Self-organization and criticality in ecological systems with antagonistic interactions

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Complex systems are characterized by a large number of components whose interactions are both nonlinear and local. Two main classes of systems are recognized that produce patterns of self-organization, with different implications for sensitivity to external perturbations and for the occurrence of large and unpredictable intermittent fluctuations. These classes correspond to systems that exhibit, respectively, classical phase-transitions [1] and self-organized criticality (SOC,[2, 3]). With two individual-based models that are spatial and stochastic and are implemented as interacting particle systems, we introduce a third class of systems. The first model is for the dynamics of predator and prey [4]; the second, for the dynamics of disturbance and recovery [5]. We show that the models exhibit a percolation-type transition with similarities and differences to static percolation. One important difference is a broader critical region, which we use to explain the origin of robust power-law scalings [6, 7]. At the critical point, these systems exhibit a drastic change in cluster connectedness but not in the biological variables of interest.

Based on these results and on the literature on spatial and individual-based models for predator-prey, disease, and disturbance dynamics, we propose a classification of ecological systems with local antagonistic interactions. We establish the biological and mathematical assumptions that differentiate the three main classes, and discuss the implications of the different types of dynamics for patterns of population 'stability' and their relationship to spatial connectedness.

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