Here, I propose and briefly detail several questions that I could investigate in the future years of my PhD. I prioritise these questions from low to high priority.

1. **How will climate change impact the functional diversity of global terrestrial assemblages? – *Low priority***

Here, I propose to compare the current functional diversity of vertebrate assemblages to the future functional diversity based on projections of future species ranges (given a scenario for future climate change). Barbet-Massin (2015) conducted such an analysis on avian communities. Nevertheless, to my knowledge, there has been no study looking at the future functional diversity of mammalian and herptilian assemblages, or all vertebrate classes together.

Current community composition will be assessed using a spatial approach where the intersection between species ranges will determine assemblage composition in each grid cell. Using species distribution modelling techniques, based on the correlation between species current ranges and climatic variables, I propose to predict species future distributions for a given scenario of CO2 emissions, from which future community composition will be determined. Various indices of functional diversity will then be calculated for the community in each grid cell, for both present and future communities. The difference in functional diversity between current and future projections (ΔFD) will then be assessed.

I will then determine whether climate change is likely to have profound impacts on the functional diversity of local vertebrate assemblages by looking at the strength and directionality of ΔFD. I will assess whether effects are uniform across space and whether certain areas stand out as being particularly sensitive to future climate change.

1. **Which traits render species more sensitive to land-use and climate change?**

In Chapter 4, I used functional indices, which enabled to consider multiple traits at the same time to assess the trait composition of ecological communities. Although land-use change was shown to significantly alter the functional diversity of local vertebrate communities, the analyses did not allow to understand which trait conferred species with increased sensitivity to land-use change. Similarly, the first question proposed here (e.g. *How will climate change impact the functional diversity of global terrestrial assemblages?*) will not allow to test whether certain traits explain species sensitivity to climate change.

Here, I propose to investigate whether species traits render them more sensitive to land-use and climate change. This question has, to my knowledge, never been tackled at global scales comparatively across all terrestrial vertebrates. I propose two separate analyses for each pressure. Results will allow to assess whether similar traits are likely to put species at greater risk from both land-use and climate change, or whether response traits to land-use and to climate change do not overlap. Assessing whether the same set of traits is likely to render species more sensitive to both pressures is important to forecast possible interactive effects.

Contrary to the previous analyses using functional diversity indices -- where trait composition was summarised into diverse metrics which were then used as dependent variables in diverse models --, traits will be used as explanatory variables.

**Land-use change – *High priority***

Some work has been conducted on tropical forest birds (Newbold et al. (2013) showed that long-lived, large, non-migratory specialist birds were more sensitive to land-use change). Nevertheless, there is to date no global comparative analyses across the four terrestrial vertebrate classes.

I aim to assess the individual effects of traits on species’ sensitivity to land-use using the PREDICTS database. The analyses I propose here are similar to analyses developed in Newbold et al. (2013). Specifically, I propose to explain species occurrence probability, and given presence, species abundance in each land-uses with species traits. The generic mixed-effect models will be written as: Species occurrence (or abundance) ~ Land-use + Traits + RE, where RE is the set of random effects to be included in the model (e.g. study identity). Using model selection approaches, I propose to select the best set of traits that explain species presence or species abundances. Then, the analyses of estimated parameters for each trait would indicate the directionality of the effects (and whether effects or consistent across Classes).

**Climate change**

I propose several approaches to investigate which traits are likely to influence species responses to climate change. Past studies have used range filling limitations (Estrada et al., 2016, 2018), historic population trends or distributions (Angert et al. 2011, Pacifici et al. 2017, Mccain and King 2014) or simulation approaches (Schloss et al. 2012, Pearson et al. 2014) to assess whether certain traits rendered species more sensitive to climate change. Nevertheless, there has been no global study investigating this question across all terrestrial vertebrates.

* **Climatic niche approach *– High priority; possible collaboration with Jess?***

Here, I propose to use species climatic tolerances as a proxy for species sensitivity to future climate change: species with broader climatic tolerances will be assumed to be less sensitive to future changes. I will assess whether species traits explain species climatic tolerances using mixed-effect models.

Climatic tolerances will be calculated from species geographical distributions, derived from extent of occurrence range maps. For a species, climatic tolerances will be measured as the breadth of climatic space covered by the distribution of the species. Climate variables could include temperature, precipitation, water availability for example. The climatic tolerance of a species with regards to each variable could be assessed using the range or upper or lower limit of the variable. A multivariate metric summarising a species climatic tolerance with regards to all variables could also be used: on a multivariate climatic space, the climatic conditions experienced in each grid cell where the species occurs could be plotted. The species climatic breadth could then be assessed as the volume of the convex hull that includes all points plotted on the space.

* **Range filling approach – *Moderate priority***

In this second approach, I propose to investigate whether species traits explain species range filling (Estrada et al. 2016). The range filling of a species is the extent to which the species occupies the area that is climatically suitable. Estrada et al. (2016) suggests that range filling can be used as a proxy for species’ abilities to shift their range under climate change. Indeed, several factors could explain that species do not occupy all climatically suitable areas: these non-climatic range limitations include, for example, geographical barriers, biotic interactions, edaphic conditions, and life-history traits.

The degree to which life-history traits explain range limitations could inform on species’ ability to track climate change, hence on their sensitivity to the threat. Estrada et al. (2017) conducted an analysis of range filling on European birds, mammals and plants, finding that traits related to establishment and proliferation had a significant effect on mammalian and avian range filling. To my knowledge, no similar study has been conducted at global scales. Using this approach, I propose to investigate whether vertebrate species traits explain species range filling.

* **Population trends approach – *Moderate priority***

Here, I propose to use historic data on population trends to assess whether both recent climate change and life-history traits explain variation in population trends. The BioTIME dataset (Dornellas, 2018) contains abundance records for many species, including vertebrates, in the form of time series with a minimal span of one year, allowing for global analyses of historic trends.

Historic trend data has been used in previous studies to identify traits that correlated with species declines due to climate change (Pacifici et al. 2017, Mccain and King 2014). Nevertheless, to my knowledge, no study has attempted to consider all terrestrial vertebrates simultaneously.

One complication when looking at historic climate change is that potential confounding effects could have been shaping species responses (importantly, land-use change). Spooner et al (2018) analysed global historic avian and mammalian population trends using, amongst other, rates of climatic warming, rates of land-use conversion and body mass as explanatory variables. They detected no significant effect of body mass on average rates of population change. Nevertheless, their study did not isolate the potential effects of body mass on species response to climate change alone.

I propose to isolate areas where climate change was known to have been the main driver of population changes. For these areas, the degree to which species traits explain rates of population change could then be assessed.

1. **Will land-use and climate change disrupt important ecosystem functions sustained by terrestrial vertebrates? – *High priority; possible collaboration with Joe?***

The aim of this part will be to assess whether land-use and climate change are likely to disrupt important ecosystem functions sustained by terrestrial vertebrates. Functional diversity indices calculated in the previous Chapters are unlikely to correlate with specific ecosystem functions, and as such should not be used as proxies for ecosystem functioning. Current knowledge of how land-use and climate change is likely to impact ecosystem processes sustained by vertebrates remains limited at global scales.

Using literature searches, I propose to identify vertebrate species that contribute to important ecosystem functions, such as pollination, seed dispersal or nutrient cycling (for instance, scavenging species). I will then assess whether species in each functional group are likely to be disproportionally sensitive to land-use or climate change. Ultimately, the aim is to predict how species in each functional group are likely to respond to land-use and climate change. The likelihood of maintenance or endangerment of ecosystem processes will be inferred from these future projections.

To that end, I will determine the trait composition of each functional group. I will use results obtained in the previous chapters to build predictive models of how species in each group will respond to future land-use and climate change.

**Proposed provisional planning:**

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|  | **2019** | | **2020** | | | | **2021** | | | | **2022** | |
| Developments and finalisation of Chapters 3 & 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| Analyses: sensitivity to land-use change |  |  |  |  |  |  |  |  |  |  |  |  |
| Analyses: sensitivity to climate change |  |  |  |  |  |  |  |  |  |  |  |  |
| Analyses: future projections, ecosystem functioning |  |  |  |  |  |  |  |  |  |  |  |  |
| Thesis writing and finalisation |  |  |  |  |  |  |  |  |  |  |  |  |