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Editorial: Modeling large-scale ecological and evolutionary dynamics

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Editorial on the Research Topic
Modeling large-scale ecological and evolutionary dynamics

In recent decades, mechanistic or process-based models for large spatial and temporal biodiversity patterns have played an increasing role in biogeography and macroecology. Pioneering modeling work in ecology has gradually reached broader geographical scales, increasingly intersecting other subjects, such as biophysics, physiology, behavior, life history, species distribution and diversity, trait evolution, diversification dynamics, and environmental changes, through various computational and statistical innovations. To account for the complexity of biodiversity dynamics at large geographical and evolutionary scales, large-scale ecological and evolutionary models have also assimilated critical conceptual issues, including stochastic, scaling, and hierarchical effects (Connolly et al., 2017). The diversity of modeling approaches and their continuous expansion and intermingles offer exciting possibilities to tackle contemporary challenges in understanding broad-scale biodiversity patterns.

To showcase representative modeling advances in biogeography and macroecology, we launched a Frontiers Research Topic "*Modeling large-scale ecological and evolutionary dynamics*." The four contributions employ different modeling strategies to approach questions bridging different levels of ecological organization, from the organismal physiology to the global biota, and integrating varying perspectives, including biophysics and physiology, niche evolution and adaptation, ecological interaction, and phylogeny.

For instance, the ecophysiological studies of animal reactions to temperature encompass multiple lines of investigation, including experimental and comparative endocrine physiology, aimed at clarifying the genetic and biochemical underpinnings of the organismal reactions, and field thermal biology addressing the evolutionary and ecological contexts of the species' thermal adaptations (Feder et al., 1987). In their contribution, Rubalcaba and Jimeno take advantage of biophysical mechanistic models of heat balance in ectotherms to interrogate physiological data and show a hormonal path linking body temperature and energy requirements of lizards. In doing so, the study bridges complementary subfields of ecophysiology toward the common and timely issue of species responses to climatic gradients.

Also aimed at understanding species' response to climatic variation, Souza et al. advance in assessing species' distributional responses to climate change. The authors focus on the capacity of amphibians to respond to ongoing climate changes by tracking suitable conditions across geographical space through either dispersal or evolutionary rescue (i.e., the capacity to adapt to environmental changes rapidly) within their current distribution. The work combines bioclimatic envelopes with an eco-evolutionary model based on quantitative genetics with a probabilistic assignment of life-history traits of nearly all amphibian species to explore the chance of dispersal and tolerance evolution as temperatures rise across the globe. Furthermore, the study explores the outcomes of the species distributional reshuffling in terms of range size, species richness, and beta-diversity. By this means, the contribution helps to improve the realism of macroecological estimates of species responses to climate change.

At the community level, understanding of spatial variation in species composition, i.e., beta-diversity patterns, has primarily relied on empirical studies using non-parametric indices of differences in taxonomic composition (e.g., Baselga, 2010) or evolutionary relatedness, in the case of phylogenetic beta-diversity (Swenson, 2011). For understanding the spatial patterns, there have been recent attempts to incorporate biogeographical and macroevolutionary processes such as dispersal and diversification (e.g., Wu et al., 2020), but species differences in dispersal capabilities along contrasting environmental gradients are difficult to quantify. Jang et al. fill this gap with an eco-evolutionary model that accounts for species-specific population growth, dispersal, niche evolution, and species diversification along an environmental gradient. The contribution offers a mechanistic understanding of diversity patterns based on combined ecological and biogeographical dynamics.

Beyond model innovations, this Frontiers Research Topic also allowed for a conceptual reassessment of the competitive exclusion principle (Gause, 1934) at the biogeographical scale. This principle is foundational to ecological theory, especially regarding species coexistence. Among the many consequences of the principle, MacArthur and Levins (1967) relied on it to explain community patterns through the hypothesis of limiting similarity. This hypothesis has been central, for example, to studies of the phylogenetic structure in community assemblages (Webb et al., 2002). In a Hypothesis and Theory article, Real et al. warn about the "crispy" and often unrealistic true-or-false logic of the competitive exclusion principle at broad scales and offer a probabilistic view based on fuzzy logic. By prescribing a broader set of outcomes involving competing species, the study can, for instance, instigate novel approaches and interpretations when investigating species coexistence and assemblage patterns in ecological communities.

These contributions illustrate the imprint of different modeling traditions in ecology and evolutionary biology and also highlight the great potential of integrating different mechanisms and data in biogeography and macroecology. We hope that they will also stimulate further innovation and integration of eco-evolutionary models at large scales.

Author contributions

SG wrote the first draft. SG and SH contributed to the final version of the manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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