

Trait evolution within bipartite ecological networks

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Bipartite ecological networks are formed by interactions between species which exploit each other for survival and are crucial components to sustain ecosystem function and services, foster biodiversity and affect community stability [1]. Despite their diversity, bipartite mutualistic interactions exhibit surprisingly well-organised structures. In particular, they are often found to be within a certain range of connectance, nestedness and modularity, as well as a right skewed degree distribution (e.g. [2]). Connectance measures the proportion of realised interactions among all possible ones in a network, and bipartite networks often have a low to moderate level of connectance. A high level of nestedness, where specialists only interact with a subset of species with which generalists interact, is also a common feature of bipartite ecological networks. Modularity depicts the extent to which a network is compartmentalized into delimited modules where species are strongly interacting with species within the same module but not those from other modules. Being a typical feature of food webs and antagonistic bipartite networks, high modularity is also common in some mutualistic networks. Most species are poorly connected, with only a small number being well connected, resulting in a degree distribution following mostly a truncated power law. Evidently, these multiple features of mutualistic networks are not independent of each other, suggesting that an integrated model is required to better capture the intrinsic dynamic features of species interactions [1, 3].

Here, we review a list of eco-evolutionary models for investigating the pattern emergence in bipartite ecological networks with trait-mediated interactions phylogenetic modelling [4, 5], adaptive interaction switching [6–8] and adaptive dynamics [9–11]. Firstly, using knowledge of the phylogenies of the interacting species, our model yielded a significantly better fit to 21% of a set of plant-frugivore mutualistic networks. This highlights the importance, in a substantial

minority of cases, of inheritance of interaction patterns without excluding the potential role of ecological novelties in forming the current network architecture. Second, the model allowing interaction switches between partner species produced predictions which fit remarkably well with observations, and thus the interaction switch is likely a key ecological process that results in nestedness of real-world networks. Finally, trait-based adaptive dynamics models highlight the importance of assortative interactions and the balance of costs incurred by coevolving species as factors determining the eventual phenotypic outcome of coevolutionary interactions. The interplay of ecological and evolutionary processes through trait-mediated interactions can explain these widely observed architectures in bipartite networks. Coevolutionary networks provide an ideal model for modelling complex adaptive systems, which can help to address challenges from global changes facing many complex social-ecological systems [3, 12]

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