

How is accessibility to cities influencing biodiversity change?

Introduction

Globally, humans have modified 50% of terrestrial land cover, leading to major pressures on the biosphere and its inhabitants (IPBES, 2020). Increasing human population and the growth of cities and road networks, which predicate the equity agenda of the UN by advancing accessibility (UN, 2015), are expected to cause additional impacts on the natural environment. Urbanisation and roads have greatly altered habitats and connectivity of those, leading to disturbances in ecological communities (Mckinney, 2006). Abundance, richness and composition of ecological communities are changing globally in complex ways (Dornelas *et al.*, 2014, 2019; Blowes *et al.*, 2019; Eriksson and Hillebrand, 2019; Magurran *et al.*, 2019). Current rates of changes of ecological communities are beyond what ecological theory predicts (Gotelli *et al.*, 2017). The consequences for ecosystem processes, such as their temporal and spatial resilience are not fully understood. Understanding drivers of global biodiversity change to establish effective conservation programs without compromising human development towards better equality, is a key topic on the agenda of decision makers all over the world. We currently only have a limited understanding of how accessibility to cities, such as the presence of cities and roads, as a global change driver, is altering the assemblages of communities.

Given the sheer extent of human impact on the natural environment, it is common convention that biodiversity is declining on a large scale. However, studies reveal a more complex picture that is very dependent on the scales and biodiversity metrics used (McGill *et al.*, 2015; Chase *et al.*, 2019). While local alpha diversity seems to show no decrease in species richness, global biodiversity seems to decline (Butchart *et al.*, 2010; Dornelas *et al.*, 2014). At the same time, local communities show high species turnover (changes in the composition of ecological communities), potentially indicating a different type of biodiversity change; large scale reorganization of communities leading to homogenization across space (Blowes *et al.*, 2019). This homogeneity leads to a decrease in biodiversity over larger scales and has serious implications on the ability of species communities to adapt to future environmental changes (Eriksson and Hillebrand, 2019).

Changes to the environment caused by the increase in accessibility, such as cities and roads, might lead to a different species filter which favour more similar species across scales. Local immigration of species can be enhanced by both changing environmental conditions and favouring species that prefer urban environments as well as through transportation and human traffic such as trade roads have led to homogenization (Mckinney, 2006). So far, research

have focussed on more direct drivers of biodiversity change, like land use conversion (Daskalova *et al.*, 2019), whereas this paper will focus on a more indirect potential driver as is accessibility.

Objectives and research questions

I will investigate the influence of accessibility of cities on compositional biodiversity changes globally. Recent global scale datasets of roads and accessibility to cities provide a new opportunity to measure this aspect of human development at a global scale. By integrating the accessibility dataset with 181 biodiversity records, my analysis provides unprecedented insight into the influence of accessibility to cities as a potential global change driver of biodiversity change.

I will address the following research questions:

1. Within sites, do locations with higher accessibility to cities experience more changes in community composition than locations with lower accessibility (temporal turnover)?
2. Across sites, do locations with higher accessibility to cities have more similar community composition than locations with lower accessibility (spatial turnover)?
3. How does each taxon respond to high/low accessibility?
4. How are spatial and temporal turnover influenced by an interaction between population density and accessibility?

Research hypotheses

My hypotheses are that there will be a positive relationship between high accessibility scores and temporal and spatial turnover and between population density and temporal and spatial turnover. When analysing taxa's responses, I hypothesize that taxa will have different relationships with accessibility scores and population density, with both positive and negative interactions present. Those hypotheses will be tested against the null hypotheses of no relationship between accessibility and temporal and spatial turnover and population density and temporal and spatial turnover, respectively.

Predictions

I predict that globally, areas with high accessibility will display higher temporal and spatial turnover than areas with lower accessibility, as human disturbances and connections such as roads tend to select similar winners (Blowes *et al.*, 2019). Based on differences in ecological characteristics among the taxa analysed, I predict that they will respond to accessibility individually. I predict that with the interaction of accessibility and population density, temporal and spatial turnover will be catalysed.

If the results agree with my null hypotheses, this will indicate that accessibility is not a global driver temporal and/or spatial turnover, thus other global drivers need to be identified and analysed. If the results support my alternative hypothesis, this will reinforce the need to better incorporate species conservation aspects in the extension of cities and roads as a human development goal.

Methods

In my analysis I ask how the magnitude of accessibility to cities influences the temporal and spatial changes of ecological communities. I assess variation in rates of turnover across amphibians, birds, mammals, reptiles, invertebrates and plants. To quantitatively test the ecological consequences of accessibility to cities, I will use three global databases.

Databases

Accessibility to cities 2015 data

I will derive accessibility to cities scores for the nominal year 2015 for ~ 100km² cells (matching the grid cells of the BioTIME database) around the location of each population in the BioTIME database from the Accessibility to Cities 2015 (Weiss *et al.*, 2018) database using the Google Earth Engine. This database calculates least-cost-path land-based travel time to the nearest densely populated area (between 85 degrees north and 60 degrees south) at a 30 arc seconds X and Y resolution. Areas with >1,500 inhabitants/km² or a majority of built-up land cover types coincident with a population centre of at least 50,000 inhabitants are defined as densely populated areas. I will bound the scores extracted between zero and one, where zero is not accessible and one is very accessible.

BioTIME Database – biodiversity time series data

I will use data from the currently largest (and open-source) database of community assemblage time series, BioTIME data base (Dornelas *et al.*, 2018). These data include 181 different studies, with records of abundance, number and identity of species. To calculate turnover, I will only include data with two or more datapoints between the years 2005-2015.

I will quantify temporal changes in community composition within sites, as the turnover component of beta diversity (species replacement rather than abundance) at the last data point available relative to the first observation data point within the time period outlined above. I will bound the scores of turnovers between zero and one, where zero is no change in community composition and one indicates that all of the original species have been replaced.

From the community composition over time model, I will extract the means for temporal turnover for each time series, which will then become the response variable in the following stage of my analysis where I will test temporal turnover against accessibility.

I will quantify changes in community composition among sites (spatial turnover) by doing pairwise comparisons of dissimilarity scores. Similarly, to the temporal turnover, I will then use the scores extracted as response variable in the following stage of my analysis where I will test spatial turnover against accessibility.

Population density dataset

I will derive population density data from the Gridded Population of the World, Version 4: Population Density, Revision 11 database (CIESIN, 2018). Human population density was defined as number of persons per square kilometre, based on national censuses counts and population registers. Data is available for the years 2000, 2005, 2010, 2015, 2020 at a 30 arc-second resolution.

Statistical analysis

All statistical analysis will be conducted in R version 3.6.1. All models will be fitted in a Bayesian framework using linear mixed effect models.

I will model temporal turnover as the response variable. Accessibility, latitude and duration of observation will be included as fixed effects. The random term in my model will be biome.

I will apply the same model approach for spatial turnover.

When analysing the taxa-specific response to accessibility, I will include taxa and the interaction of accessibility:taxa as a fixed effect.

When analysing the interaction between population density and accessibility on temporal and spatial turnover, I will include an interaction term of accessibility:population density as a fixed effect.

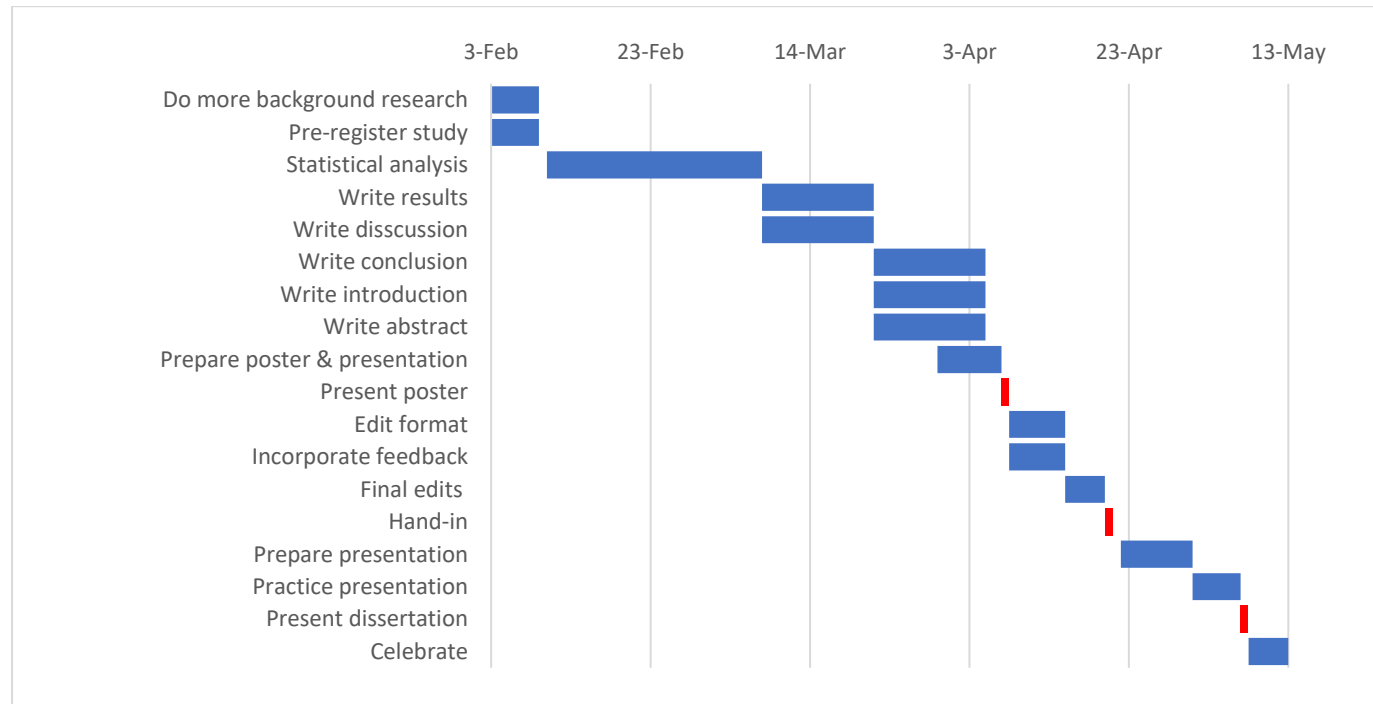
Risk mitigation

My dissertation depends on data from the BioTIME database, which I have only explored superficially so far. There is the risk that I won't have the data I need to do my planned research. I will try to overcome that by doing data exploration as the next step and trying to stay flexible in my approaches to answer the research questions I set out.

As this dissertation is based on computer only, I will mitigate the risk of data loss (eg by computer damage) by using GitHub. This allows me to store all my files and code online and gives me the flexibility to work from any device.

Proposed timetable of activities

Given the upcoming presentation at the Scottish Ecology, Environment and Conservation Conference on 7th and 8th of April, I am planning to have the first draft done by then. This will leave me sufficient time to fine tune and edit the dissertation afterwards.



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