**General abstract** (currently 300 words; max 300 words)

Human activities have profoundly impacted global biodiversity. Currently, anthropogenic land-use and climate change figure among the major threats to the world’s fauna. However, not all species respond similarly to these pressures. Interspecific variability in responses to human threats is notably underpinned by the fact that different species possess different attributes and intrinsic characteristics (traits), some of them allowing species to cope with environmental changes, while others confer a disadvantage to species in modified environments. Understanding what renders species sensitive to anthropogenic pressures is vital to inform and prioritise conservation efforts. Yet, in terrestrial vertebrates, a group for which ecological data is the most abundant, it remains unclear which traits are associated with higher sensitivity to human pressures. The aims of my thesis are to investigate whether and which traits are associated with land-use responses and climate-change sensitivity in terrestrial vertebrates, and to highlight some of the consequences for ecosystem functioning. I first assess the global availability of ecological trait data for terrestrial vertebrates, evidencing understudied groups and regions (e.g., Central-African reptiles). I then show that, at global scales, disturbed land uses negatively impact the functional diversity of vertebrate assemblages. Further, I find that in all classes, higher sensitivity to land-use and climate change is associated with narrower ranges, smaller habitat breath and inability to use human-modified habitats. Both land-use responses and climate-change sensitivity are unevenly distributed among dietary groups, highlighting potential food web disruptions in assemblages under pressure. Finally, I show that land-use responses are influenced by species energetic requirements, so that energetic fluxes within vertebrate assemblages are likely modified under human-driven land-use change. Overall, my thesis highlights the compositional reshaping of vertebrate assemblages under human pressure and furthers our understanding of anthropogenic impacts on biodiversity. The large-scale consequences of these changes for ecosystem functioning remain to be fully understood.

**Impact statement** (currently 499 words; max 500 words)

As anthropogenic pressures on the world’s biota keep increasing, it is vital to put into place conservation measures to prevent further species loss. Beyond ethical and moral considerations, there is an urgent need to protect biodiversity because it sustains a range of ecological processes essential to human well-being and planetary health. Effectively managing biodiversity and related ecosystem processes in a changing world requires to understand how different species respond to anthropogenic disturbances. My thesis integrates various data sources to investigate the influence of traits on species land-use responses and on species climate-change sensitivity – two of the most pressing threats on biodiversity – at global scales and comparatively across the four terrestrial vertebrate classes. By asking whether interspecific trait variation is associated with species land-use responses and with climate-change sensitivity, my work consolidates our understanding of what renders species sensitive to environmental change, which can help prioritise conservation efforts.

Chapter 2 presents a trait data collection for terrestrial vertebrates, targeting seven commonly-used traits. I highlight the global taxonomic, geographical, and phylogenetic biases in the trait data, revealing knowledge gaps which could guide future data collection efforts. Chapter 2 was published in *Global Ecology and Biogeography* and may be useful to other researchers working with trait data in vertebrate species. The compiled data were made available and have since been used by researchers in the field (e.g., Capdevila *et al.* (2022), *preprint*) and downloaded 267 times as of April 2022. Chapter 3 uses the collected trait data and reveals profound effects of land-use change on vertebrate functional diversity, which contributes to documenting global human impacts on vertebrates and also underlines the possible threats posed by land-use change to ecosystem processes sustained by vertebrates. Chapter 3 was published in *Ecology Letters*. In Chapter 4, I ask whether traits are associated with species land-use responses and with species climate-change sensitivity, comparatively across the four vertebrate classes. Chapter 4 thus puts into perspective the usefulness of trait data for understanding how species respond to these anthropogenic changes, which is valuable for conservation planning and prioritisation. In Chapter 5, I ask whether species energetic requirements, estimated from metabolic rates, influence species persistence in disturbed land uses. Chapter 5 thus integrates physiological data to further our fundamental understanding of how vertebrate species respond to land-use change and of the potential consequences for ecosystem functioning.

Beyond publishing two of my PhD Chapters, I have been able to disseminate my work at various international conferences, notably at the annual meeting of the British Ecological Society (in 2019, 2020 and 2021), at the annual meeting of the Macroecology Special Interest Group (in 2019), and at the International Biogeography Society early-career conference (in 2021). I will additionally present my PhD work at the International Biogeography Society conference in June 2022. Overall, my PhD work consolidates our knowledge of the role of vertebrate traits for understanding species responses to human pressures and highlights the value of trait data, and more widely, of ecological knowledge, for preserving vertebrate species in a changing world.

**Thesis outline of contents, authorship and collaborations**

**Chapter 1: General introduction**

Chapter 1 presents the background for this Thesis, exposes the fundamental concepts, and highlights the research questions I investigated in the different Chapters.

**Chapter 2: Global gaps and biases in trait data for terrestrial vertebrates**

In Chapter 2, I present an analysis of the global gaps and biases in terrestrial vertebrate trait data. To this end, I collate data on seven traits commonly measured in terrestrial vertebrates. I then evaluate the availability of these trait data across the vertebrate classes, assessing whether there are taxonomic, phylogenetic and spatial biases. This chapter was published in *Global Ecology and Biogeography* in 2020 (DOI: 10.1111/geb.13184; Etard et al., 2020). The paper was co-authored by Sophie Morrill who collated some of the data on reptile traits as part of an MRes project at UCL, and by Tim Newbold, who participated in the development of the research questions, provided detailed feedback on the analyses, and contributed to the writing of the paper.

**Chapter 3: Intensive human land uses negatively affect vertebrate functional diversity**

In this Chapter, I investigate how land-use change affects the functional composition of local vertebrate assemblages. This chapter was published in *Ecology Letters* in 2022 (DOI: 10.1111/ele.13926; Etard et al. 2022) and co-authored by Alex Pigot and Tim Newbold, who helped construct the hypotheses, provided detailed feedback on the work, and took part in the writing of the paper.

**Chapter 4: Geographical range area, habitat breadth and specialisation on natural habitats explain land-use responses and climate-change sensitivity more consistently than life-history and dietary traits in terrestrial vertebrates**

In this chapter, I assess whether ecological traits as well as geographical range area are associated with species land-use responses and species estimated climate-change sensitivity, comparatively among terrestrial vertebrate classes. Rhiannon Osborne-Tonner contributed to this chapter by collecting data on amphibian and reptile diet during her MSc project at UCL, which I used to complement my datasets. This chapter was conducted in collaboration with Tim Newbold who helped develop the research questions and provided detailed feedback on the work and on the writing.

**Chapter 5: Energetic constraints and trophic group explain species persistence in disturbed land uses**

In Chapter 5, I evaluate the impacts of land-use change on community energetic requirements, and I assess whether species energetic requirements influence species persistence in disturbed land uses. To this end, I use physiological data, compiling species resting metabolic rates (used as a proxy for energetic requirements) from the literature. Meghan Hayden and Laura Dee of the University of Colorado, Boulder, as well as Tim Newbold, contributed to the elaboration of the research questions for this Chapter. Meghan Hayden further contributed to this Chapter by retrieving information on net primary productivity for PREDICTS sites, using data from MODIS satellite imagery. All collaborators also provided feedback on the work and participated in writing the manuscript. This Chapter was submitted to a scientific journal and underwent a round of peer-review.

**Chapter 6: General discussion**

This final chapter summarises the main findings of my thesis and assesses their contributions to the field.

**General introduction**

Humans have been modifying Earth’s ecosystems for thousands of years. Archaeological and palaeontological evidence suggest that human activities may have played a major role in the extinction of Australian’s megafauna as early as fifty thousand years ago (Johnson *et al.* 2016; Miller *et al.* 2016; Van Der Kaars *et al.* 2017). The subsequent arrival of modern humans in other parts of the world has also been associated with extinctions, of the megafauna in particular (Sandom *et al.* 2014; Broughton & Weitzel 2018). However, the global signature of human presence on Earth has never been as prominent as in the recent decades. The past two hundred years have been characterised by a sharp increase in the rates of human-driven changes at the planetary scale, termed “the Great Acceleration” (Steffen *et al.* 2015). To emphasize the recent impacts of human activities on the Earth’s systems, Crutzen & Stoermer (2000) proposed that we have entered a new geological epoch, which they called “the Anthropocene”. Although the formal acceptation of this epoch and the timing of its start are still debated within the stratigraphic community (Lewis & Maslin 2015; Monastersky 2015), the coined term reflects the profound effects of humans on planetary processes and on the biosphere, such that its use has largely surpassed the geological field (Malhi 2017).

The Anthropocene can be characterised with Earth-system and socio-economic indicators (Steffen *et al.* 2011; Biermann *et al.* 2016). Two of the major signatures are the human-driven transformations of the land surface and the changes in atmospheric composition, associated with the onset of anthropogenic climate change (Lewis & Maslin 2015). Altogether, the development of human activities at unprecedented scales and magnitude of has led to the alteration of many ecosystems. As a result of combined anthropogenic pressures, the world’s biodiversity has been changing (Dirzo *et al.* 2014; McGill *et al.* 2015; Johnson *et al.* 2017; Daru *et al.* 2021). Decreases in a range of biodiversity indicators have been reported for many taxonomic groups (Butchart *et al.* 2010). Human-mediated invasions and translocations of species, coupled with local declines in native species, have promoted biotic homogenisation (Newbold *et al.* 2018; Finderup Nielsen *et al.* 2019; Daru *et al.* 2021). In addition, species have gone extinct at higher rates than expected from natural background variability, with current extinction rates estimated to exceed those inferred from fossil records by a hundred to a thousand times (Barnosky *et al.* 2011; De Vos *et al.* 2015). Biodiversity loss and ecosystem change have become such major issues in the 21th century that the prevention of biodiversity erosion and the protection of ecosystems have become priority goals on international agendas (Convention on Biological Diversity 2020; Hoban *et al.* 2020). Indeed, it is now well established that biodiversity is tightly linked with ecosystem functioning and ecosystem services delivery (refs), and thus ultimately, with human well-being. However, the difficulty in achieving global conservation goals – such as the failure to reach the Aichi targets (Butchart 2010) – highlights the need strengthen global conservation efforts if we are to protect biodiversity and related ecosystem services from global threats (Butchart *et al.* 2016).

1. *Land-use change and climate change, two major drivers of global biodiversity loss in the Anthropocene*

The biggest anthropogenic threats to biodiversity have been well characterised (Maxwell *et al.* 2016). Currently, land-use change is the primary driver of global biodiversity loss (Newbold *et al.* 2015; Chaudhary *et al.* 2018; Jetz & Pyron 2018; Powers & Jetz 2019). However, the negative effects of climate change on biodiversity could equate those of land-use change in their magnitude by 2070 (Newbold 2018), emphasizing that together, these two threats urge towards immediate conservation and mitigation action.

*Land-use change*

Land-use change refers to the process by which humans transform the landscape to achieve socio-economic needs, such that the use of the land is characterised by the main purpose it fulfils (in other words, land use describes the human intent behind a particular land cover; Lambin *et al.* 2001). Land-use change includes transitions from natural to anthropized landscapes, as exemplified by agricultural-driven deforestation in tropical areas (Jayathilake *et al.* 2021); land-use change also describes transitions between different forms of human-dominated land uses, with, for instance, the expansion of urban areas over agricultural lands (Ustaoglu & Williams 2017). Although humans have been modifying terrestrial ecosystems for millennia – between 75% and 95% of the total land surface could have been altered by human activities (Ellis *et al.* 2013), other refs –, only during the past three centuries has the terrestrial surface made the transition from mostly wild to mostly human-dominated (Ellis *et al.* 2010). The most important driver behind this transition has been agricultural expansion, with major increases in cropland and grazing areas from the mid-18th century (Figure 1; refs). In the recent decades, the expansion of grazing areas and animal feed crops, fuelled by the rising demand in animal products, has been identified as the most important driver of land-use change (Alexander *et al.* 2015).

Chart

Description automatically generated

**Figure 1: Land surface (and land-surface proportion) used for agricultural purposes between 2000 BCE and 2016.** Data from the HYDE database (Goldewijk *et al.* 2017), downloaded from <https://ourworldindata.org/land-use> (24/01/2022).

The effects of land-use change on biodiversity have been characterised at local, regional and global scales – although global-scale studies represent a small proportion of the published research (Davison *et al.* 2021). Overall, published research highlights the negative impacts of land-use change on species richness and abundance (Newbold *et al.* 2015), as well as key impacts of future land-use change scenarios for ecosystem processes and services (Lawler *et al.* 2014). For example, and although they currently represent a small proportion of the terrestrial surface (about 1%; Goldewijk *et al.* (2017)), urban areas have been expanding at faster rates than urban populations themselves (Seto *et al.* 2010), and can cause considerable damage to biodiversity and ecosystem services. In particular, the expansion of impervious surfaces has been linked to reduction in species richness (Souza *et al.* 2019; Yan *et al.* 2019) and to increases in ecological risks (e.g., due to flooding, Hou *et al.* 2022). However, another important aspect of land-use change for biodiversity outcomes is the level of intensity at which the land is used to fulfil its purpose. For example, introducing and managing green spaces can lead to positive biodiversity outcomes in urban environments (Ives *et al.* 2016; Aronson *et al.* 2017). Yet, land-use intensity has not been explicitly considered by a majority of past studies investigating impacts of land-use change on biodiversity (Davison *et al.* 2021), despite its likely importance for biodiversity (Dullinger *et al.* 2021; Millard *et al.* 2021).

*Climate change*

According to the World Meteorological Organization, climate change can be defined as long-term changes (i.e, at least over several decades) to the mean state or to the variability of the climate, attributable to human activity or to natural causes. There is a strong scientific consensus that current climate change (starting ~1850 D.C) is the result of human activity, onset by the anthropogenic changes to atmospheric composition. Current manifestations of ongoing climate change include rising average temperatures, increases in the frequency of extreme events and changes in global rainfall patterns.

There is now accumulating empirical evidence that climate change affects biodiversity globally, with documented changes in phenology (), in the geographical distributions of species (Arctic greening), in species physiology (), with consequences for species interactions that can exacerbate local impacts ().

Responses to climate change encompass three cornerstones : sensitivity, exposure, vulnerability.

As the world’s population continues to grow and as the demand for food, energy and other commodities keeps rising, rates of global land-use and climate change are unlikely to curb without the implementation of strong international regulations and consumption changes (Stehfest *et al.* 2019) (add cc ref). In this context, understanding the effects of land-use and climate change on biodiversity and associated ecosystem services has become vital in order to put into place mitigation measures.

1. *Informing and prioritising vertebrate conservation with trait-based approaches*

***Ecological importance of terrestrial vertebrates and current threats***

Vertebrate species play significant roles in ecosystem functioning and support a wide range of processes, most notably as pollinators (Ratto *et al.* 2018), seed dispersers (Tiffney 2004), regulators of lower trophic levels (Barber *et al.* 2010; Salo *et al.* 2010; Luck *et al.* 2012; Lin *et al.* 2018; Zhang *et al.* 2018), nutrient cyclers (Wilson & Wolkovich 2011; Inger *et al.* 2016; Cunningham *et al.* 2018) and ecosystem engineers (Severtsov 2012). Vertebrates are also important for human societies, both culturally and as sources of proteins (Hirons *et al.* 2016; Albert *et al.* 2018; Alves *et al.* 2018). However, terrestrial vertebrates are highly threatened by human activities, with ().For instance, the latest Living Planet Report highlights that vertebrate populations have decreased by 70% on average since 1970 (). Percent of different groups classified -> amphibians particularly threatened. Vertebrate species are particularly threatened (Monastersky 2014).

***Using traits to understand species responses to environmental change***

Despite the global average declines reported for vertebrate diversity (), not all species respond similarly to environmental changes. Past work has shown highlighted interspecific variation in species responses to land-use and climate change. For instance, past studies have underlined that some species may benefit from global changes, while others are projected to decline.

The idea that species traits mediate species responses to environmental change was formalized in the “response-effect” framework in the 2000s (REFS), where traits that influence species responses to changes were termed “response traits”, and those that are implicated in ecological processes termed “effect traits”. This framework provides with a conceptual mechanistic understanding of how environmental changes can affect ecosystem processes through effect trait composition modification mediated by response traits. Although this framework initially built upon the field of plant ecology, response traits have also been identified in vertebrate species.

In this thesis, I ask whether species traits are associated with species land-use responses and with species climate-change sensitivity, at global scales, and comparatively across the four terrestrial vertebrate classes. I explore some of the consequences of land-use change for ecosystem functioning.

To this end, I use one of the most comprehensive database (the PREDICTS database, refs), to investigate the effects of land-use change on terrestrial vertebrates using a “space-for-time” substitution approach.

1. *Aims, hypotheses and outline of the following Chapters*

The overarching aims of my thesis are to investigate whether species traits explain species land-use responses and species climate-change sensitivity comparatively across the four vertebrate classes, and to highlight some of the consequences for ecosystem functioning. One of the obstacles that have hindered the application of trait-based approaches at large scales in animal taxa is the lack of a centralised repository for readily available trait data, as emphasized by the recent calls to compile and release trait data for animals (***refs***). Thus, collecting trait data and investigating the current availability of the data for terrestrial vertebrates was an important and necessary prerequisite to any analysis.

In Chapter 2, I present a trait data collection for terrestrial vertebrates. Because using similar traits in the different vertebrate classes is necessary to be able to make comparisons among vertebrate classes, I target seven traits that are commonly used in any taxonomic group: body mass/size, a proxy for lifespan, litter/clutch size, trophic level, diel activity, habitat breadth, and a broad degree of habitat specialisation. Chapter 2 assesses the availability of the trait data across the terrestrial vertebrate classes, and investigates whether the trait data present global taxonomic, phylogenetic and spatial biases. On the basis of past work (Titley *et al.* 2017), I hypothesize that amphibians and reptiles are undersampled compared to mammals and birds. Further, I hypothesize that trait data are less abundant for the narrower-ranging species and in species-richer regions. This Chapter was published in *Global Ecology and Biogeography* (Etard *et al*. 2020).

Chapter 3 focuses on assessing the effects of land-use change on the functional diversity of local vertebrate assemblages. To this end, I combine the trait data collected in Chapter 2 with the PREDICTS database (which contains records of species occurrence in different land uses; Hudson et al. 2014, 2017). After imputing missing trait values evidenced in Chapter 2, I investigate the effects of land use on the functional diversity of local terrestrial vertebrate assemblages, across and within vertebrate classes, using a “space-for-time” approach facilitated by the PREDICTS database. I hypothesize that the functional diversity of vertebrate assemblages in disturbed land uses is lower than in undisturbed land uses. I further predict that decreases in functional diversity in disturbed land uses are driven by high levels of functional loss and that observed declines in functional diversity exceed those expected from random species loss. This Chapter was published in *Ecology Letters* (Etard *et al*. 2022).

Chapter 4 then investigates whether ecological traits and geographical range area are associated with species land-use responses and species climate-change sensitivity, comparatively among the terrestrial vertebrate classes. I enhance the trait data compiled in Chapter 2 with diet information for vertebrate species. I investigate whether there are associations between ecological traits (including geographical range area) and species land-use responses on the one hand, and between ecological traits and species climate-change sensitivity on the other hand. I further assess whether these associations can be generalised across classes and threats by looking for emerging patterns in the associations between traits and land-use responses and between traits and climate-change sensitivity.

Chapter 5 develops our understanding of the impacts of land-use change on ecosystem functioning by focusing on species energetic requirements. I first assess the effects of land use on the total energetic requirements of vertebrate assemblages. Second, I assess whether species energetic requirements influence species persistence in disturbed land uses. To this end, I collect resting metabolic rates for vertebrate species, which I use as a proxy for species-level energetic expenditure, and I combine these estimates with the PREDICTS database. Assuming that there is less energy available in disturbed land uses, I hypothesize that the assemblage-level energetic requirements of vertebrates are lower in disturbed land uses compared to undisturbed land uses, and that species with lower mass-independent energetic requirements are favoured over species with higher mass-independent energetic requirements in disturbed land uses.

Finally, inChapter 6, I summarise the findings of this thesis, highlight some of the limitations and examine the relevance of the findings for the field. By investigating whether traits are associated with species land-use responses and climate-change sensitivity across the terrestrial vertebrates, my thesis furthers our understanding of what could render species more sensitive to human threats, and underlines the role and usefulness of vertebrate trait data for understanding species responses to human pressures.

**References**

Albert, C., Luque, G.M. & Courchamp, F. (2018). The twenty most charismatic species. *PLoS One*.

Alexander, P., Rounsevell, M.D.A., Dislich, C., Dodson, J.R., Engström, K. & Moran, D. (2015). Drivers for global agricultural land use change: The nexus of diet, population, yield and bioenergy. *Glob. Environ. Chang.*, 35, 138–147.

Alves, R.R.N., Souto, W.M.S., Fernandes-Ferreira, H., Bezerra, D.M.M., Barboza, R.R.D. & Vieira, W.L.S. (2018). *The Importance of Hunting in Human Societies*. *Ethnozoology Anim. our Lives*. Elsevier Inc.

Aronson, M.F.J., Lepczyk, C.A., Evans, K.L., Goddard, M.A., Lerman, S.B., MacIvor, J.S., *et al.* (2017). Biodiversity in the city: key challenges for urban green space management. *Front. Ecol. Environ.*, 15, 189–196.

Barber, N.A., Mooney, K.A., Greenberg, R., Philpott, S.M., Van Bael, S.A. & Gruner, D.S. (2010). Interactions among predators and the cascading effects of vertebrate insectivores on arthropod communities and plants. *Proc. Natl. Acad. Sci.*

Barnosky, A.D., Matzke, N., Tomiya, S., Wogan, G.O.U., Swartz, B., Quental, T.B., *et al.* (2011). Has the Earth’s sixth mass extinction already arrived? *Nature*.

Biermann, F., Bai, X., Bondre, N., Broadgate, W., Arthur Chen, C.T., Dube, O.P., *et al.* (2016). Down to Earth: Contextualizing the Anthropocene. *Glob. Environ. Chang.*, 39, 341–350.

Broughton, J.M. & Weitzel, E.M. (2018). Population reconstructions for humans and megafauna suggest mixed causes for North American Pleistocene extinctions. *Nat. Commun.*, 9, 1–12.

Butchart, S.H.M., Di Marco, M. & Watson, J.E.M. (2016). Formulating Smart Commitments on Biodiversity: Lessons from the Aichi Targets. *Conserv. Lett.*, 9, 457–468.

Capdevila, P., Noviello, N., Mcrae, L., Freeman, R., Life, B., Building, S., *et al.* (2022). Body mass and latitude as global predictors of vertebrate Running title : Global predictors of multiple threats, 1–25.

CBD. (2020). Update of the zero draft of the post-2020 global biodiversity framework. *Proc. United Nations Environ. Program. Conf. Parties to UN Conv. Biol. Divers.*, Post2020/P, 1–9.

Chaudhary, A., Pourfaraj, V. & Mooers, A.O. (2018). Projecting global land use-driven evolutionary history loss. *Divers. Distrib.*, 24, 158–167.

Crutzen, P. & Stoermer, E. (2000). Sustaining Earth’s Life Support Systems – the Challenge for the Next Decade and Beyond. *IGBP Newsl.*, 17–18.

Cunningham, C.X., Johnson, C.N., Barmuta, L.A., Hollings, T., Woehler, E.J. & Jones, M.E. (2018). Top carnivore decline has cascading effects on scavengers and carrion persistence. *Proc. R. Soc. B Biol. Sci.*

Daru, B.H., Davies, T.J., Willis, C.G., Meineke, E.K., Ronk, A., Zobel, M., *et al.* (2021). Widespread homogenization of plant communities in the Anthropocene. *Nat. Commun.*, 12, 1–10.

Davison, C.W., Rahbek, C. & Morueta-Holme, N. (2021). Land-use change and biodiversity: Challenges for assembling evidence on the greatest threat to nature. *Glob. Chang. Biol.*, 27, 5414–5429.

Dirzo, R., Young, H.S., Galetti, M., Ceballos, G., Isaac, N.J.B. & Collen, B. (2014). Defaunation in the Anthropocene. *Science (80-. ).*, 345, 401–406.

Dullinger, I., Essl, F., Moser, D., Erb, K., Haberl, H. & Dullinger, S. (2021). Biodiversity models need to represent land-use intensity more comprehensively. *Glob. Ecol. Biogeogr.*, 30, 924–932.

Ellis, E.C., Goldewijk, K.K., Siebert, S., Lightman, D. & Ramankutty, N. (2010). Anthropogenic transformation of the biomes, 1700 to 2000. *Glob. Ecol. Biogeogr.*, 19, 589–606.

Ellis, E.C., Kaplan, J.O., Fuller, D.Q., Vavrus, S., Goldewijk, K.K. & Verburg, P.H. (2013). Used planet: A global history. *Proc. Natl. Acad. Sci. U. S. A.*, 110, 7978–7985.

Finderup Nielsen, T., Sand-Jensen, K., Dornelas, M. & Bruun, H.H. (2019). More is less: net gain in species richness, but biotic homogenization over 140 years. *Ecol. Lett.*, 22, 1650–1657.

Goldewijk, K.K., Beusen, A., Doelman, J. & Stehfest, E. (2017). Anthropogenic land use estimates for the Holocene - HYDE 3.2. *Earth Syst. Sci. Data*, 9, 927–953.

Hirons, M., Comberti, C. & Dunford, R. (2016). Valuing Cultural Ecosystem Services. *Annu. Rev. Environ. Resour.*, 41, 545–574.

Hoban, S., Bruford, M., D’Urban Jackson, J., Lopes-Fernandes, M., Heuertz, M., Hohenlohe, P.A., *et al.* (2020). Genetic diversity targets and indicators in the CBD post-2020 Global Biodiversity Framework must be improved. *Biol. Conserv.*, 248, 108654.

Hou, Y., Ding, W., Liu, C., Li, K., Cui, H., Liu, B., *et al.* (2022). Influences of impervious surfaces on ecological risks and controlling strategies in rapidly urbanizing regions. *Sci. Total Environ.*, 153823.

Inger, R., Cox, D.T.C., Per, E., Norton, B.A. & Gaston, K.J. (2016). Ecological role of vertebrate scavengers in urban ecosystems in the UK. *Ecol. Evol.*

Ives, C.D., Lentini, P.E., Threlfall, C.G., Ikin, K., Shanahan, D.F., Garrard, G.E., *et al.* (2016). Cities are hotspots for threatened species. *Glob. Ecol. Biogeogr.*, 25, 117–126.

Jayathilake, H.M., Prescott, G.W., Carrasco, L.R., Rao, M. & Symes, W.S. (2021). Drivers of deforestation and degradation for 28 tropical conservation landscapes. *Ambio*, 50, 215–228.

Jetz, W. & Pyron, R.A. (2018). The interplay of past diversification and evolutionary isolation with present imperilment across the amphibian tree of life. *Nat. Ecol. Evol.*

Johnson, C.N., Alroy, J., Beeton, N.J., Bird, M.I., Brook, B.W., Cooper, A., *et al.* (2016). What caused extinction of the pleistocene megafauna of sahul? *Proc. R. Soc. B Biol. Sci.*, 283.

Johnson, C.N., Balmford, A., Brook, B.W., Buettel, J.C., Galetti, M., Guangchun, L., *et al.* (2017). Biodiversity losses and conservation responses in the Anthropocene. *Science (80-. ).*

Van Der Kaars, S., Miller, G.H., Turney, C.S.M., Cook, E.J., Nürnberg, D., Schönfeld, J., *et al.* (2017). Humans rather than climate the primary cause of Pleistocene megafaunal extinction in Australia. *Nat. Commun.*, 8, 1–7.

Lambin, E.F., Coomes, O.T., Turner, B.L., Geist, H.J., Agbola, S.B., Angelsen, A., *et al.* (2001). The causes of land-use and land-cover change : Moving beyond the myths. *Glob. Environ. Chang.*, 11, 261–269.

Lawler, J.J., Lewis, D.J., Nelson, E., Plantinga, A.J., Polasky, S., Withey, J.C., *et al.* (2014). Projected land-use change impacts on ecosystem services in the United States. *Proc. Natl. Acad. Sci. U. S. A.*, 111, 7492–7497.

Lewis, S.L. & Maslin, M.A. (2015). Defining the Anthropocene. *Nature*, 519, 171–180.

Lin, F., Jia, S., Luskin, M.S., Ye, J., Hao, Z., Wang, X., *et al.* (2018). Global signal of top-down control of terrestrial plant communities by herbivores. *Proc. Natl. Acad. Sci.*

Luck, G.W., Lavorel, S., Mcintyre, S. & Lumb, K. (2012). Improving the application of vertebrate trait-based frameworks to the study of ecosystem services. *J. Anim. Ecol.*

Malhi, Y. (2017). *The Concept of the Anthropocene*. *Annu. Rev. Environ. Resour.*

Maxwell, S.L., Fuller, R.A., Brooks, T.M. & Watson, J.E.M. (2016). Biodiversity: The ravages of guns, nets and bulldozers. *Nature*.

McGill, B.J., Dornelas, M., Gotelli, N.J. & Magurran, A.E. (2015). Fifteen forms of biodiversity trend in the anthropocene. *Trends Ecol. Evol.*, 30, 104–113.

Millard, J., Outhwaite, C.L., Kinnersley, R., Freeman, R., Gregory, R.D., Adedoja, O., *et al.* (2021). pollinator biodiversity. *Nat. Commun.*, 1–11.

Miller, G., Magee, J., Smith, M., Spooner, N., Baynes, A., Lehman, S., *et al.* (2016). Human predation contributed to the extinction of the Australian megafaunal bird Genyornis newtoni ∼47 ka. *Nat. Commun.*, 7, 1–7.

Monastersky, R. (2014). Life - a status report. *Nature*, 516, 161.

Monastersky, R. (2015). The human age. *Nature*, 519, 144–147.

Newbold, T. (2018). Future effects of climate and land-use change on terrestrial vertebrate community diversity under different scenarios. *Proc. R. Soc. London Ser. B, Biol. Sci.*, 20180792.

Newbold, T., Hudson, L.N., Contu, S., Hill, S.L.L., Beck, J., Liu, Y., *et al.* (2018). Widespread winners and narrow-ranged losers: Land use homogenizes biodiversity in local assemblages worldwide. *PLoS Biol.*

Newbold, T., Hudson, L.N., Hill, S.L., Contu, S., Lysenko, I., Senior, R. a, *et al.* (2015). Global effects of land use on local terrestrial biodiversity. *Nature*.

Powers, R.P. & Jetz, W. (2019). Global habitat loss and extinction risk of terrestrial vertebrates under future land-use-change scenarios. *Nat. Clim. Chang.*, 9, 323–329.

Ratto, F., Simmons, B.I., Spake, R., Zamora-Gutierrez, V., MacDonald, M.A., Merriman, J.C., *et al.* (2018). Global importance of vertebrate pollinators for plant reproductive success: a meta-analysis. *Front. Ecol. Environ.*

Salo, P., Banks, P.B., Dickman, C.R. & Korpimäki, E. (2010). Predator manipulation experiments: Impacts on populations of terrestrial vertebrate prey. *Ecol. Monogr.*

Sandom, C., Faurby, S., Sandel, B. & Svenning, J.C. (2014). Global late Quaternary megafauna extinctions linked to humans, not climate change. *Proc. R. Soc. B Biol. Sci.*, 281.

Seto, K.C., Sánchez-Rodríguez, R. & Fragkias, M. (2010). The new geography of contemporary urbanization and the environment. *Annu. Rev. Environ. Resour.*, 35, 167–194.

Severtsov. (2012). *The Significance of Vertebrates in the Structure and Functioning of Ecosystems*.

Souza, F.L., Valente-Neto, F., Severo-Neto, F., Bueno, B., Ochoa-Quintero, J.M., Laps, R.R., *et al.* (2019). Impervious surface and heterogeneity are opposite drivers to maintain bird richness in a Cerrado city. *Landsc. Urban Plan.*, 192, 103643.

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O. & Ludwig, C. (2015). The trajectory of the anthropocene: The great acceleration. *Anthr. Rev.*

Steffen, W., Grinevald, J., Crutzen, P. & Mcneill, J. (2011). The anthropocene: Conceptual and historical perspectives. *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.*, 369, 842–867.

Stehfest, E., van Zeist, W.J., Valin, H., Havlik, P., Popp, A., Kyle, P., *et al.* (2019). Key determinants of global land-use projections. *Nat. Commun.*, 10, 1–10.

Stuart H. M. Butchart, Matt Walpole, Ben Collen,Arco van Strien, Jörn P. W. Scharlemann,Rosamunde E. A. Almond , Jonathan E. M. Baillie, Bastian Bomhard, Claire Brown, John Bruno , Kent E. Carpenter, Geneviève M. Carr , Janice Chanson, Anna M. Chenery, Jo, R.W. (2010). Global biodiversity: indicators of recent declines. *Science (80-. ).*, 328, 1164–1168.

Tiffney, B.H. (2004). Vertebrate dispersal of seed plants through time. *Annu. Rev. Ecol. Evol. Syst.*, 35, 1–29.

Titley, M.A., Snaddon, J.L. & Turner, E.C. (2017). Scientific research on animal biodiversity is systematically biased towards vertebrates and temperate regions. *PLoS One*.

Ustaoglu, E. & Williams, B. (2017). Determinants of Urban Expansion and Agricultural Land Conversion in 25 EU Countries. *Environ. Manage.*, 60, 717–746.

De Vos, J.M., Joppa, L.N., Gittleman, J.L., Stephens, P.R. & Pimm, S.L. (2015). Estimating the normal background rate of species extinction. *Conserv. Biol.*

Wilson, E.E. & Wolkovich, E.M. (2011). Scavenging: How carnivores and carrion structure communities. *Trends Ecol. Evol.*

Yan, Z., Teng, M., He, W., Liu, A., Li, Y. & Wang, P. (2019). Impervious surface area is a key predictor for urban plant diversity in a city undergone rapid urbanization. *Sci. Total Environ.*, 650, 335–342.

Zhang, J., Qian, H., Girardello, M., Pellissier, V., Nielsen, S.E. & Svenning, J.C. (2018). Trophic interactions among vertebrate guilds and plants shape global patterns in species diversity. *Proc. R. Soc. B Biol. Sci.*