**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 (~3300 words)**

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 (Duraiappah *et al.* 2005, Oliver *et al.* 2015, Hooper *et al.* 2005), and thus ultimately, with human well-being. However, the difficulty in achieving global conservation goals – such as the failure to reach the Aichi targets (Buchanan *et al.* 2020) – highlights the need to 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 mitigation and conservation 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, 2021) –, 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). 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 instance, 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 is 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 ~A.D. 1850) is the result of human activity, and that it is has been onset by the human-driven changes to atmospheric composition (Crowley 2000; IPCC 2013; Maibach *et al.* 2014). Current manifestations of climate change include rising average temperatures (Valipour *et al.* 2021; Figure 2), increases in the frequency of extreme events (Seneviratne *et al.* 2012) and changes in global rainfall patterns (Dore 2005; Trenberth 2011).

A picture containing text, writing implement, stationary, pencil

Description automatically generated

**Figure 2: Land surface temperature anomaly between A.D 1880 and A.D. 2022.** Data retrieved from the National Oceanic and Atmospheric Administration – National Centers for Environmental Information, downloaded from [https://www.ncdc.noaa.gov/cag/](https://www.ncei.noaa.gov/cag/) (May 2022), and plotted for the month of March. The anomalies are calculated with reference to the global temperature average for the 20th century.

There is accumulating empirical evidence that climate change affects biodiversity globally, with documented changes in phenology (Inouye 2022), in the geographical distributions of species (Chen *et al.* 2011; Lenoir & Svenning 2015), and in species physiology (Pörtner & Farrell 2008; Chown *et al.* 2010). Climate-change impacts on individual species have consequences for whole communities, through the disruptions of species interactions, which can in turn exacerbate impacts on individual species (Cahill *et al.* 2013; Kharouba *et al.* 2018).

Projecting future land-use and climate-change impacts on biodiversity highlights the key role of human-development scenarios for global biodiversity outcomes (Newbold 2018) and for the long-term viability of animal populations (Spooner *et al.* 2018). 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 (Intergovernmental Panel on Climate Change 2022; Stehfest *et al.* 2019). In this context, evaluating 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. In particular, understanding what makes species more sensitive to land-use and climate change can help conservation efforts.

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

*Ecological importance of terrestrial vertebrates and current threats*

Vertebrates 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), and figure among the most charismatic species (Courchamp *et al.* 2018). Despite their cultural and ecological importance, terrestrial vertebrates are highly threatened by human activities. The latest Living Planet Report revealed that vertebrate populations have decreased by 70% on average since 1970 (WWF 2020). According to the IUCN Red List of Threatened Species, about 41% of assessed amphibian species are classified as threatened, 26% of the mammals, 21% of the reptiles and 13% of the birds (IUCN 2022, <https://www.iucnredlist.org/resources/summary-statistics>). A recent assessment of vertebrates listed in the IUCN Red List of Threatened Species highlights habitat destruction as the predominant human threat (Cox *et al.* 2022), but direct exploitation also figures among the major factors of decline (Monastersky 2014). Although climate change is not the principal driver of current population declines (Caro *et al.* 2022), the first extinction of a mammal attributed to anthropogenic climate was reported in 2016 (Watson 2016), and future projections highlight that between 10% and 30% of vertebrate species could be locally lost by 2070 depending on climate-change scenarios (Newbold 2018).

*Using traits to understand species responses to environmental change*

Despite the global average declines reported for vertebrate populations, not all species respond similarly to environmental changes (Dornelas *et al.* 2019; Leung *et al.* 2020): while some species are projected to decline, others may benefit from global changes (Thomas 2013; Newbold *et al.* 2018). One of the reasons why species differ in their ability to cope with disturbances is that species present different intrinsic characteristics, or traits. Although the formal definition of ‘a trait’ can vary depending on studies, in this thesis, I consider traits to be characteristics measurable at the organismal level, that likely influence organismal fitness and performance (this is the definition adopted in McGill *et al.* (2006)). The idea that species traits mediate species responses to environmental change was formalised in the “response-effect” framework, developed on the grounds of plant ecology (Lavorel & Garnier 2002), where traits that influence species responses to environmental change were termed “response traits” (and those that underpin ecological processes were termed “effect traits”). Trait-based approaches rapidly developed (Hevia et al. 2017). One of the appeals of trait-based approaches is that individual species are no longer the fundamental unit of biodiversity investigations. Rather, traits become the focus and act as “common currencies” across species, which is of particular interest for conservation when long-term population data are lacking. Indeed, if species’ responses to human threats consistently relate to certain traits, it may be possible to generalise patterns and estimate the responses of species for which population data is not available (Verberk *et al.* 2013). As such, traits have been used to assess species vulnerability to global changes (in particular to climate change; Foden *et al.* (2013); Pacifici *et al.* (2015)), with frameworks assuming that species traits predict species sensitivity to environmental change. A number of studies have focused on explaining species extinction risk with traits (Lebreton 2011; Chichorro *et al.* 2019), which is of high interest for conservation but often lack threat-specific considerations (Gonzalez-Suarez *et al.* 2013). Among studies focused on land-use change, empirical evidence linking traits and biodiversity responses rely mostly on (1) functional diversity indices to evaluate the effects of land-use disturbance on the functional composition of local assemblages (Flynn *et al.* 2009), and (2) on correlative assessments aiming to explain land-use responses with traits (Newbold *et al.* 2013). Correlative trait-based approaches have also been used to understand species responses to climate change (with studies focusing on explaining interspecific variation in past or projected range shifts with traits (Schloss *et al.* 2012; Pacifici *et al.* 2017; Di Marco *et al.* 2021); and with range-filling approaches (Estrada *et al.* 2018)). However, such studies investigating relationships between traits and environmental change have mostly been conducted at local to regional scale (Hevia *et al.* 2017; Davison *et al.* 2021). Thus, although response traits to land-use and climate change have been identified in various vertebrate taxa, whether the effects of such traits can be generalised geographically and taxonomically remains largely uncertain, emphasising the need for global comparative assessments of the relationships between traits and species responses to human threats. In this thesis, I set out to fill in this gap by asking whether interspecific trait variation is associated with species land-use responses and with climate change sensitivity, at global scales, and comparatively across the four vertebrate classes. Such an assessment helps to understand what species are at most risk from global changes and may be useful to the prioritisation of conservation efforts. I also aim to highlight some of the consequences of global changes for ecosystem functioning. Throughout my thesis, assemblage-level and species-level responses to land use and land-use intensity are assessed using a “space-for-time” approach (De Palma *et al.* 2018). To this end, I use one of the most comprehensive databases recording species occurrence and abundance in different land uses (the PREDICTS database, Hudson *et al.* (2014, 2017)). I estimate sensitivity to climate change from properties of species climatic niche space, and thus I would like to emphasize that I do not assess species *responses* to climate change (which would require to integrate considerations of species exposure to climate change; Foden (2016)).

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

The overarching aims of my thesis are to investigate whether species traits are associated with species land-use responses and species climate-change sensitivity in terrestrial vertebrates, and to highlight some 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 (Kissling *et al.* 2018; Junker *et al.* 2022). 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. Because of data limitation constraints, I am not able to consider intraspecific variation in the data compilation. 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).

At the assemblage level, multivariate trait composition can be summarised with functional diversity indices (Villéger *et al.* 2008; Schleuter *et al.* 2010; Legras *et al.* 2018). Past research has shown that land-use disturbances affect the functional composition of vertebrate assemblages (Flynn *et al.* 2009; Tinoco *et al.* 2018). However, to the best of my knowledge, a global assessment of how the functional diversity of terrestrial vertebrate assemblages respond to land use and land-use intensity, within and across taxonomic classes, has not yet been undertaken. Chapter 3 aims to fill in this gap, by investigating the effects of land use and land-use intensity on the functional diversity of local vertebrate assemblages. To this end, I combine the trait data collected in Chapter 2 with the PREDICTS database. 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. 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 3 highlights the effects of land-use change on the functional composition of vertebrate assemblages, but does not allow to assess the effects of particular traits on species land-use responses, as multidimensional trait variation is summarised into single indices of functional diversity. In Chapter 4, I investigate 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. To the best of my knowledge, Chapter 4 constitutes the first global comparative assessment, among vertebrate classes, of associations between traits and species land-use responses and between traits and species climate-change sensitivity.

Chapter 5 develops our understanding of the impacts of land-use change on ecosystem functioning by focusing on species energetic requirements. First, I 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. Chapter 5 highlights the impacts of land-use change on vertebrate community metabolism.

Finally, inChapter 6, I summarise the findings of my thesis, I highlight some of the limitations and I 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, underlines possible modifications to ecosystem functioning and stresses the role and usefulness of vertebrate trait data and ecological knowledge for understanding species- and community-level 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.

Buchanan, G.M., Butchart, S.H.M., Chandler, G. & Gregory, R.D. (2020). Assessment of national-level progress towards elements of the Aichi Biodiversity Targets. *Ecol. Indic.*, 116, 106497.

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.

Cahill, A.E., Aiello-Lammens, M.E., Caitlin Fisher-Reid, M., Hua, X., Karanewsky, C.J., Ryu, H.Y., *et al.* (2013). How does climate change cause extinction? *Proc. R. Soc. B Biol. Sci.*, 280.

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.

Caro, T., Rowe, Z., Berger, J., Wholey, P. & Dobson, A. (2022). An inconvenient misconception: Climate change is not the principal driver of biodiversity loss. *Conserv. Lett.*, 1–6.

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.

Chen, I.C., Hill, J.K., Ohlemüller, R., Roy, D.B. & Thomas, C.D. (2011). Rapid range shifts of species associated with high levels of climate warming. *Science (80-. ).*, 333, 1024–1026.

Chichorro, F., Juslén, A. & Cardoso, P. (2019). A review of the relation between species traits and extinction risk. *Biol. Conserv.*, 237, 220–229.

Chown, S.L., Hoffmann, A.A., Kristensen, T.N., Angilletta, M.J., Stenseth, N.C. & Pertoldi, C. (2010). Adapting to climate change: A perspective from evolutionary physiology. *Clim. Res.*, 43, 3–15.

Courchamp, F., Jaric, I., Albert, C., Meinard, Y., Ripple, W.J. & Chapron, G. (2018). Loved and ignored to death: the paradoxical extinction of the most charismatic animals. *PLoS Biol.*, 16, e2003997.

Cox, N., Young, B.E., Bowles, P., Fernandez, M., Marin, J., Rapacciuolo, G., *et al.* (2022). A global reptile assessment highlights shared conservation needs of tetrapods. *Nature*.

Crowley, T.J. (2000). Causes of climate change over the past 1000 years. *Science (80-. ).*, 289, 270–277.

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.

Dore, M.H.I. (2005). Climate change and changes in global precipitation patterns: What do we know? *Environ. Int.*, 31, 1167–1181.

Dornelas, M., Gotelli, N.J., Shimadzu, H., Moyes, F., Magurran, A.E. & McGill, B.J. (2019). A balance of winners and losers in the Anthropocene. *Ecol. Lett.*, 22, 847–854.

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., Gauthier, N., Goldewijk, K.K., Bird, R.B., Boivin, N., Díaz, S., *et al.* (2021). People have shaped most of terrestrial nature for at least 12,000 years. *Proc. Natl. Acad. Sci. U. S. A.*, 118, 1–8.

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.

Estrada, A., Morales-Castilla, I., Meireles, C., Caplat, P. & Early, R. (2018). Equipped to cope with climate change: traits associated with range filling across European taxa. *Ecography (Cop.).*

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.

Flynn, D.F.B., Gogol-Prokurat, M., Nogeire, T., Molinari, N., Richers, B.T., Lin, B.B., *et al.* (2009). Loss of functional diversity under land use intensification across multiple taxa. *Ecol. Lett.*, 12, 22–33.

Foden, W. (2016). *Guidelines for assessing species’ vulnerability to climate change*.

Foden, W.B., Butchart, S.H.M., Stuart, S.N., Vié, J.C., Akçakaya, H.R., Angulo, A., *et al.* (2013). Identifying the World’s Most Climate Change Vulnerable Species: A Systematic Trait-Based Assessment of all Birds, Amphibians and Corals. *PLoS One*.

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.

Gonzalez-Suarez, M., Gomez, A. & Revilla, E. (2013). Which intrinsic traits predict vulnerability to extinction depends on the actual threatening processes. *Ecosphere*.

Hevia, V., Martín-López, B., Palomo, S., García-Llorente, M., de Bello, F. & González, J.A. (2017). Trait-based approaches to analyze links between the drivers of change and ecosystem services: Synthesizing existing evidence and future challenges. *Ecol. Evol.*

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.

Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., *et al.* (2005). Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. *Ecol. Monogr.*

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.

Hudson, L.N., Newbold, T., Contu, S., Hill, S.L.L., Lysenko, I., De Palma, A., *et al.* (2014). The PREDICTS database: A global database of how local terrestrial biodiversity responds to human impacts. *Ecol. Evol.*

Hudson, L.N., Newbold, T., Contu, S., Hill, S.L.L., Lysenko, I., De Palma, A., *et al.* (2017). The database of the PREDICTS (Projecting Responses of Ecological Diversity In Changing Terrestrial Systems) project. *Ecol. Evol.*

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.*

Inouye, D.W. (2022). Climate change and phenology. *Wiley Interdiscip. Rev. Clim. Chang.*, 1–17.

Intergovernmental Panel on Climate Change. (2014). Mitigation of Climate Change Summary for Policymakers (SPM). *Cambridge Univ. Press*, 1–30.

IPCC2013. (2013). *CLIMATE CHANGE 2013 Climate Change 2013*. *Researchgate.Net*.

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-. ).*

Junker, R.R., Albrecht, J., Becker, M., Keuth, R., Farwig, N. & Schleuning, M. (2022). Towards an animal economics spectrum for ecosystem research. *Funct. Ecol.*, 1–16.

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.

Kharouba, H.M., Ehrlén, J., Gelman, A., Bolmgren, K., Allen, J.M., Travers, S.E., *et al.* (2018). Global shifts in the phenological synchrony of species interactions over recent decades. *Proc. Natl. Acad. Sci. U. S. A.*, 115, 5211–5216.

Kissling, W.D., Walls, R., Bowser, A., Jones, M.O., Kattge, J., Agosti, D., *et al.* (2018). Towards global data products of Essential Biodiversity Variables on species traits. *Nat. Ecol. Evol.*

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.

Lavorel, S. & Garnier, E. (2002). Predicting changes in community composition and ecosystem functioning from plant traits: Revisiting the Holy Grail. *Funct. Ecol.*

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.

Lebreton, J.D. (2011). The impact of global change on terrestrial vertebrates. *Comptes Rendus - Biol.*, 334, 360–369.

Legras, G., Loiseau, N. & Gaertner, J.C. (2018). Functional richness: Overview of indices and underlying concepts. *Acta Oecologica*.

Lenoir, J. & Svenning, J.C. (2015). Climate-related range shifts - a global multidimensional synthesis and new research directions. *Ecography (Cop.).*, 38, 15–28.

Leung, B., Hargreaves, A.L., Greenberg, D.A., McGill, B., Dornelas, M. & Freeman, R. (2020). Clustered versus catastrophic global vertebrate declines. *Nature*, 588, 267–271.

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.*

Maibach, E., Myers, T. & Leiserowitz, A. (2014). Climate scientists need to set the record straight: There is a scientific consensus that human‐caused climate change is happening. *Earth’s Futur.*, 2, 295–298.

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

Di Marco, M., Pacifici, M., Maiorano, L. & Rondinini, C. (2021). Drivers of change in the realised climatic niche of terrestrial mammals. *Ecography (Cop.).*, 44, 1180–1190.

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.

McGill, B.J., Enquist, B.J., Weiher, E. & Westoby, M. (2006). Rebuilding community ecology from functional traits. *Trends Ecol. Evol.*

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*.

Newbold, T., Scharlemann, J.P.W., Butchart, S.H.M., Sekercioğlu, C.H., Alkemade, R., Booth, H., *et al.* (2013). Ecological traits affect the response of tropical forest bird species to land-use intensity. *Proc. Biol. Sci.*

Oliver, T.H., Heard, M.S., Isaac, N.J.B., Roy, D.B., Procter, D., Eigenbrod, F., *et al.* (2015). Biodiversity and Resilience of Ecosystem Functions. *Trends Ecol. Evol.*

Pacifici, M., Foden, W.B., Visconti, P., Watson, J.E.M., Butchart, S.H.M., Kovacs, K.M., *et al.* (2015). Assessing species vulnerability to climate change. *Nat. Clim. Chang.*

Pacifici, M., Visconti, P., Butchart, S.H.M., Watson, J.E.M., Cassola, F.M. & Rondinini, C. (2017). Species’ traits influenced their response to recent climate change. *Nat. Clim. Chang.*

De Palma, A., Sanchez-Ortiz, K., Martin, P.A., Chadwick, A., Gilbert, G., Bates, A.E., *et al.* (2018). Challenges With Inferring How Land-Use Affects Terrestrial Biodiversity: Study Design, Time, Space and Synthesis. In: *Advances in Ecological Research*.

Pörtner, H.O. & Farrell, A.P. (2008). Physiology and Climate Change. *Science (80-. ).*, 322, 690–692.

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.

Schleuter, D., Daufresne, M., Massol, F. & Argillier, C. (2010). A user’s guide to functional diversity indices. *Ecol. Monogr.*

Schloss, C.A., Nunez, T.A. & Lawler, J.J. (2012). Dispersal will limit ability of mammals to track climate change in the Western Hemisphere. *Proc. Natl. Acad. Sci.*

Seneviratne, S.I., Nicholls, N., Easterling, D., Goodess, C.M., Kanae, S., Kossin, J., *et al.* (2012). Changes in climate extremes and their impacts on the natural physical environment. *Manag. Risks Extrem. Events Disasters to Adv. Clim. Chang. Adapt. Spec. Rep. Intergov. Panel Clim. Chang.*, 9781107025, 109–230.

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.

Spooner, F.E.B., Pearson, R.G. & Freeman, R. (2018). Rapid warming is associated with population decline among terrestrial birds and mammals globally. *Glob. Chang. Biol.*

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.

Thomas, C.D. (2013). The Anthropocene could raise biological diversity. *Nature*, 502, 7.

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

Tinoco, B.A., Santillán, V.E. & Graham, C.H. (2018). Land use change has stronger effects on functional diversity than taxonomic diversity in tropical Andean hummingbirds. *Ecol. Evol.*

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*.

Trenberth, K.E. (2011). Changes in precipitation with climate change. *Clim. Res.*, 47, 123–138.

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

Valipour, M., Bateni, S.M. & Jun, C. (2021). Global surface temperature: A new insight. *Climate*, 9, 1–4.

Verberk, W.C.E.P., van Noordwijk, C.G.E. & Hildrew, A.G. (2013). Delivering on a promise: integrating species traits to transform descriptive community ecology into a predictive science. *Freshw. Sci.*

Villéger, S., Mason, N.W.H. & Mouillot, D. (2008). New multidimensional functional diversity indices for a multifaceted framework in functional ecology. *Ecology*.

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.*

Watson, J. (2016). WORLD VIEW Bring climate change back from the future. *Nature*, 534.

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

WWF. (2020). *Living Planet Report 2020 - Bending the curve of biodiversity loss*. *Wwf*.

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.*