The study of global biodiversity patterns has occupied a prominent role in macroecological discussion since the infancy of evolutionary biology as a discipline12–14 The biodiversity levels in a given geographic area are ultimately determined by three processes: speciation, extinction, and dispersal16–18, which result in the unequal accumulation of species across regions and clades. Variations in these three processes may be influenced by biotic and abiotic factors operating at regional and local scales19–21, such as ecological interactions22, evolutionary time23,24, ecomorphological dynamics25,26, environmental conditions27,28, climatic trends29, or topography and plate tectonics30–32.

The emergence of spatial phylogenetics33,34 has advanced our understanding of macroecological dynamics by combining phylogenetic relatedness with geographic biodiversity patterns. The use of phylogeny-based metrics (e.g., Faith’s phylogenetic diversity; PD35) enables investigations into the geographic distribution of species relatedness by considering the length of the phylogenetic branches connecting the species present in a region. Namely, high PD results from distantly related species, while low PD indicates closely related species inhabiting a given area. The explicit inclusion of the phylogenetic dimension may greatly improve our ability to elucidate the synergistic effects of evolution, ecology, and the environment on diversity dynamics36,37 in addition to providing essential information for conservation purposes35,38.

Species richness and PD are in general positively correlated: regions showing high and low species richness have high and low levels of PD, respectively (e.g.,36,39). A positive linear relationship between richness and PD is expected under a null scenario of balanced phylogeny and species distributions: if all the species and clades in particular regions were subjected to homogeneous and constant diversification and dispersal rates, an increase (or decrease) in richness would be reflected in a proportional increase (or decrease) in the number of clades, such that the degree of phylogenetic relatedness would change accordingly and invariably across regions. This makes species richness a generally good proxy of PD40. However, geographic patterns of richness and PD are not necessarily congruent41. There are regions where species are more distantly (high PD) or more closely (low PD) related than would be predicted by richness (Fig. 1a). These deviations from the expected relationship of PD to species richness (residual PD42) are the result of variations in the generative processes (i.e., speciation, extinction, and dispersal) across regions and clades, and therefore studying them is essential to understand the factors underpinning global biodiversity patterns.

For example, high residual PD might represent the so-called “museums” or “sanctuaries” of biodiversity6,43 resulting from the gradual accumulation of species by immigration or by low turnover rate, but they might also arise through a different combination of processes, such as fast speciation in the past followed by reduced extinction of old lineages, or, alternatively, exceptionally high extinction rates of younger lineages. Conversely, low residual PD can indicate “cradles” of biodiversity43 resulting from high turnover rates, but it can also arise through reduced extinction of young lineages or increased extinction of older clades. The multiplicity of scenarios able to generate similar patterns of lineage and phylogenetic diversity (Fig. 1b) highlights the importance of investigating the underlying processes beyond solely focusing on elucidating whether specific regions are cradles or museums of biodiversity44.

The increasing availability of distribution and phylogenetic data from species-rich clades allows for the exploration of large-scale diversity patterns and processes. In the last decade, residual PD patterns have been addressed for the four major clades of living tetrapods: mammals36, amphibians39, birds45, and squamates46,47. This constitutes an exciting, but unrealized, opportunity for a detailed comparison of residual PD patterns across tetrapods, identifying differences and similarities in the factors underpinning global patterns. Here, we characterize geographic patterns of tetrapod richness and PD, and we test the impact of multiple factors on residual PD: recent speciation, evolutionary time, and environmental conditions. We identify key regions with extreme levels of residual PD across tetrapod clades that shed light on the processes underlying these patterns. Beyond informing our understanding of evolutionary dynamics, our study ultimately aims to help identifying priorities for conservation strategies in the face of the challenges imposed by the global environmental crisis.