

DECLINE OF HUMAN MODERN BIODIVERSITY

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ABSTRACT

Biodiversity is a term increasingly recognized in science, policy, and society, accompanied by a growing body. In this article, we focus on key concepts, debates, patterns, trends, and drivers related to biodiversity. We begin by reviewing the history of the term and its various dimensions and values. Next, we explore what is known and unknown about global biodiversity patterns and examine changes from early human history to the present, including extinction rates and direct drivers of biodiversity change, while also highlighting some lesser-known factors. Lastly, we consider possible ways to stop the ongoing loss of life on earth and address the causes of global biodiversity loss, especially humanity's growing consuming footprint.

Keywords: Biological diversity, Biodiversity decline, Modern trend.

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INTRODUCTION

Biodiversity is a prominent and increasingly recognized concept in science, policy, and society, but it means different things to different people. Numerous textbooks and reviews cover nearly all aspects of biodiversity, and there is widespread acknowledgment of the global biodiversity crisis, which the United Nations has addressed through dedicated conventions [1]. In recent years, there have been an unprecedented number of comprehensive scientific assessments on the state and trends of life on Earth [2]. The 1995 Global Biodiversity Assessment, the 2005 Millennium Ecosystem Assessment, and the 2019 Intergovernmental Science-Policy

Platform on Biodiversity and Ecosystem Services (IPBES) first intergovernmental global assessment are significant turning points.

According to some accounts, J. Arthur Harris's 1916 account of the natural history of the southwestern North American desert is where the idea of biological diversity first appeared in the academic world in the middle of the 20th century. Initially, it was often understood in terms of species number and relative abundance within a defined study area; this definition dominated biology education until the early 1990s [3]. The term "biological diversity," or its abbreviated form "biodiversity," began to encompass

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biological variability both within and beyond species in the 1980s. T.E. Lovejoy is credited with the first use of the term "biological diversity" in the foreword of a book on conservation biology, and it gained prominence in scientific and science-policy literature during that decade, notably through the works of W.G. Rosen, E. Norse, and E.O. Wilson. Their efforts aimed to raise public awareness of the richness of life on Earth and the urgent need for its protection. The term was officially recognized in the intergovernmental science-policy arena in 1992 at the United Nations Conference on Environment and Development and was formally incorporated into international policy when the United Nations Convention on Biological Diversity came into force in 1993. CBD defines biological diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". Importantly, this definition explicitly includes ecosystems, a departure from earlier academic definitions that often excluded them [4-7]. This omission likely stemmed from the fact that ecosystems comprise both living and nonliving components (such as water and minerals), which previous definitions did not consider part of taxonomic biodiversity. Consequently, many ecologists have questioned this broader definition that encompasses variation among ecosystems. However, including ecosystems in the CBD definition is practical from policy, legislative, and public communication perspectives. Policies and regulations that focus solely on species or communities, while neglecting the ecosystems that support them, would be challenging to implement effectively. The IPBES established the most recent intergovernmental consensus definition of biodiversity, which was greatly impacted by

the CBD. "The variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part," the statement reads. This encompasses shifts in abundance and distribution within and between species, biological groups, and ecosystems over time and place, as well as variation in genetic, phenotypic, phylogenetic, and functional characteristics [8-10]. The IPBES definition emphasizes the living components, aiming to adhere to the spirit of the CBD definition while aligning more closely with contemporary ecological theory.

HUMANS AND BIODIVERSITY CHANGE IN PREMODERN TIMES

As social, omnivorous predators and competitors, species of the genus *Homo* have likely always influenced the biodiversity of the ecosystems they inhabit. A key characteristic of *Homo* is its ability to create a diverse range of environmental niches. Human impact on biota began in the Pleistocene, marked by hunting, the transport of other species, and the use of fire. By the start of the Holocene, around 12,000 years ago, approximately three-quarters of terrestrial ecosystems were already inhabited by humans [11]. Evidence suggests that some species extinctions coincided with the emergence of *Homo erectus*, which had a larger brain, shifted to a more meat-based diet, and utilized fire to modify ecosystems and prepare food. This extinction may have occurred in Africa 1–2 million years ago.

More compelling evidence arises from the megafaunal extinctions associated with the spread of *Homo sapiens* out of Africa and across various continents and islands. Vertebrate megafauna was particularly vulnerable due to their slow reproductive rates and large habitat requirements. The role of humans in Pleistocene megafaunal extinctions remains debated, partly because it can be difficult to differentiate human

presence from other environmental factors in specific locations. However, when viewed globally, it is evident that human arrival correlates with the loss of many species, potentially exacerbated by climate variations that placed short-term stress on megafaunal populations [11-14]. This assertion is supported by the fact that climate has fluctuated between glacial and interglacial conditions throughout the Pleistocene without leading to widespread megafaunal extinction.

In total, 178 megafaunal mammals are believed to have gone extinct during the Late Pleistocene. Estimates indicate that Eurasia lost 9 of 28 megafauna species, Australia 14 of 16, North America 50 of 60, and South America 34 of 47. Africa was the least affected continent, prompting speculation about the reasons. One common argument suggests that species in Africa co-evolved with hominids and learned to recognize them as predators, while species on other continents were ecologically naive to the threat posed by these relatively small primates. However, several megafaunal species, such as proboscideans, exhibit high behavioral and social intelligence, indicating they could quickly adapt to new threats [15]. A different or complementary view suggests that during the two million years of the Pleistocene, Africa had a protracted megafaunal decline as a result of successive waves of hominids. A recent study from the southern Levant shows that during the Pleistocene, when *Homo erectus*, *Homo neanderthalensis*, and *Homo sapiens* were present, large-mammal biomass steadily decreased. The impacts of these extinctions likely extended beyond the species themselves, as large animals play crucial roles in shaping ecosystem structure and functions, including nutrient cycling.

During the Holocene, species loss persisted in island ecosystems, including large islands like Madagascar and Aotearoa/New Zealand,

affecting a broader range of body sizes. Endemic island fauna is especially vulnerable due to their limited environmental resources, ecological naivety, and susceptibility to invasive species, such as rats. The Polynesian expansion across the Pacific is linked to the extinction of approximately 1,000 endemic bird species, primarily flightless rails, marking it as likely the largest vertebrate extinction event of the Holocene [16].

This history of global extinctions since the Pleistocene, along with the modern trends discussed in the next section, may suggest that human impacts on biodiversity are inherently negative. While the overall global trend is predominantly negative, particularly affecting megafauna and island endemics, human activities have also, both intentionally and unintentionally, contributed to biodiversity throughout history and into the present day. This can occur in various ways. Following the extinction event triggered by the arrival of humans in new ecosystems, many Indigenous cultures developed systems of reciprocity and stewardship grounded in a deep understanding of local ecosystems [17-20]. In its simplest form, human-induced disturbances, especially at low to moderate intensities and small spatial scales, create habitat heterogeneity that prevents competitive dominance, promoting the coexistence of a greater number of species at both local and landscape levels.

Additionally, many ancient and sophisticated farming or stewardship practices employed by Indigenous peoples and local communities globally have intentionally nurtured specific organisms, biotic assemblages, or entire ecosystems. Some of the most diverse meadows and grasslands, rich in vascular plants, are found in long-managed landscapes in Europe, sustained by extensive traditional management by local communities over centuries or millennia. In areas that would otherwise be dominated by coniferous or broad-leaved forests, these practices have

maintained ecological diversity. Evidence of ancient gardening for useful wild plants in many regions has also contributed to their prevalence. Today, complex cultural landscapes that integrate wild and cultivated plants and animals continue to thrive worldwide. Intricate agricultural mosaics in the Pacific Islands, hay and sheep grasslands in Europe and Asia, forest gardens in tropical Asia, Africa, and Latin America, Vegas in the high Andes, and Satoyama landscapes in Japan—a mosaic of forests, rice fields, grasslands, streams, and irrigation systems—are a few examples. Although these practices typically focus on a limited number of species, the managed patches often support a variety of other wild organisms across all trophic levels, including bees, other insects, frugivorous mammals and birds, and fungi, which are less common in either more pristine or more industrially managed areas [21].

The examples provided primarily highlight the preference for organisms that already exist in a region, albeit in fewer locations and/or at lower densities. Another significant way in which people have encouraged diversity is through the deliberate selection of initially wild species, leading to the creation of numerous domesticated plants, animal, and microbial phenotypes. These include livestock, poultry, work and ornamental animals, food, fiber and fuel crops, ornamental plants, yeasts, and fungi. While domesticated diversity is small compared to the overall wild genetic diversity on Earth, it remains significant. The total number of domesticated phenotypes unknown beyond specific groups. However, a rough estimate suggests there are about 300 well-monitored species of domesticated terrestrial animals and plants that contribute to major food groups. This pales in comparison to the nearly 1 million derived varieties, predominantly consisting of grains, tubers, and legumes. A survey focused on terrestrial

farm mammals and birds, excluding those believed to be extinct, identified 8,179 species in 2016. The actual numbers are likely much higher when including aquatic animals, ornamental and companion animals, ornamental plants, and microorganisms. The social, cultural, and economic significance of domesticated biodiversity to humanity is immense [22-25].

BIODIVERSITY DECLINE

The decline in biodiversity has accelerated in modern times. While several characteristics of the current model of human appropriation of nature were present in premodern times, the scale of these practices has dramatically increased, particularly with the rise of globalization and economic mercantilism. The Industrial Revolution in the late eighteenth and early nineteenth centuries, the Great Acceleration since the 1950s, and European exploitation of the Americas and other colonial regions in the late sixteenth century are important historical occurrences. The size and geographic distribution of plant and animal populations, the number of species, the intraspecific genetic variety of both wild and domesticated creatures, the scope and integrity of natural ecosystems, and the distinctiveness of local communities have all decreased as a result. Two other worldwide phenomena that have not gotten as much public attention are accompanied by these decreases. The first is called "biotic homogenization," and it describes how human movement of organisms, whether intended or not, has reduced the taxonomic, functional, phylogenetic, and species-richness diversity of regional biotas around the world. Harold A. Mooney has termed this extensive reshaping of global biogeography as "New Pangaea." For instance, over the past five centuries, plant communities have become increasingly homogenized, primarily due to species naturalizing beyond their native ranges rather than through the extinction of native species [26, 27].

The second widespread process is contemporary evolution, which describes the recent or ongoing heritable phenotypic changes that occur in wild populations as a result of directional selection pressures brought about by humans, such as urbanization, hunting, fishing, the use of agricultural biocides, and the construction of irrigation or transportation infrastructure. Unlike selective breeding, these pressures are mostly unintentional, and the ensuing phenotypic alterations are side effects rather than intended results. Recent years have seen a rise in the number of reported examples, most likely as a result of a change in emphasis rather than a real acceleration of modern evolution. The global transformation of life on Earth, from genes to biomes, by human activities has sparked extensive discussions in ecological, philosophical, and policy contexts. We will now turn our attention to wild species extinctions and trends in the taxonomic and functional composition of local communities, as these areas have abundant global data, standardized methodologies.

It is well known among scientists that our planet is rapidly losing species, a decline that is also recognized by the general public. Therefore, assessing biodiversity at the species level must encompass not only the number of species and higher-order taxa, their geographical distribution, and their abundance but also their risk of extinction within human-relevant timescales. There are three relevant types of species-level extinctions. While catastrophic events that suddenly eliminate a species do occur, most extinctions happen gradually. This process begins when species become increasingly rare in certain areas; although their populations may still be sufficient for long-term survival, they become too small to effectively fulfill their ecological roles, a situation known as functional extinction [28-30]. The second type is local extinction,

where a species vanishes from part of its range but continues to exist elsewhere. For instance, lions, guanacos, and bison now occupy only a fraction of their historical ranges. Finally, a species is considered globally extinct when it no longer exists anywhere on Earth. While the first two types of extinction are undoubtedly significant, most global monitoring efforts—and consequently the majority of published information—focus on global extinctions, which we will discuss in this section. The two primary terms used to describe global extinctions are extinction risk and extinction rate. These complementary metrics offer different insights into the extinction process [31].

Extinction risk refers to the likelihood of a species becoming extinct. This assessment is typically conducted for well-defined species, usually before they vanish, and takes into account the species' biology as well as the external threats it faces. The primary system for categorizing extinction risk is the one developed by the International Union for Conservation of Nature (IUCN). The IUCN employs a standardized set of categories known as the IUCN Red List categories. These categories range from "least concern" to "critically endangered". Threatened species—those classified as vulnerable, endangered, or critically endangered—are currently considered to be at high risk of extinction [32].

In contrast, extinction rates measure how quickly species disappear over a specific time period. These rates are often estimated retrospectively (after species have already gone extinct) and generally focus on large groups of species or entire biotas rather than individual species. Extinction rates are typically expressed as the number of extinctions per million species per year, allowing for standardized comparisons across different time frames and species sets. These rates are frequently compared to the

background extinction rate, which represents the average extinction rate due to natural, nonhuman causes throughout geological history. The current consensus estimates the background extinction rate to be approximately 1 E/MSY, though some debate exists regarding whether this figure should be higher or lower. For context, 1 E/MSY equates to one species going extinct in a sample pool of 10,000 species over a century. According to the most comprehensive review available, around 1 million animal and plant species—both known and unknown to science—are currently threatened with extinction. This estimation is based on two factors: the total estimated number of plant and animal species on Earth (approximately 8.1 million, including 5.5 million insects) and the proportion of threatened species within various major groups as categorized by the IUCN Red List. However, this proportion is not uniformly well understood across all groups. For instance, legumes, ferns, monocots, mammals, birds, and reptiles have been thoroughly assessed, while groups like fish and invertebrates (including certain mollusks, insects, crustaceans, and corals) have only had representative samples evaluated. Among the comprehensively assessed groups, many species lack sufficient data to be assigned an extinction risk category; the percentage of data-deficient species varies widely, ranging from 0.4% in cycads to over 40% in some invertebrates. Despite these uncertainties, the average proportion of threatened species (across all categories, from vulnerable to critically endangered) for assessed groups of animals, plants, and invertebrates is roughly 25%. The extinction risk for insects as a whole remains largely unknown. For Odonata, the only globally assessed insect group, about 15% are considered threatened. However, given the numerous threats facing freshwater habitats, other insect groups may have lower extinction risks. Assessments of certain

insect groups in Europe, such as bees, butterflies, and saproxylic beetles, have indicated a risk prevalence closer to 10%. Therefore, 10% is used as a conservative estimate for the overall risk to insects; while the actual figure could be higher, it is unlikely to be lower. When extrapolating these risks to the total number of plants and animals (25%) and to the total number of insects (10%), the estimated total number of threatened species approaches 1 million. The total number of species on Earth and whether the extinction risks of well-studied groups are reflective of less-assessed taxa—particularly the large and poorly understood group of insects—remain unresolved, though. As a result, although this the most accurate and transparent worldwide estimate to date, it should be considered an estimate [33].

Considering both extinction and species origination as natural phenomena that have been occurring since life began on Earth, how do current extinction rates compare to those expected from nonhuman causes and historical rates? While precise estimates of present extinction rates vary based on time frames, taxonomic groups, and estimation methods—making direct comparisons challenging—scientific consensus indicates that the extinction rate of wild species is at least tens to hundreds of times higher than the background rate and is likely increasing rapidly.

A 50% chance of disappearing within the next 10 years, which is the average risk for critically endangered species, seems alarmingly high. In contrast, some might perceive the risk to vulnerable species, with a 10% chance of extinction over 100 years, as relatively low. To contextualize these figures, consider a species as a 50-year-old human with a life expectancy of 80 years. A non-threatened human would have, on average, 30 more years to live, while a vulnerable individual would have about one week left,

and a critically endangered one could survive as little as three hours [34-37].

To illustrate the urgency, consider how long it would take to lose half of the currently existing animal and plant species on Earth. Under natural conditions (background extinction rates), this would take approximately 1 million years. If all species were classified as vulnerable, it would take around 600 years to lose them—about 1500 times faster than the natural extinction rate. If all species were critically endangered, complete loss would occur in just 10 years, over 100000 times faster than the background rate. Consequently, the overall extinction risk for threatened species is estimated to be 1000-100000 times higher than the background extinction risk. The extinction risk for all species, both threatened and nonthreatened, is significantly lower [38].

CAUSES OF BIODIVERSITY DECLINE

What causes nature's pervasive decline? Indirect drivers work more covertly by affecting the level, direction, rate, and intensity of direct drivers, while direct drivers have direct physical effects on the environment. El Niño–Southern Oscillation phenomena or zoonotic diseases made worse by anthropogenic climate change are examples of direct drivers that can be either natural (such as volcanic eruptions, earthquakes, and weather events) or human-caused (such as deforestation, hunting, pollution, and anthropogenic climate change) [39].

In contrast, all indirect drivers are human-caused and encompass social, economic, demographic, cultural, institutional, and political factors, ultimately rooted in societal values and narratives. They include patterns of supply and production of goods and services, consumption habits, technology adoption, dietary preferences, demographic trends, lifestyle choices, fashion trends, and institutions in the broad sense of socially shared rules, from local customary

inheritance laws to international agreements like the Convention on Biological Diversity (CBD) and the World Trade Organization. Understanding the distinction between direct and indirect drivers is crucial both conceptually and practically; while efforts can be made to mitigate or temporarily halt direct drivers, these will likely be ineffective in the long term unless the underlying indirect drivers, which are the root causes of the current biodiversity decline, are addressed [40-42].

According to the most thorough global systematic review to date, direct exploitation (such as hunting, fishing, and selective logging) and changes in land and sea use (such as deforestation, agricultural expansion, and coastal development) are the main direct causes of nature's decline globally. Other factors are less important, such as pollution (including point-source organic and chemical pollution, ocean acidification from elevated CO₂ levels, and light and noise pollution), invasive species (intentionally and unintentionally introduced by humans, or occasionally arriving independently), and climate change (which affects mean temperature, precipitation, and the frequency and intensity of extreme weather events) [43-46]. Despite their vastly different physical characteristics, these emerging drivers share key traits: they are relatively novel, allowing little time for organisms to adapt; their magnitude is either already extremely high or rapidly increasing; and they involve coupled systems. We will examine these emerging direct drivers in the following subsections [47, 48].

CONCLUSION

Today, there is heightened awareness of the global decline in biodiversity and its critical role in Earth's functioning and human well-being. However, the term "biodiversity" can be challenging; it encompasses various meanings and values while highlighting something essential for our understanding

and stewardship as we seek to navigate toward a sustainable future within the biosphere that sustains us.

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REFERENCES

1. Reddy E. 2014. What does it mean to do anthropology in the Anthropocene? Platypus The CASTAC Blog, April 8. <https://blog.castac.org/2014/04/what-does-it-mean-to-do-anthropology-in-the-anthropocene/>
2. Díaz S, Settele J, Brondizio ES, Ngo HT, Agard J, et al. 2019. Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science* 366:eaax3100
3. Magurran AE. 2003. *Measuring Biological Diversity*. Hoboken, NJ: Wiley
4. Malhi Y. 2017. The concept of the Anthropocene. *Annu. Rev. Environ. Resour.* 42:77–104
5. Ducarme F, Flipo F, Couvet D. 2021. How the diversity of human concepts of nature affects conservation of biodiversity. *Conserv. Biol.* 35:1019–28
6. Pascual U, Adams WM, Díaz S, Lele S, Mace GM, Turnhout E. 2021. Biodiversity and the challenge of pluralism. *Nat. Sustain.* 4:567–72.
7. Larsen BB, Miller EC, Rhodes MK, Wiens JJ. 2017. Inordinate fondness multiplied and redistributed: the number of species on Earth and the new pie of life. *Q. Rev. Biol.* 92:229–65
8. Pedrós-Alió C, Manrubia S. 2016. The vast unknown microbial biosphere. *PNAS* 113:6585–87
9. Gogarten JP, Doolittle WF, Lawrence JG. 2002. Prokaryotic evolution in light of gene transfer. *Mol. Biol. Evol.* 19:2226–38
10. Louca S, Mazel F, Doebeli M, Parfrey LW. 2019. A census-based estimate of Earth's bacterial and archaeal diversity. *PLOS Biol.* 17:e3000106
11. Wiens JJ. 2021. Vast underestimation of global biodiversity. *PLOS Biol.* 19:e3001192
12. Louca S, Mazel F, Doebeli M, Parfrey LW. 2021. Response to “Vast (but avoidable) underestimation of global biodiversity.” *PLOS Biol.* 19:e3001362
13. Singer D, Seppey CVW, Lentendu G, Dunthorn M, Bass D, et al. 2021. Protist taxonomic and functional diversity in soil, freshwater and marine ecosystems. *Environ. Int.* 146:106262
14. Bar-On YM, Phillips R, Milo R. 2018. The biomass distribution on Earth. *PNAS* 115:6506–11
15. Davidson N, Finlayson M. 2019. Updating global coastal wetland areas presented in Davidson and Finlayson (2018). *Mar. Freshw. Res.* 70:1195–200
16. Duarte CM, Gattuso J-P, Hancke K, Gundersen H, Filbee-Dexter K, et al. 2022. Global estimates of the extent and production of macroalgal forests. *Global Ecol. Biogeogr.* 31:1422–39
17. Benton MJ, Wilf P, Sauquet H. 2021. The angiosperm terrestrial revolution and the origins of modern biodiversity. *New Phytol.* 233:2017–35
18. Svenning J-C, Skov F. 2007. Ice Age legacies in the geographical distribution of tree species richness in Europe. *Global Ecol. Biogeogr.* 16:234–45
19. Hagen O, Skeels A, Onstein RE, Jetz W, Pellissier L. 2021. Earth history events shaped the evolution of uneven biodiversity across tropical moist forests. *PNAS* 118:e2026347118

20. Cracraft J, Ribas CC, d'Horta FM, Bates J, Almeida RP, et al. 2020. The origin and evolution of Amazonian species diversity. In *Neotropical Diversification: Patterns and Processes*, ed. V Rull, AC Carnaval, pp. 225–44. Cham, Switz.: Springer
21. Daru BH, Davies TJ, Willis CG, Meineke EK, Ronk A, et al. 2021. Widespread homogenization of plant communities in the Anthropocene. *Nat. Commun.* 12:6983
22. Palumbi SR. 2001. Humans as the world's greatest evolutionary force. *Science* 293:1786–90
23. Hendry AP. 2017. *Eco-Evolutionary Dynamics*. Princeton, NJ: Princeton Univ. Press
24. Hendry AP, Gotanda KM, Svensson E. 2017. Human influences on evolution, and the ecological and societal consequences. *Philos. Trans. R. Soc. B* 372:20160028
25. Jørgensen PS, Folke C, Carroll SP. 2019. Evolution in the Anthropocene: informing governance and policy. *Annu. Rev. Ecol. Evol. Syst.* 50:527–46
26. Thomas CD. 2020. The development of Anthropocene biotas. *Philos. Trans. R. Soc. B* 375:20190113
27. Ceballos G, Ehrlich PR, Barnosky AD, García A, Pringle RM, Palmer TM. 2015. Accelerated modern human-induced species losses: entering the sixth mass extinction. *Sci. Adv.* 1:e1400253
28. De Vos JM, Joppa LN, Gittleman JL, Stephens PR, Pimm SL. 2015. Estimating the normal background rate of species extinction. *Conserv. Biol.* 29:452–62
29. Proença V, Pereira H. 2013. Comparing extinction rates: past, present and future. *Encycl. Biodivers.* 2:167–76
30. Purvis A, Butchart SHM, Brondizio ES, Settele J, Díaz S. 2019. No inflation of threatened species. *Science* 365:767
31. Humphreys AM, Govaerts R, Ficinski SZ, Lughadha EN, Vorontsova MS. 2019. Global dataset shows geography and life form predict modern plant extinction and rediscovery. *Nat. Ecol. Evol.* 3:1043–47
32. Barnosky AD, Matzke N, Tomiya S, Wogan GOU, Swartz B, et al. 2011. Has the Earth's sixth mass extinction already arrived? *Nature* 471:51–57
33. Rounsevell MDA, Harfoot M, Harrison PA, Newbold T, Gregory RD, Mace GM. 2020. A biodiversity target based on species extinctions. *Science* 368:1193–95
34. Gonzalez A, Cardinale BJ, Allington GRH, Byrnes J, Arthur Endsley K, et al. 2016. Estimating local biodiversity change: a critique of papers claiming no net loss of local diversity. *Ecology* 97:1949–60
35. Vellend M, Dornelas M, Baeten L, Beausejour R, Brown CD, et al. 2017. Estimates of local biodiversity change over time stand up to scrutiny. *Ecology* 98:583–90
36. Cardinale BJ, Gonzalez A, Allington GRH, Loreau M. 2018. Is local biodiversity declining or not? A summary of the debate over analysis of species richness time trends. *Biol. Conserv.* 219:175–83
37. De Palma A, Sanchez-Ortiz K, Martin PA, Chadwick A, Gilbert G, et al. 2018. Challenges with inferring how land-use affects terrestrial biodiversity: study design, time, space and synthesis. *Adv. Ecol. Res.* 58:163–99.
38. Puskic PS, Lavers JL, Bond AL. 2020. A critical review of harm associated with plastic ingestion on vertebrates. *Sci. Total Environ.* 743:140666
39. Foley CJ, Feiner ZS, Malinich TD, Höök TO. 2018. A meta-analysis of the effects of exposure to microplastics on fish and aquatic invertebrates. *Sci. Total Environ.* 631–632:550–59

40. Lim X. 2021. Microplastics are everywhere – but are they harmful? *Nature* 593:22–25
41. Dittmer MA, Francis CD, Barber JR, Stoner DC, Seymoure BM, et al. 2021. Assessing the vulnerabilities of vertebrate species to light and noise pollution: Expert surveys illuminate the impacts on specialist species. *Integr. Comp. Biol.* 61:1202–15
42. Duarte CM, Chapuis L, Collin SP, Costa DP, Devassy RP, et al. 2021. The soundscape of the Anthro- pocene ocean. *Science* 371:eaba4658
43. McMahon TA, Rohr JR, Bernal XE. 2017. Light and noise pollution interact to disrupt interspecific interactions. *Ecology* 98:1290–99
44. Leduc AOHC, Nunes JACC, de Araújo CB, Quadros ALS, Barros F, et al. 2021. Land-based noise pollution impairs reef fish behavior: a case study with a Brazilian carnival. *Biol. Conserv.* 253:108910
45. McClure CJW, Ware HE, Carlisle J, Kaltenecker G, Barber JR. 2013. An experimental investigation into the effects of traffic noise on distributions of birds: avoiding the phantom road. *Proc. R. Soc. B* 280:20132290
46. Shannon G, McKenna MF, Angeloni LM, Crooks KR, Fristrup KM, et al. 2016. A synthesis of two decades of research documenting the effects of noise on wildlife. *Biol. Rev.* 91:982–1005
47. Kunc HP, Schmidt R. 2019. The effects of anthropogenic noise on animals: a meta-analysis. *Biol. Lett.* 15:20190649
48. Gómez C, Lawson J, Wright A, Buren A, Tollit D, Lesage V. 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. *Can. J. Zool.* 94:801–19.