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Intermittent transitions between rich and poor communities in evolutionarily constructed food webs

The emergence and maintenance of biodiversity is one of the most fundamental challenges in ecology. Recent studies have demonstrated that evolutionary processes affecting interactions within and among species can be faster than previously thought, that the effect of such evolution on the underlying ecology can be appreciable, and that this ecology can in turn affect, through eco-evolutionary feedback, the shape of the fitness landscapes driving adaptive evolutionary change. While several models have been proposed to investigate the emergence and maintenance of community structures, most of these are based on separating the timescales of ecology (describing changes in species abundances) and evolution (describing changes in species traits).

Here, we develop an individual-based model that does not impose an artificial separation of ecological and evolutionary timescales. Our model considers the evolution of two quantitative traits expressed and inherited by each individual, called foraging and vulnerability traits, that control trophic interactions and interference competition between individuals. Specifically, the foraging intensity of one individual with respect to another is determined by the similarity between the former's foraging trait and the latter's vulnerability trait. Analogously, the intensity of interference competition between two individuals is determined by the similarity of their foraging traits. Population dynamics are represented stochastically, as an individual-based birth-death process, and also evolution is represented stochastically, resulting from rare and small mutational steps in trait values potentially occurring at birth.

Analyzing our model, we (1) observe the robust and recurrent emergence of two different metastable community states, one in which producers are dominating the community and an alternative one in which producers are coexisting with consumers. We also (2) demonstrate a distinctive pattern of intermittent transitions between those two metastable states and (3) explain the eco-evolutionary mechanisms underpinning this transition process. In conclusion, we suggest that evolutionarily induced transitions between metastable community states, through community breakdown and subsequent rebound, could be important for understanding the long-term dynamics of empirical patterns of biological diversity.