Emergence of Stochastic Oscillations in Small Predator-Prey Systems: The Role of Fluctuations and System Size

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In this work, we explore the behavior of a small predator-prey system using an individual-based model. Birth, death, and immigration events occur probabilistically, introducing stochastic fluctuations in population sizes. Unlike deterministic mean-field (MF) models, which predict a stable equilibrium, we observe that in small systems these fluctuations can lead to coherent oscillations. By analyzing the power spectrum of the population time series, we find a clear peak at a frequency which is lower than the frequency predicted by the linearized deterministic model (MF model). This peak signals the presence of noise-driven oscillations that do not exist in the deterministic case. At high frequencies, the power spectrum shows a decay proportional to the square of the frequency, a typical signature of Brownian motion or random walk dynamics. As the system size increases, fluctuations become less important and the dynamics approach the mean-field behavior, where oscillations disappear. We also observe that there is an optimal value of the prey growth rate that maximizes the coherence of oscillations.