

Geographical variations in the sensitivity of terrestrial biodiversity to anthropogenic pressures

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14 **Declaration**

15 Was the data provided to you or did you collect or assemble it?

16 Were you responsible for data processing or cleaning, if required?

17 Were any mathematical models developed by you or by your supervisor?

18 What role, if any, did your supervisor play in developing the analyses presented?

19 Introduction

20 Biodiversity is important because it supports life on earth via the ecosystem services provided. When
21 ecosystems have their biodiversity intact, they can provide services such as clean air and pollination,
22 which makes the earth habitable for humans. Biodiversity loss leads to unstable environments, as
23 ecosystems with low biodiversity are less resistant to change. Biodiversity loss diminishes ecosystem
24 productivity [?] and threatens human well-being [?].

25
26 Biodiversity is impacted by both natural and anthropogenic pressures [?], however any mention
27 of 'biodiversity pressures' in this study refers only to the latter. Understanding the impacts of anthro-
28 pogenic pressures on biodiversity is important for creating accurate policies and conservation strate-
29 gies. Accurate information about biodiversity pressures can produce more effective conservation
30 strategies, and better informed decisions can be made, including biodiversity-conscious investments.
31 One of many responses to the biodiversity crisis [?] is the beginning of a global movement towards
32 sustainable business and biodiversity-conscious investment [?][?][?].

33
34 Assessing the impact that investments have on biodiversity involves calculating the magnitude of
35 association they have with each biodiversity pressure. Information is often available on the geography
36 of a company's activities, such as where they base their factories or where they source their materials
37 from. In the interest of making estimates about each company's biodiversity impact more accurate,
38 the location of each company's biodiversity-related activities could be considered. If the location and
39 magnitude of a biodiversity pressure is provided (by the company), then information about current
40 local biodiversity and sensitivity of the biome to the pressure, accurate predictions could be made
41 about how biodiversity-friendly such an investment would be.

42
43 Given that anthropogenic impact on the environment is worldwide [?], the question should be
44 raised of whether the geographic location of biodiversity pressures affects their impact on global bio-
45 diversity. In other words, are some parts of the world more sensitive to biodiversity pressures than
46 others? For example, does the location that a biodiversity pressure takes place change its impact on
47 global biodiversity (regardless of magnitude)? If such geographic differences exist, they should be
48 taken into account when attributing biodiversity-related merit to investments. Better understanding
49 of biodiversity pressures will aid a better understanding of the implications of investments on natural
50 ecosystems .

51

Literature Review

Literature is abundant on how biodiversity varies by country reference, and why this may be, including how various direct and indirect pressures correlate with these differences [?], [?] melusine's paper. Various studies have mapped the magnitude of biodiversity pressures across regions/biomes [?] [?], and their spatial couplings [?], however to our knowledge, no prior research has studied geographic differences in sensitivity to such pressures. Bowler et al.(2020) concluded that despite any patterns observed in magnitude of pressures, there will always be variation in biodiversity response to such pressures due to species' varying sensitivities. Research about species-specific sensitivities in each ecosystem is useful for local conservation policy however it would be more useful for large scale projects/policies to have information about the sensitivity of regions/biomes on the whole. The current assumption in literature is that whilst magnitude of exposure varies, sensitivity to biodiversity pressures is constant across biomes [?], however there is no research to support this assumption. Hence, studying variation in biome sensitivity would be useful in comparing the impact of pressures in these areas on global biodiversity.

There is adequate research to prove that inter-species responses to biodiversity pressures vary find reference. Given that species vary in their sensitivity, and therefore response, to biodiversity pressures, and that each region of the world comprises different combinations of species groups find reference, there is reason to believe that sensitivity to biodiversity pressure could vary depending on region.

One of the papers which studied sensitivity of species to environmental pressures [?], developed a set of sensitivity scores for European species, determining which species will benefit from, be indifferent to, or be negatively affected by environmental change. This 'Bioscore' study used such sensitivity scores to create a tool for predicting the effect of a policy change on Europe's biodiversity. The proportion of affected species in each region was used to map the effects of a change in each biodiversity pressure. The sensitivity scores for each species were obtained from published literature about individual species' responses to change in different environmental variables. The BioScore tool suggests that even if the magnitude of a biodiversity pressure is constant across Europe, biodiversity's response can still vary according to country, due to varying sensitivity of the species within such country. This study is a predictive tool based on published studies about individual species, and a wider-breadth study is necessary to observe worldwide variances in countries sensitivities to biodiversity pressures. The BioScore tool's predictions support the concept that country-wide differences in sensitivity could exist.

A wider spectrum study examined sensitivity to environmental change at a broader level, and found variation between taxa [?]. This between-taxa variation further supports the concept that sensitivity to biodiversity pressures could vary between countries, and the authors emphasise that their findings suggest that sensitivity to environmental change should not be assumed to be constant across taxa, as is currently common. This supports the idea that researching differences between countries' sensitivity, could contribute to more accurate predictions of how biodiversity pressures impact biodiversity.

Studies show impacts of socioeconomic status and cultural impacts on biodiversity [?]. This gives reason to believe that pressures impacting biodiversity loss could have varying impacts based on their location. This research aims to investigate whether the location of a pressure affects its' level of impact on biodiversity.

Methods

Data

The focus of this study is on anthropogenic biodiversity pressures only. Anthropogenic pressures on biodiversity are typically grouped, in the current literature, into 5 main pressures; climate change, land use change, pollution, invasive species and overexploitation. In order to assess whether sensitivity to each pressure varies by country, data was needed in the form of time series (how each of these pressures had been changing in each country over time, as well as how each country's biodiversity had been changing over time). The time series of biodiversity in a country was compared to the time series of a pressure on biodiversity in that country, in order to extract a 'sensitivity score' for each country to assess any effect of geography.

The variable chosen to represent biodiversity was biodiversity intactness. The National History Museum's (NHM) Biodiversity Intactness Index (BII) was chosen as it presents biodiversity in the context of how many original species remain (relative to reference populations). The NHM's Index is the best for this project as the database used is that of the PREDICTS project, which more geographically representative than other datasets [?]. This allows for direct comparison of these changes, with the changes in anthropogenic pressures. Historical BII data spanned 1970 - 2014.

Time series data for climate change was obtained in the form of annual average temperature for each country. The temperature dataset chosen was from the World Bank's Climate Change Knowledge Portal. This dataset was chosen because it contains comprehensive historical data, providing an annual average temperature for every year from 1900 until 2020.

To represent land use change, the dataset used was The Global Human Settlement Layer data package [?]. The data contains information on built-up area change over time, which is the variable chosen to represent land use change. Collective land use change is difficult to quantify from land use statistics. Although satellite data is available to categorise land cover type over time, calculating annual land use change from the proportion of each land cover type is not necessarily accurate, as land use change can be multi-directional. Current studies assessing the impact of land use change on biodiversity are often meta-analyses or use a natural regional situation as the reference land type [?] as opposed to observing direct impacts of land use change. Statistics

With the focus being on terrestrial biodiversity, greenhouse gases (GHG) were used as the representative variable for 'pollution' as a biodiversity pressure. The dataset used to access GHG emissions for each country over time was the 'National Inventory Submissions' section of the United Nations - Climate Change website [?]. GHG emissions are presented both including and excluding 'Land Use, Land-Use Change and Forestry (LULUCF)' related emissions data. When assessing

137 pollution and biodiversity links in isolation, LULUCF was included. However, when modelling all bio-
138 diversity pressures together, LULUCF was tested for collinearity with the land use change variable,
139 and consequently included/excluded.

140
141 The OECD.stat website was used to download the land use change and pollution data.

142

143 **Individual Pressures**

144 For each biodiversity pressure, a linear model was created for each country using time series of bio-
145 diversity data and the corresponding pressure's time series. For each country in which the pressure
146 was found to have a significant effect on biodiversity ($p < 0.05$), the sensitivity score was noted, repre-
147 senting such country's 'sensitivity' to this particular biodiversity pressure.

148

149 First, each pressure's geographic relationship with biodiversity was assessed in isolation. It is
150 important to look at individual biodiversity pressures, as opposed to an aggregated pressure on bio-
151 diversity, because the pressures have spatial differences [?], meaning the geographical magnitude of
152 each pressure varies. Therefore in order to understand how countries differ in their responses to bio-
153 diversity pressures, it must be taken into account the magnitude of each pressure that each country
154 experiences.

155

156 Each data set has data from a different combination of years, and countries. For each pressure
157 being investigated, only data from years and countries that are shared between that particular dataset
158 and the biodiversity dataset is included.

159

160 For each pressure, the datasets were wrangled and refined to obtain two time series (at an annual
161 level) for each country; biodiversity and the magnitude of the particular pressure.

162 old method For each country, a linear model was fit with biodiversity as the response variable, and
163 the biodiversity pressure (e.g. pollution) as the explanatory variable. For those countries where the
164 gradient was found to be statistically significant ($p < 0.05$), the gradient was recorded as a 'sensitivity
165 score'. This sensitivity score is representative of the sensitivity of that country's biodiversity, to the
166 particular biodiversity pressure (e.g., sensitivity of Spain's biodiversity to one unit of pollution)

167

168 old method Sensitivity scores were then used to visualise the differences between countries. (I
169 could insert a map with a colour scale representing the sensitivity score values from different coun-
170 tries)

171

172 new method. The data for all countries was pooled into one dataset, and a column added for
173 continent. Because assessing differences in each country would remove too many degrees of free-
174 dom, differences between the sensitivities of continents were assessed. A multiple linear model was
175 created for each pressure. Continent was coded as a factor, in order for R to treat it as a dummy
176 variable. The alphabetically first continent acting as the reference variable (usually Africa), in order
177 to avoid multicollinearity. So that the slopes of each continent could be compared, interactions were
178 also added between continent and the climate

180 **Results**

181 **Individual Pressures**

182 **Multi-Pressure Model**

184 **Conclusion**

185 optional section

186 **Data and Code Availability**

187 Data and Code Availability statement: At the end of your Main text, before the References section, you
188 must provide a statement titled “Data and Code Availability”, where you name a data (e.g., Dropbox,
189 FigShare, Zenodo, etc) and a code (e.g., Dropbox, GitHub, etc.) archive 20from where the data and
190 code can be obtained that will allow replication of your results. The code may be in the form of a
191 single script file.