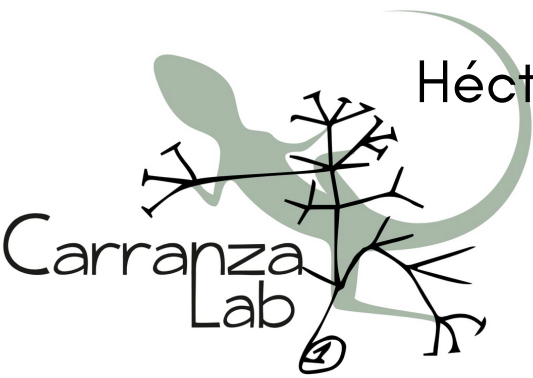# LIZARD DIVERSITY IN EARTH'S DESERTS

What are (not) the causes of the dramatic richness differences between deserts?

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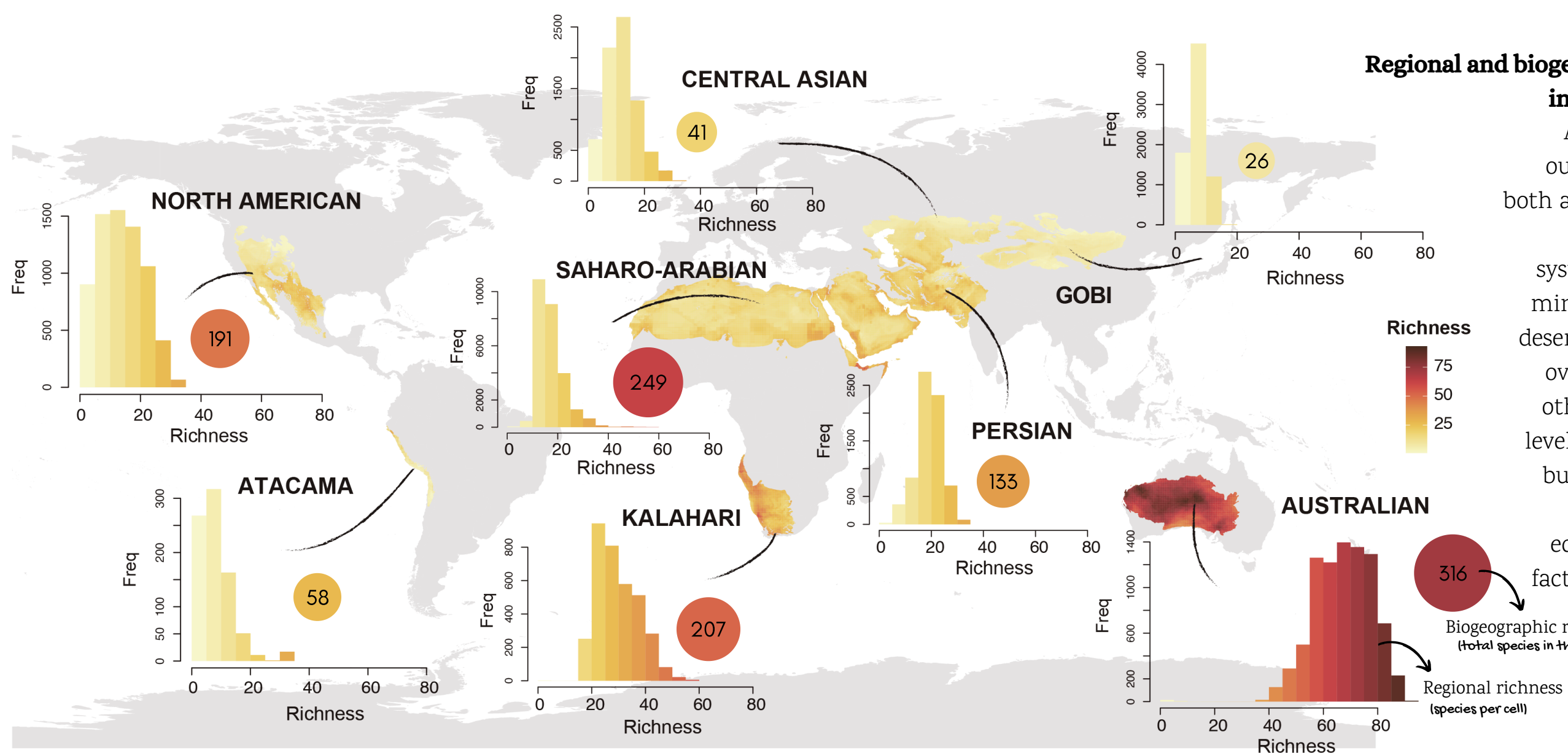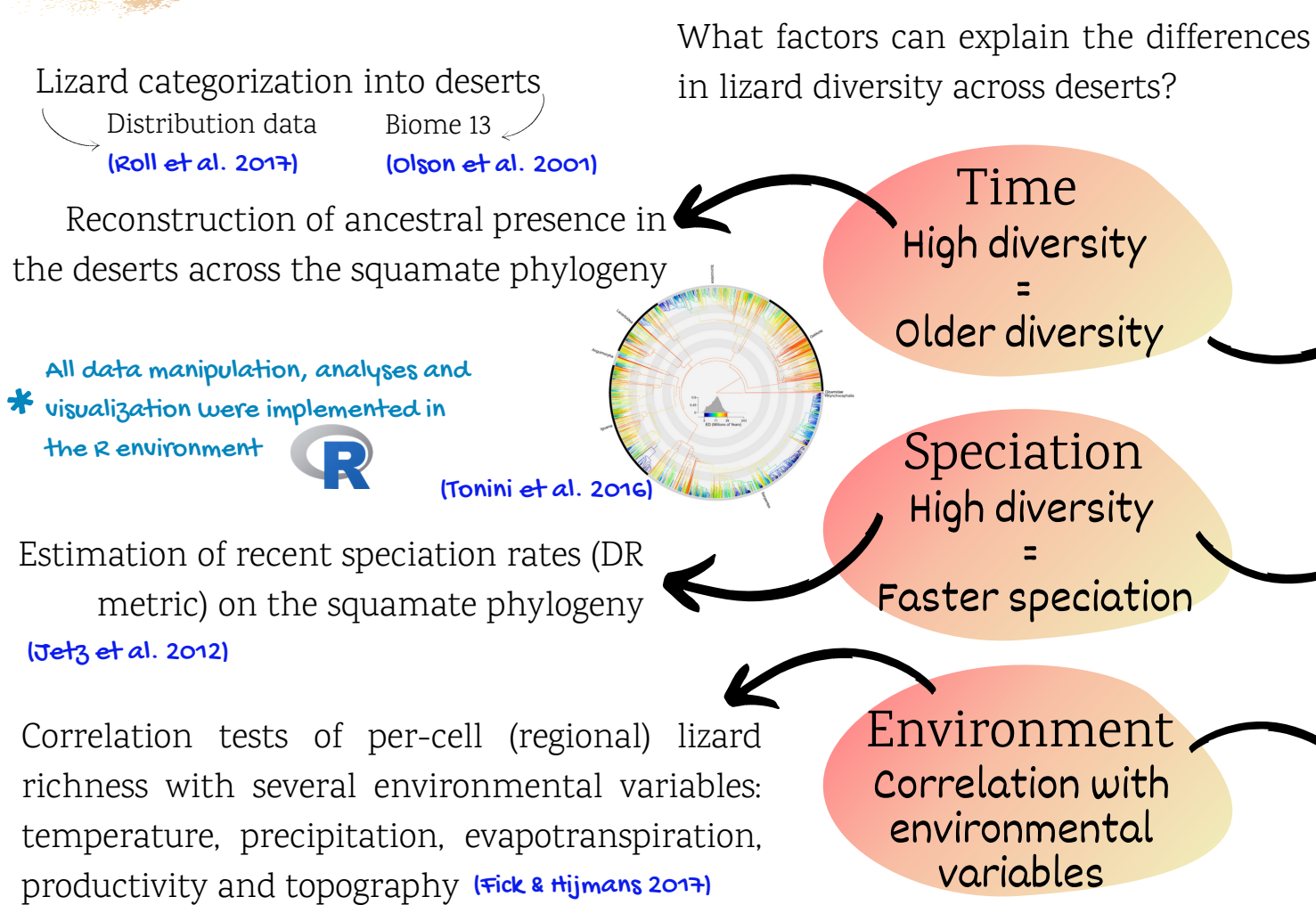
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INTRODUCTION

Biodiversity is not uniformly distributed across the Earth, even between geographic areas under similar environmental conditions. Multiple ecological and evolutionary factors interplay influencing the assembly of regional species pools through their effects on dispersal, speciation and extinction, but there is no general consensus on their relative importance. High species diversity can result from the relatively long and undisturbed history of a region and its lineages (evolutionary time hypothesis). Accelerated diversification (high speciation / low extinction rates) might also explain high species richness. Environmental conditions (e.g., climate, topography) can further influence diversity through impacts on primary productivity, resource availability or diversification.

Ecological systems physiographically similar but geographically distinct (e.g., Earth's arid regions) allow for the exploration of the factors shaping diversity patterns. Lizard diversity in the deserts shows an unbalanced distribution, from Australian deserts, which harbor astoundingly high levels of diversity at biogeographic and regional scales, to the rest of the deserts, some of them really species-poor (e.g., Gobi).
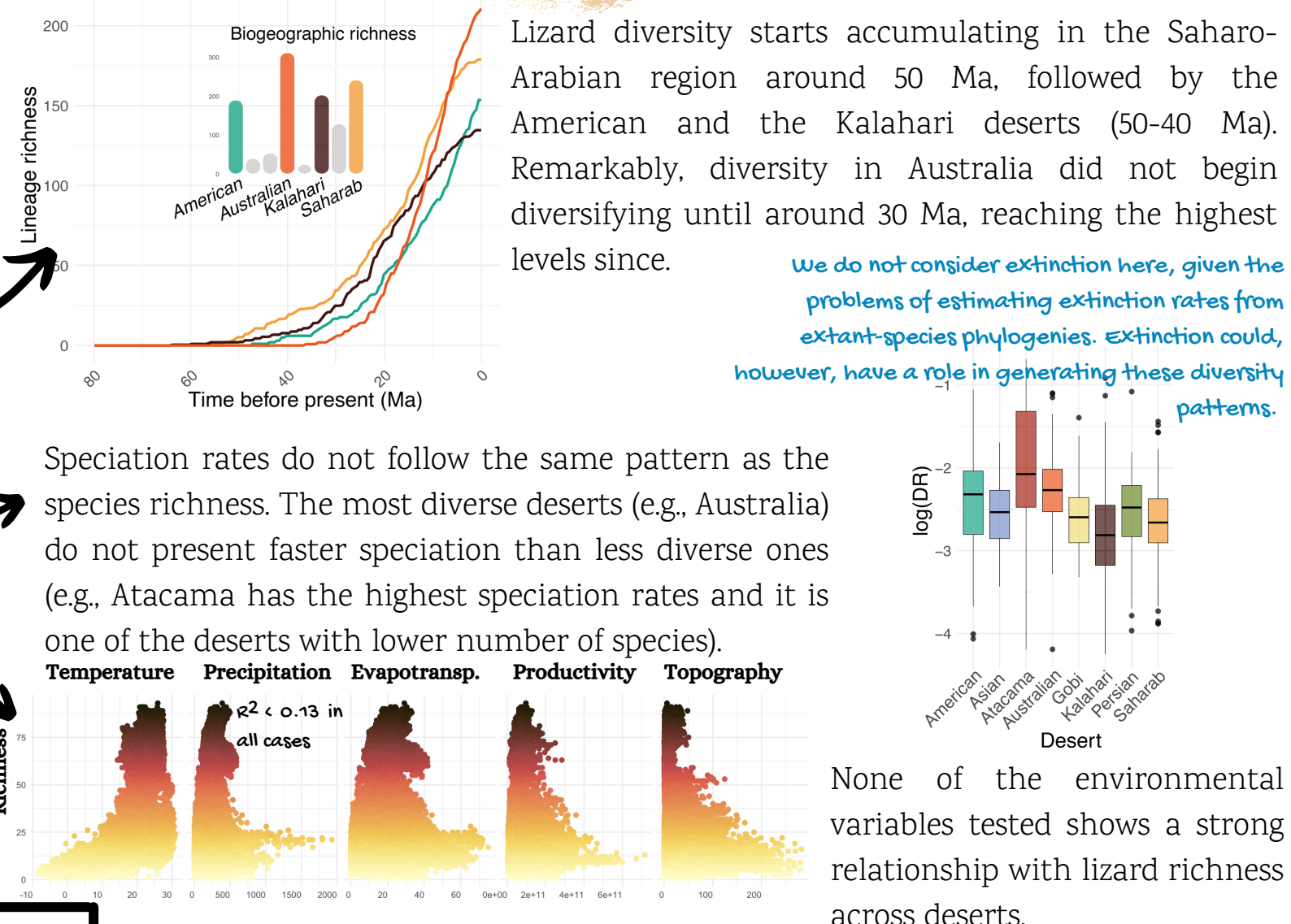Here we test hypotheses that could explain pronounced differences in lizard species richness at biogeographic and regional scales across the Earth's largest deserts. We investigate if lizard richness is related to: 1) the age of the arid-adapted lineages in each system; 2) within-region speciation rates; and 3) environmental variables: temperature, precipitation, evapotranspiration, topography and productivity.

CENTRAL ASIAN — 41
NORTH AMERICAN — 191
SAHARO-ARABIAN — 249
GOBI — 26
ATACAMA — 58
PERSIAN — 133
KALAHARI — 207
AUSTRALIAN — 316

Richness: 75, 50, 25

Regional and biogeographic lizard richness in the deserts of the world

Australian deserts present outstanding lizard diversity, both at the biogeographic (total number of species in the system) and regional (10 arc-minute grid cell) levels. Some deserts have very low diversity overall (e.g., Gobi), and some others present intermediate levels (e.g., high biogeographic but low regional diversity in Saharo-Arabia). Different ecological and evolutionary factors might be causing this diversity pattern.

Biogeographic richness (total species in the desert)
Regional richness (species per cell)

METHODS

Lizard categorization into deserts
Distribution data (Roll et al. 2017)
Biome 13 (Olson et al. 2001)

Reconstruction of ancestral presence in the deserts across the squamate phylogeny

* All data manipulation, analyses and visualization were implemented in the R environment (Tonini et al. 2016)

Estimation of recent speciation rates (DR metric) on the squamate phylogeny (Jetz et al. 2012)

Correlation tests of per-cell (regional) lizard richness with several environmental variables: temperature, precipitation, evapotranspiration, productivity and topography (Fick & Hijmans 2017)

What factors can explain the differences in lizard diversity across deserts?

Time — High diversity = Older diversity

Speciation — High diversity = Faster speciation

Environment — Correlation with environmental variables

Temperature | Precipitation | Evapotransp. | Productivity | Topography
R² < 0.13 in all cases

RESULTS

Lizard diversity starts accumulating in the Saharo-Arabian region around 50 Ma, followed by the American and the Kalahari deserts (50-40 Ma). Remarkably, diversity in Australia did not begin diversifying until around 30 Ma, reaching the highest levels since.

We do not consider extinction here, given the problems of estimating extinction rates from extant-species phylogenies. Extinction could, however, have a role in generating these diversity patterns.

Biogeographic richness
American, Australian, Kalahari, Saharab

Speciation rates do not follow the same pattern as the species richness. The most diverse deserts (e.g., Australia) do not present faster speciation than less diverse ones (e.g., Atacama has the highest speciation rates and it is one of the deserts with lower number of species).

log(DR)
American, Asian, Atacama, Australian, Gobi, Kalahari, Persian, Saharab
Desert

None of the environmental variables tested shows a strong relationship with lizard richness across deserts.

Additionally, we did the analyses for each desert independently, and we only found considerable relationships of temperature in the North American, the Central Asian and the Gobi deserts. In general, none of the environmental variables selected seems to play a determinant role in generating the diversity differences we observe in the deserts.

CONCLUSIONS

☒ Time hypothesis ⟶ Lizard communities in Australia began to build up later than in other less diverse deserts

☒ Speciation hypothesis ⟶ Highly diverse deserts (e.g. Australia) do not present higher speciation rates

☒ Environmental variables ⟶ There are not clear relationships between desert lizard richness and any of the factors tested

Our results reject long-standing hypotheses proposed to explain the tremendous differences in lizard diversity among arid systems. Some factors not included here (e.g., extinction, ecological interactions), as well as system-specific ecological dynamics, likely determine the assembly of desert lizard communities. Ultimately, this study highlights the complexity of evolutionary processes that determine large-scale diversity patterns.

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