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Meta-stable states and macro-evolutionary transitions in an eco-evolutionary food-web model

Eco-evolutionary food-web models help elucidate the processes responsible for the emergence and maintenance of complex community structures. However, most existing community-evolution models are based on random speciation, and thus do not consider the gradual evolution of trophic traits. Furthermore, intermittent bursts of evolution associated with punctuated equilibria highlight the importance of describing not only an evolved community's structure, but also the underlying evolutionary dynamics. While models based on the concept of self-organized criticality help understand non-equilibrium community dynamics, they have so far been based on strongly simplified assumptions about ecological interactions. Using an individual-based model, here we incorporate the gradual evolution of key traits for foraging and interference interaction into a model of non-equilibrium community evolution. We find that our model communities quickly diversify into autotrophs (plants) and consumers (herbvivores), with distinctive phenotypic clusters resulting from successive speciation driven by plant-herbivore coevolution. Occasionally, all herbivores go extinct in sudden macroevolutionary transitions, with the remaining community primarily featuring plants. Our findings thus reveal a pattern of community macroevolution involving two meta-stable states, corresponding to a plant–herbivore community and a plant community, respectively. On the evolutionary timescale, our model community switches stochastically and rapidly between these two alternative community states. We explain the processes responsible for the breakdown of plant–herbivore communities in our model, as well as for the subsequent reestablishment of herbivore diversity. Our model thus helps us understand the eco-evolutionary mechanisms underlying these recurrent dynamics of rapid community breakdown and regeneration, which terminate intermittent periods of near-stasis or punctuated equilibrium.