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Derivations of Animal Movement Models with Explicit Memory

Highly evolved animals continuously update their knowledge of social factors, refining movement decisions based on both historical and real-time observations. Despite its significance, research on the underlying mechanisms remains limited. In this study, we explore how the use of collective memory shapes different mathematical models across various ecological dispersal scenarios. Specifically, we investigate three memory-based dispersal scenarios: gradient-based movement, where individuals respond to environmental gradients; environment matching, which promotes uniform distribution within a population; and location-based movement, where decisions rely solely on local suitability. These scenarios correspond to diffusion advection, Fickian diffusion, and Fokker-Planck diffusion models, respectively. We focus on the derivation of these memory-based movement models using three approaches: spatial and temporal discretization, patch models in continuous time, and discrete-velocity jump process. These derivations highlight how different ways of using memory lead to distinct mathematical models. Numerical simulations reveal that the three dispersal scenarios exhibit distinct behaviors under memory-induced repulsive and attractive conditions. The diffusion advection and Fokker-Planck models display wiggle patterns and aggregation phenomena, while simulations of the Fickian diffusion model consistently stabilize to uniform constant states.