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Editorial: Spatial constraints on multiple dimensions of biodiversity

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Editorial on the Research Topic
Spatial constraints on multiple dimensions of biodiversity

Earth's biological diversity is investigated, in ecological research, relying on a broad spectrum of measures, including species richness at local-to-landscape scales (i.e., α and γ diversity), compositional dissimilarity between biotic communities (i.e., β diversity), and amount and complexity of interspecific links within food-webs (Pereira et al., 2013; Gaüzère et al., 2022). All these complementary measures change in response to spatially structured environmental gradients, anthropogenic disturbances, and large-scale climatic and geologic shifts. However, the relative contribution of these factors to spatio-temporal variation in biodiversity largely varies based on the specific ecosystems analyzed and the spatial scales over which observations are taken (Keil et al., 2012; Galiana et al., 2021). Disentangling the drivers behind observed biodiversity patterns at the spatial scale of interest has become more feasible with recent theoretical and practical advances in ecological analyses. The latter include, among others: virtual simulations of species' niches, dispersal processes and biotic interactions (Zurell et al., 2010; O'Sullivan et al., 2021); Distance-decay and Generalized Dissimilarity Models targeting β diversity (Brown and Swan, 2010; Gómez-Rodríguez and Baselga, 2018; Mokany et al., 2022); and Habitat Suitability and Landscape Connectivity Models highlighting the environmental factors which shape the species' realized niches and possibilities for dispersal (Thuiller et al., 2009; Huang et al., 2020; Cerasoli et al., 2021).

In this context, we launched the Research Topic entitled "*Spatial Constraints on Multiple Dimensions of Biodiversity*" to provide space for researchers to showcase novel evidence about how different biodiversity features vary along spatial gradients associated with environmental, anthropogenic, and biotic factors. The five papers published herein span virtual landscapes, riverine and groundwater ecosystems, and terrestrial habitats (Figure 1).

Catella and Abbott used a spatially explicit, individual-based model to simulate virtual landscapes with varying degrees of environmental heterogeneity and spatial autocorrelation, over which virtual plant communities structured themselves according

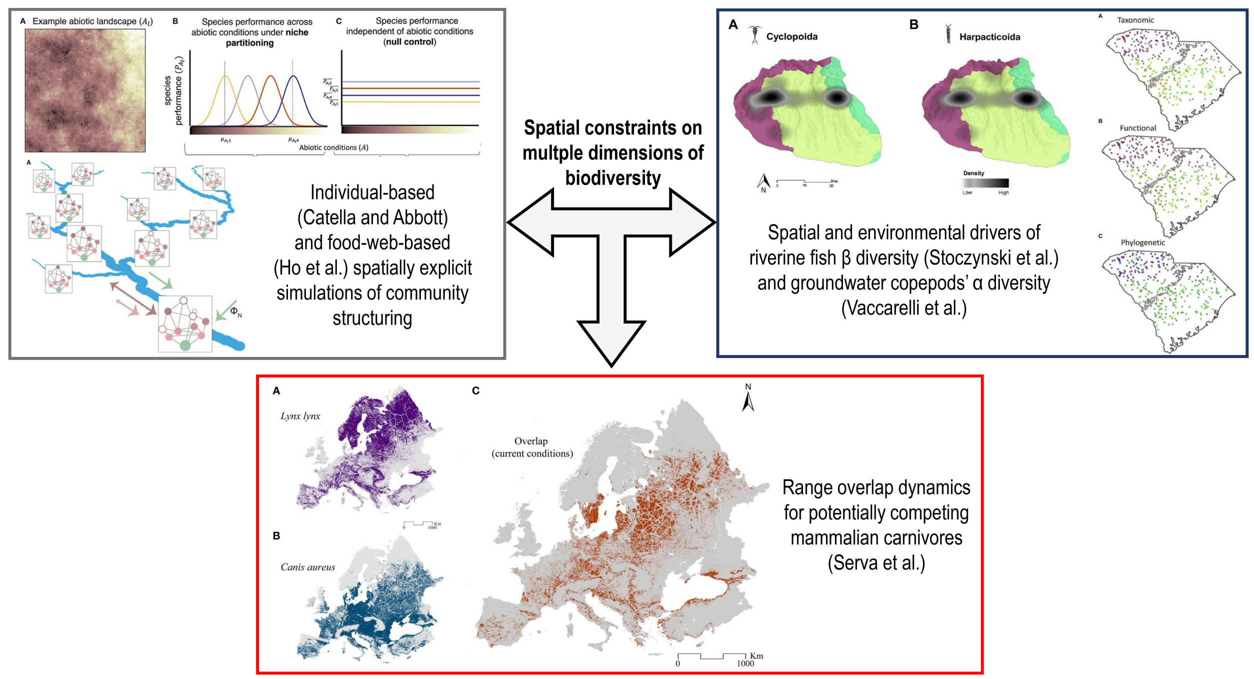

FIGURE 1
Schematic representation of how the five papers published within the Research Topic "*Spatial Constraints on Multiple Dimensions of Biodiversity*" explored the spatial and environmental drivers shaping biodiversity within simulated and real landscapes. Plots and maps within each colored rectangle are extracted from the papers cited therein.

to two distinct pathways: (i) environmental factors influencing species' persistence probability during the germination phase, thus shaping initial densities; and (ii) the same factors affecting the strength of interspecific interactions after germination occurs, thus influencing species' persistence later on during their life cycle. The authors showed that higher landscape heterogeneity increased species richness and interspecific competitive balance when the environmental gradients affected germination probability. At the same time, the same did not occur when such gradients only affected biotic interactions. However, species richness also decreased within this second pathway in simulations where overall landscape heterogeneity was intentionally lowered. This suggests that different heterogeneity-diversity relationships can emerge when species respond to environmental pressures during distinct life stages.

Ho et al. simulated a virtual river network composed of 236 reaches, classified as high-elevation headwaters, mid-positioned reaches, lowland headwaters, or downstream reaches. Within each node (i.e., reach), local food webs were simulated based on a generalized Lotka-Volterra model where the consumer-resource relationships depended on body size and trophic connectance. In contrast, nutrient availability depended on hydrographic parameters and node position within the network. These local food webs were integrated into different realizations of a meta-food-web by simulating downward nutrient fluxes and bidirectional species' dispersal. Within this spatial food-web (SFW) model, predicted species richness and food-web metrics were compared among the four classes of river reaches. Further, local food web metrics were regressed against the distance of the reaches from the river outlet and against drainage area. Finally, outputs from the SFW model were compared to those from three different null models. Modeled species richness was high, driven by high nutrient availability, in lowland headwaters and downstream reaches, where food webs also showed high modularity and link density and low interspecific overlap in trophic niches. Additionally, changes in how nutrient availability and species dispersal were simulated between the SFW and the null models led to different emerging meta-food-web properties, suggesting that riverine metacommunities are shaped by the synergistic effects of hydrographic structure, trophic interactions, nutrient fluxes, and organism displacement.

These findings were complemented by those from Stoczynski et al., who analyzed fish abundance data across 350 sites spanning the entire South Carolina state, four distinct watersheds, and two ecoregions (i.e., upstate *versus* lowlands). The two ecoregions were defined by a geomorphic break corresponding to the maximum inland extent of sea waters during the Cretaceous period. The authors computed taxonomic, phylogenetic, and functional β diversity between sites according to the three metacommunity delineations (i.e., whole state, ecoregions, or single watersheds), then assessing how much variation was explained within each setting by natural environmental (e.g., dissolved oxygen), anthropogenic (e.g., dam density) and purely spatial (i.e., vectors from Principal Coordinate Neighbor Matrices) variables. Taxonomic diversity was generally higher than phylogenetic and functional diversities, and the use of biologically relevant anthropogenic variables increased explained variation. Further, the relative weight of the three classes of variables varied according to the chosen metacommunity delineation, indicating that methodological choices influence our capability of explaining β diversity patterns in riverine networks.

In a different aquatic system, groundwater of 52 karst caves from northern Italy, Vaccarelli et al. investigated the α diversity of copepods (Crustacea Copepoda), its climatic and geologic correlates, and its spatial patterns. They found that overall species richness, richness of single orders (i.e., Cyclopoida *versus* Harpacticoida) and that of obligate *versus* non-obligate groundwater dwellers, was explained by a mix of factors, particularly the drainage basin the single caves belong to, their lithology, and surface temperature variability. The authors argued that drainage basin and lithology represent historical factors shaping underground habitat heterogeneity and possible dispersal barriers, while considerable above-ground thermal variations may favor the colonization of non-obligate groundwater dwellers from surface waters due to their generally wider thermal niche compared to obligate groundwater species. Groundwater biodiversity is thus sensitive to spatial features of karst systems, their hydrogeology, and surface climate, highlighting the need for further research to appropriately preserve it.

Finally, Serva et al. investigated the potential range overlap in Europe for an iconic predator, the Eurasian lynx, and its potential kleptoparasite, the golden jackal, which is in rapid expansion. The authors took advantage of climatic, topographic, anthropogenic (e.g., built-up areas), and habitat-related (e.g., forest cover) variables to model habitat suitability across Europe for these two carnivores under current conditions and various future scenarios delineated by different Shared Socio-Economic Pathways (SSPs). Further, the authors estimated the possible increase in range overlap between these species and the Eurasian wolf, one of their strongest competitors. Outputs of their modelling exercise provided useful information about which European regions could host broader coexistence in the future among these three predators and thus possible novel biotic interactions.

In conclusion, the papers published in this Research Topic expand current understanding about the spatial – and associated environmental – constraints that ecological systems face at various scales, paving the way to future studies aiming at effectively deploying the gained ecological knowledge to protect biodiversity.

Author contributions

FC: Conceptualization, Visualization, Writing – original draft, Writing – review & editing. BB: Conceptualization, Writing – review & editing. CS: Conceptualization, Writing – review & editing.

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.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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