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Editorial: Patterns and processes in ecological networks over space

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Editorial on the Research Topic
Patterns and processes in ecological networks over space

Network theory has become a fundamental conceptual framework and analytical tool in ecological research by facilitating our understanding of the interactions between individuals or species in nature (Proulx et al., 2005; Bascompte, 2007). Nowadays, applying network theory to single communities or ecosystems is a common approach for ecologists studying in different environments, allowing them to disentangle the complex processes involved in antagonistic or mutualistic interactions (Dormann et al., 2017; Delmas et al., 2019). Several recent studies analyzed ecological networks' topological and statistical properties (Dale and Fortin, 2021), linking these network properties to functional diversity or other ecological processes. However, the presence and strength of the ecological interactions vary over time and space (Pellissier et al., 2018), influencing the structure and organization of the communities and, in some cases generating complex dynamics (Holme and Saramäki, 2012; Tylianakis and Morris, 2017; Fortin et al., 2021). The ecological mechanisms that promote this variability can encompass different scales and ecological hierarchies from animal behavior to population dynamics and predator–prey cycles (Dormann et al., 2017; Lopez et al., 2017; Gelmi Candusso et al., 2023). The exact way these mechanisms interactively influence the spatiotemporal fluctuations of ecological communities is still a matter of discussion. In particular, space can be an intrinsic component of an ecological network (e.g., landscape use, metapopulations, transport networks), whereas spatial heterogeneity can account for a large proportion of the differences between local networks (Fortin et al., 2012; Anderson and Dragićević, 2020; Galiana et al., 2022). Nevertheless, in many cases, an explicit representation of the spatial dimension of the biological phenomenon is absent.

Several network theory approaches can help us deal with this spatiotemporal variability. Traditionally, minimum spanning tree or minimum cost arborescence (Boruvka, 1926; Kruskal, 1956; Prim, 1957) are methods that allow the incorporation of space or temporal heterogeneity. These approaches explicitly project the network into space/time, including link weights defining dimensional relationships between nodes. Contemporary approaches include multilayer networks (Pilosof et al., 2017; Aleta and Moreno, 2019). Multilayer networks are objects with two or more layers, and each layer is a network representing, for example, community configuration at different points in time (Pilosof et al., 2017). Classical spatiotemporal phenomena like diffusion and percolation can be efficiently represented using multilayer networks (Aleta and Moreno, 2019).

In this vein, the explicit incorporation of space in ecological network analysis becomes a necessary next step in ecological research. This Research Topic, *Patterns and Processes in Ecological Networks over Space*, aims to collect experiences and perspectives from different research areas where the application of spatial networks represents a step forward in our understanding of the natural world.

An excellent example of the strength of combining empirical data and novel ways to use network theory to study the variability of food webs is presented by Moisan et al. The authors used 30 years of ecological monitoring at Bylot Island (Canada) to build community migration networks based on multipartite networks connecting different biogeographic regions with the summer High-Arctic terrestrial community. Their study provided an excellent example stressing that migrants modify the dynamics of the food web seasonally.

Similarly, Borthagaray et al. analyzed the landscape's effect on biodiversity by considering species' dispersal capacity in pond metacommunities from Europe and South America. They found that peripheral communities present a lower richness and higher beta diversity at intermediate dispersal abilities than central communities. Their study provides an exciting view of the importance of metacommunity structure on diversity using a combined approach of empirical data and theoretical simulations.

Then, Julien and Melles investigated how landscape characteristics influence species accumulation curves along the Canadian side of the Great Lakes Basin. Their findings stressed that the potential maximum species richness varies due to watershed position and land cover. Their study is an interesting example of the importance of analyzing land–water interactions in a landscape as a mosaic of watersheds.

In a different application, Estay et al. used spatial networks, particularly a Minimum Cost Arborescence (MCA), to model the spread of an invasive species, *Drosophila suzukii*. MCAs are graphs that allow the incorporation and minimization of spatial distance among nodes following a temporal sequence (temporal direction). This approach facilitates the estimation of dispersal speed and its variability through the time window of the study. The approach has several advantages over other classical techniques to estimate key invasion dispersal statistics, for example, facilitating the estimation of dispersal rate and its variability over time.

These examples represent an essential contribution to the theory and applications of spatial networks. Studies presented here show us how to deal with many still complex ecological problems through their use. This growing research area offers new perspectives to scientists and strategies for decision-makers facing the enormous challenge of environmental problems. We hope this Research Topic provides some background and motivates more people to apply this approach.

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Conflict of interest

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