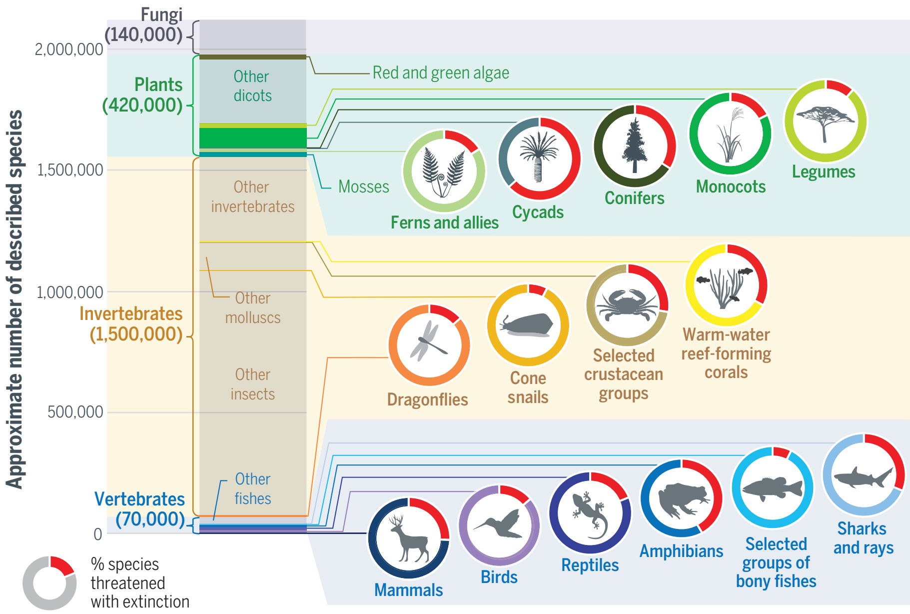

Fig. 2. Extinction risk and diversity in different taxonomic groups. Approximate number of described species of animals, plants, and fungi (bar) and the proportion of species that are threatened with extinction (pie charts) in groups that have been globally assessed for the IUCN Red List (54), either 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 (12). 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,

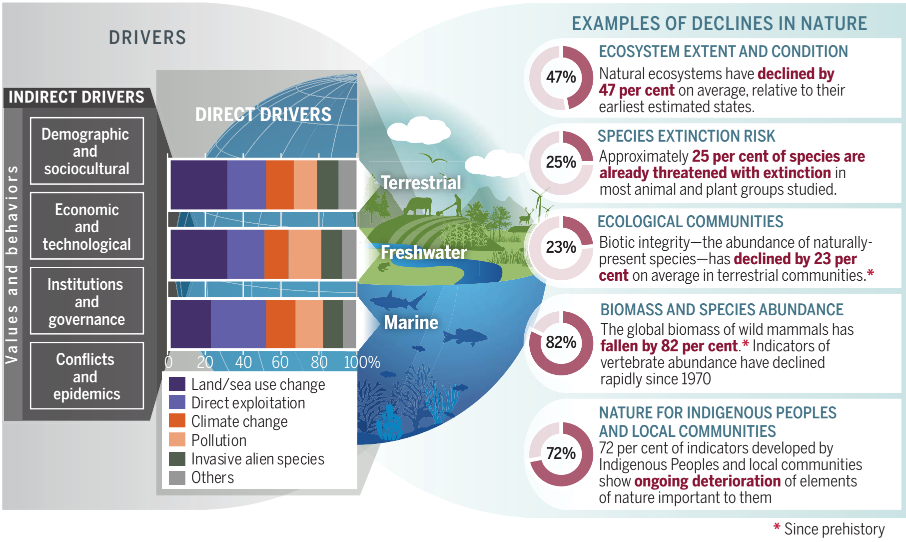

Fig. 3. Examples of global declines in nature that have been and are being caused by direct and indirect drivers of change. Each of the direct drivers of changes (land or sea use change; direct exploitation of organisms; climate change; pollution, including plastics, heavy metals, and direct effects of elevated CO_2 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

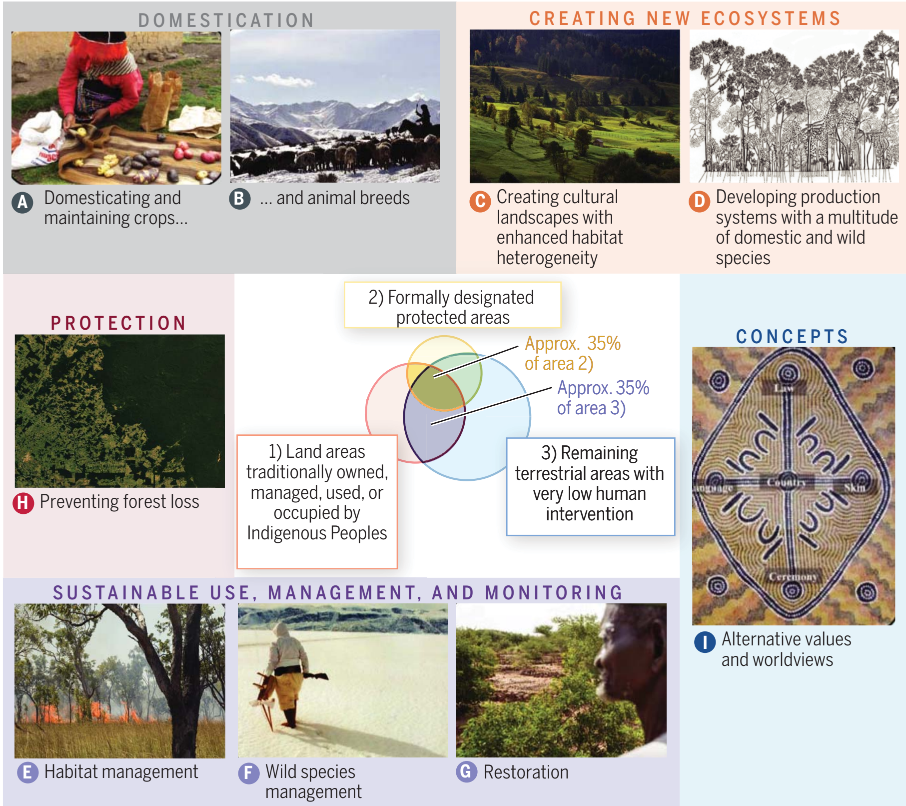

Fig. 4. Contribution of Indigenous Peoples and local communities to biodiversity. A wide range of practices of Indigenous Peoples and local communities maintain and enhance wild and domestic biodiversity. (**A** and **B**) Domestication and maintenance of locally adapted crop and fruit varieties and 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 km^2 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 Cespoli; (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

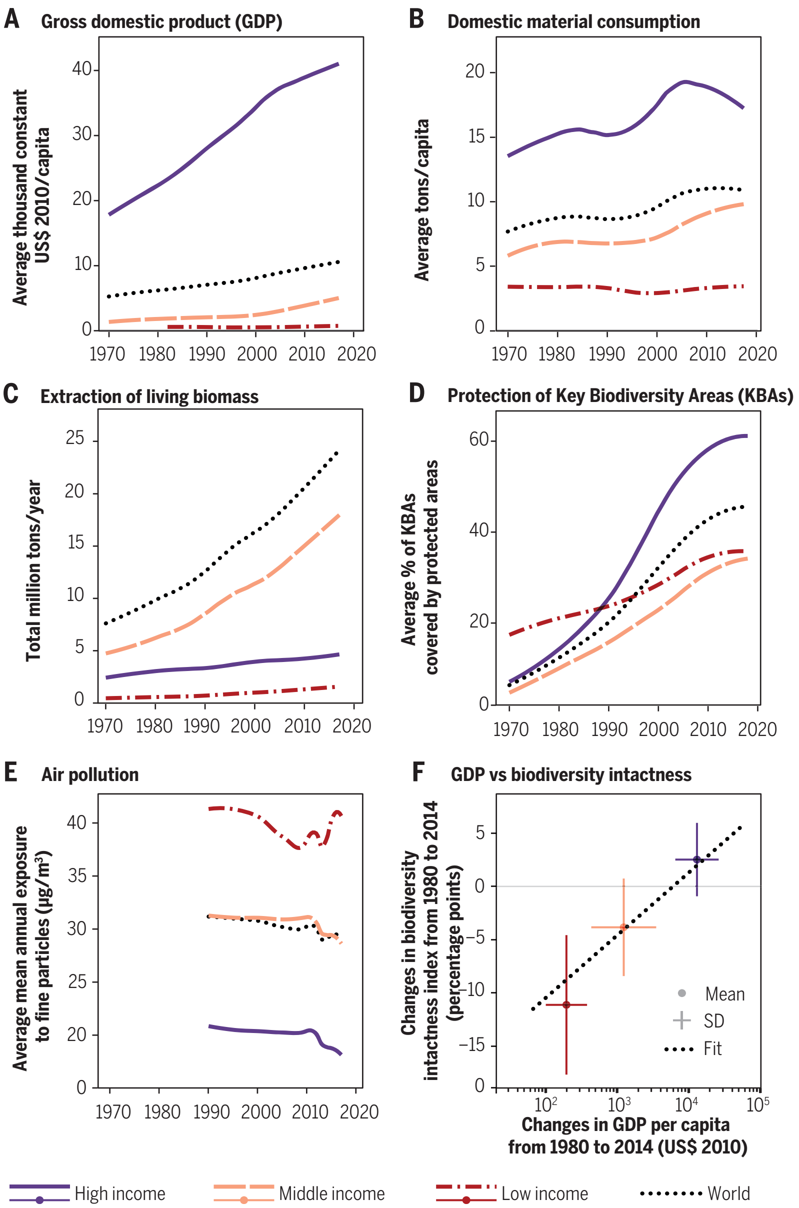

Fig. 5. Development pathways since 1970 have featured unequal impacts on people and nature across countries. (**A**, **B**, and **C**) Increased trade between countries has shifted the tradeoffs between environmental and other goals, with the footprints of increasing consumption in higher-income countries 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*).]

A

Goal	Aichi Target (abbreviated)	Progress towards elements of each target			
		Poor	Moderate	Good	Unknown
Drivers	1 Awareness		∼∼		
	2 Planning and accounting	✗✗	∼∼		
	3 Incentives	✗✗			
	4 Production and consumption	✗✗			
Pressures	5 Habitat loss	✗✗			
	6 Fisheries	✗✗			?
	7 Agriculture and forestry	✗✗	∼		
	8 Pollution	✗✗			
	9 Invasive alien species	✗✗		✓	?
	10 Coral reefs etc	✗✗			
Status	11 Protected and conserved areas		∼∼∼∼	✓✓	
	12 Extinctions prevented	✗✗			
	13 Genetic diversity		∼∼∼∼		?
Benefits	14 Ecosystem services	✗			?
	15 Ecosystem restoration				??
	16 Access and benefit sharing		∼	✓	
Implementation	17 Strategies and action plans		∼∼	✓	
	18 Indigenous and local knowledge		∼		??
	19 Biodiversity science		∼		?
	20 Financial resources		∼		

B

Selected Sustainable Development Goals	Recent status and trends in aspects of nature and nature's contributions to people that support progress to selected targets		
	Poor/Declining	Mixed	Unknown
1 No poverty	↓↓		
2 Zero hunger	↓	→→→	
3 Good health and well-being			??
6 Clean water and sanitation	↓↓↓	→	
11 Sustainable cities and communities	↓↓↓↓	→	
13 Climate action	↓	→	???
14 Life below water	↓↓↓↓	→→→	
15 Life on land	↓↓↓↓↓↓	→→→→→	

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

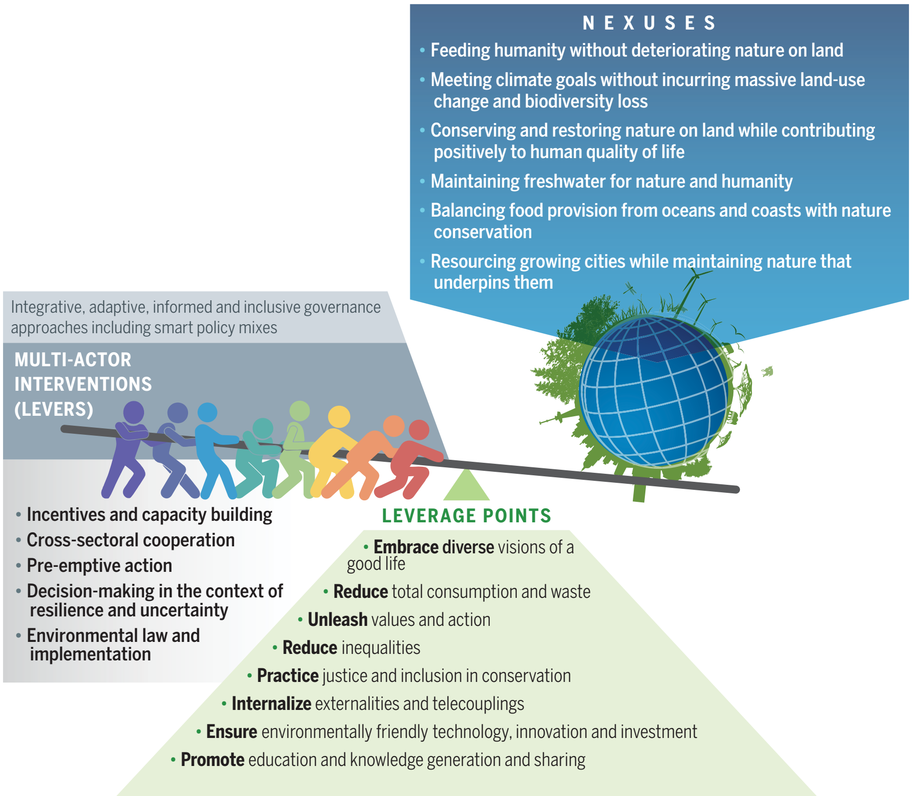

Fig. 7. Enabling transformative change. Collaborative implementation of priority interventions (levers) targeting key points of intervention (leverage points representing major indirect drivers) could enable transformative change from current trends toward more sustainable ones. Effectively addressing 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 ín 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.

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SUPPLEMENTARY MATERIALS

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Table S1
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