Competing associations

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Abstract

The multi-species predator-prey lattice models can exhibit a large number of possible stationary states. The real spatial state, however, is selected by the evolutionary rules defining the local variation in the distribution of species [1]. Now our attention is focused on a system describing the toxic warfare among bacteria using two toxins and/or antitoxins.

For one toxin we can distinguish toxic (T), resistant (R), and sensitive (S) species dominating cyclically each other, i.e., T invades S invades R invades T. For two toxins nine species (TT, TR, TS, RT, etc.) are defined with many cycles in the corresponding food web [2]. In the initial state these species are distributed randomly on a square lattice and the system evolution is governed by invasions between two randomly chosen neighboring sites if a predator-prey pair (e.g., TT and TR) is staying there. For neutral pairs (e.g., TS and ST) the given species can exchange their position with a probability X. These elementary processes are repeated until the system reaches a stationary state.

For low rates of mixing (X¡0.056) the mortal enemies form three (spatially separated) defensive alliances [namely (TT+RR+SS), (TR+RS+ST), and (TS+RT+SR)] whose average area grows linearly with time and finally one of them will dominate the whole system. Within these defensive alliances the cyclic invasion provides a mechanism defending them against the external invaders. On the contrary, for high rate of mixing ($X > 0.070$) the well-mixed states of neutral triplets (e.g., TT+RS+SR) form a self- organizing pattern maintained by cyclic invasions between these well-mixed phases. Monte Carlo simulations indicate an intermediate phase (for $0.056 < X < 0.070$) exhibiting permanent formation of different associations of species and huge avalanches of invasions between them. The latter two self-organizing patterns maintain all the species alive.

References

[1] G. Szabó and G. Fáth, Evolutionary games on graphs
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[2] G. Szabó and T. Czárán, Phys. Rev. E 63 (2001) 061904.