

Impacts of global warming, habitat loss, and homogenization on global biodiversity

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ABSTRACT

Background: Rosenzweig and colleagues (2013) utilized a species–area approach to examine the impacts of anthropogenic habitat loss and loss of geographic barriers on the future of global terrestrial vertebrate biodiversity. Their study included temperature, but with variation over space and not time. Patterns in the fossil record indicate that global biodiversity tended to track global temperature changes, with higher diversity associated with higher temperatures.

Goal: Examine the added impact of global warming on biodiversity.

Method: Use a range of predicted temperature increases based on estimates from the National Research Council (NRC, 2010).

Results: Global warming (especially at higher levels) may, over evolutionary time scales, mitigate the biodiversity losses caused by other impacts of human activity, such as loss of habitat and geographic barriers.

Keywords: biodiversity, global warming, habitat loss, homogenization.

INTRODUCTION

Predicting future human impacts on global biodiversity is clearly one of the most important tasks facing biologists in the modern era (Wilson, 2002). This is obviously a very difficult task owing to many uncertainties, including that many of the most threatened species are poorly known and are yet to be described (Pimm *et al.*, 2014). Nevertheless, the urgency of this effort requires that current and future extinction estimates be made. Methods used to make such estimates have included the use of known geographic ranges (Pimm *et al.*, 2014) as well as information from IUCN Red List criteria including rates of population decline (Keith *et al.*, 2014).

Recently, Rosenzweig and colleagues (2013) utilized a species–area approach to examine the future status of global terrestrial vertebrate biodiversity. Specifically, they predicted the impacts of the loss of geographic barriers (New Pangaea) and the cumulative effects of accelerating habitat loss on species and genus diversity. The results are striking, if perhaps not too surprising: the loss of geographic barriers alone could decrease the number of

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terrestrial vertebrate species and genera by roughly half. If the impact of habitat loss is added, then species and generic numbers will decline well below 50%, perhaps precipitously so depending on how much habitat is lost. Here I want to explore a third global human impact, global warming, on global biodiversity. The method used by Rosenzweig *et al.* (2013) improved upon typical species–area approaches by incorporating the additional variables of mean annual evapotranspiration (as a proxy for plant productivity) and mean annual temperature. While their estimates held mean global temperature as a constant, it seems worth exploring what happens to future biodiversity if mean global temperature is increased under various scenarios predicted by most climate models. This will produce a prediction of future biodiversity that includes all three anthropogenic global impacts that are often listed as major threats (Murray *et al.*, 2014): loss of geographic barriers (species introductions), habitat loss, and climate change.

METHODS

Rosenzweig *et al.* (2013) used data sets of global terrestrial vertebrates (reptiles, amphibians, mammals, and birds) from the World Wildlife Fund. Least-squares regressions with mean global temperature revealed the following relationship for global terrestrial vertebrate species (S) and genera (G):

$$\log S = -1.50 + 0.631 \log A + 0.033 T$$

$$\log G = -0.97 + 0.488 \log A + 0.025 T$$

where A is global area and T is mean global temperature.

For their results, Rosenzweig *et al.* (2013) used $T = 14.2782^\circ\text{C}$ (the current terrestrial average temperature). To estimate the effects of increasing global temperature, I used estimates from the National Research Council (NRC, 2010) that summarized a range of possible change scenarios. These predicted that average global temperature increase will be in the range of 2–11°F. Converting to Celsius, this increases T in the above equation from 14.2782°C to a minimum of 15.3891°C and a maximum of 20.3890°C . These are obviously very broad and rough estimates but they provide a way of looking at the potential synergistic impacts of climate change on the other human impacts of local habitat loss and loss of geographic barriers.

RESULTS

For species, global warming may reduce the number of taxa lost from the combined effects of habitat homogenization and habitat loss (Fig. 1). This reduction is markedly greater for the higher-temperature scenario of warming. The reduction is much more pronounced at low levels of habitat loss and becomes less pronounced with increasing habitat loss.

Figure 2 shows a similar pattern for genera, with far fewer losses for the high-temperature scenario. A direct comparison of species and genera indicates that species losses are particularly mitigated by high global temperature at lower levels of habitat loss (Fig. 3).

DISCUSSION

These results imply that global warming could buffer biodiversity against the effects of increasing habitat loss, habitat homogenization, and species introductions. This conforms to

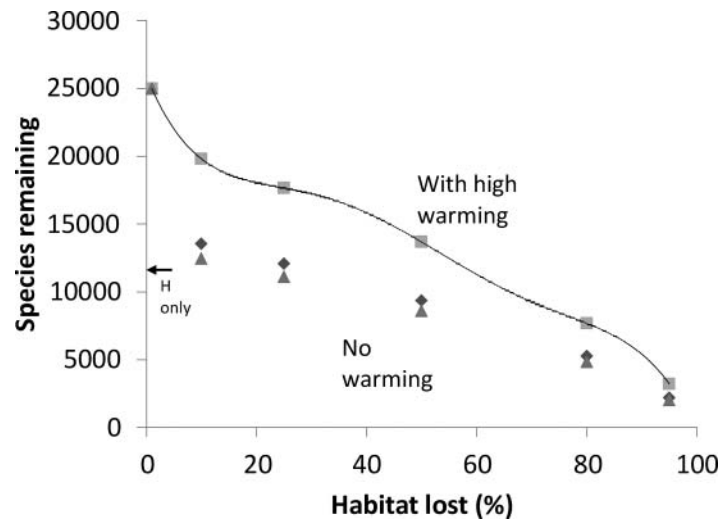


Fig. 1. The combined effects of habitat loss, habitat homogenization, and climate change on estimates of standing species diversity of terrestrial vertebrates. Triangles = no global warming; diamonds = minimal projected warming (2°F); squares = maximal projected warming (11°F). Line for maximal warming is best-fit polynomial (fifth-order) for visual comparison only. H-only arrow refers to species diversity predicted from global homogenization (New Pangaea) with no impacts from habitat loss and temperature change.

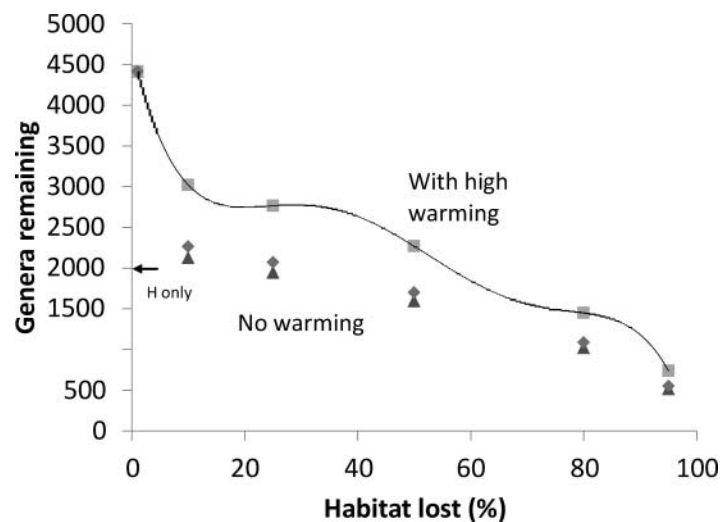


Fig. 2. The combined effects of habitat loss, habitat homogenization, and climate change on estimates of standing genus diversity of terrestrial vertebrates. Triangles = no global warming; diamonds = minimal projected warming (2°F); squares = maximal projected warming (11°F). Line for maximal warming is best-fit polynomial (fifth-order) for visual comparison only. H-only arrow refers to genus diversity predicted from global homogenization (New Pangaea) with no impacts from habitat loss and temperature change.

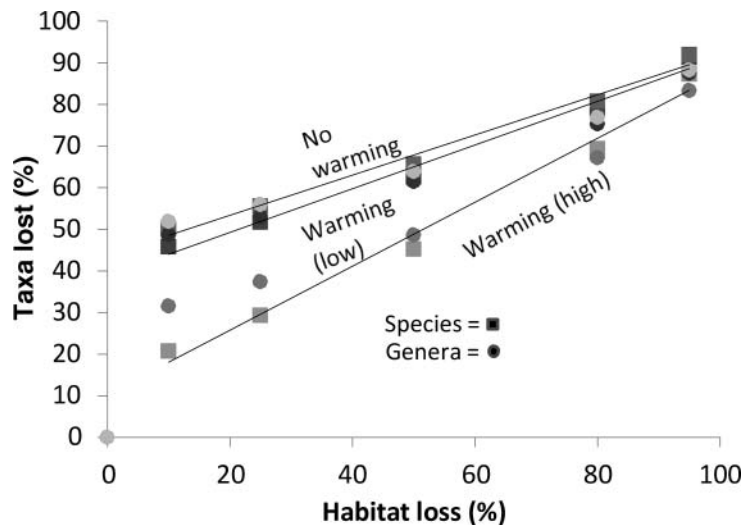


Fig. 3. The combined effects of habitat loss, homogenization, and climate change on species and genus losses. Regression line is for species data points (squares) and is for visual comparison and not rigorous statistical interpretation.

the well-documented global pattern whereby biodiversity decreases with latitude, and the positive relationship between warmer climate regimes and greater numbers of species (Willig *et al.*, 2003; Krug *et al.*, 2009). Thus, from a very coarse mechanistic view, the predicted buffering described here might be seen as a consequence of the expansion of warmer (e.g. tropical and subtropical) and therefore generally more speciose habitats towards the poles. For example, emerging evidence indicates that geographic migrations from climate changes are widespread (Root *et al.*, 2003), although the process is more than a simple poleward migration, involving instead a shifting mosaic of geographic range alterations and phenology changes (Burrows *et al.*, 2011).

Perhaps most relevant and supportive of these findings is the fossil evidence showing that global biodiversity over geological time has tended to increase or decrease in accordance with increases or decreases in global temperature (Mayhew *et al.*, 2012). This pattern concurs with the results herein. This does, however, raise the crucial dimension of time scale. The positive association between global temperature and biodiversity includes speciation events and long-term evolutionary adaptations to a warmer planet. The rapid acceleration of anthropogenic climate change is obviously much greater than typical geological changes. The likely outcome is that, in the short term, global warming will lead to a net decrease in biodiversity (Thomas and Williamson, 2012), with evolutionary recovery and an increase in biodiversity a long-term process.

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