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Coevolution of habitat choice in a stochastic world

Species live and interact in patchy landscapes where environmental conditions vary both in time and space. In the face of this spatial-temporal heterogeneity, species may co-evolve how they select habitat patches. Under equilibrium conditions, coevolution of patch-selection is predicted to give rise to ideal-free distributions of all species: their per-capita growth rates are zero in occupied patches and negative in unoccupied patches. While ideal-free distributions explain observed empirical patterns including enemy-free space and the ghost of competition past, they do not explain why some species occupy sink patches, why competitors have overlapping spatial ranges, or why predators avoid highly productive patches. To understand these patterns, we analyze stochastic Lotka-Volterra models accounting for spatial heterogeneity, environmental stochasticity, and any number of interacting species. We derive an analytically tractable characterization of coevolutionarily stable strategies (coESS) for patch-selection and introduce a numerical algorithm for solving for a coESS. The analytic characterization shows whenever there is selection for a species to occupy multiple patches, their local stochastic growth rates will be negative in the occupied patches i.e., all populations are sink populations. Applying our methods to models of antagonistic interactions reveals that environmental stochasticity can partially exorcise the ghost of competition past, select for new forms of enemy-free and victimless space, and generate hydra effects over evolutionary time scales. To provide additional perspective on our results, we discuss how they relate to the Modern Portfolio Theory of economics. Our results highlight how environmental stochasticity can reverse or amplify evolutionary outcomes due to species interactions or spatial heterogeneity. This work is in collaboration with Alex Hening (College Station) and Dang Nguyen (Tuscaloosa).