Oscillatory Turing patterns in network-organized reaction-diffusion systems

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Along with his work on cryptanalysis and mathematical algorithms, the discovery of diffusion-induced instabilities was one of the greatest contributions by Alan Turing [1]. Turing patterns, developing in chemical reactions and playing an important role in biological morphogenesis [2-5], provide a classical example of self-organization. It is known that their analogs are possible in networks of coupled reactors or biological cells [6,7] and statistical properties of stationary Turing patterns in large random networks have been investigated [8]. Here, our attention is focused on ecological systems representing metapopulations formed by habitats with dispersal connections [9,10]. Our analysis reveals that dispersal-induced instabilities should be typical for such ecosystems. However, starting from three trophic levels, they often correspond to a different bifurcation, also introduced by Turing [1] but remaining less known. Instead of static differentiation [6-8], oscillations are then spontaneously developing in a fraction of populations, depending on the network architecture and species mobility. Such behavior may be essential for understanding the stability and dynamics of metapopulations, contrasting the view that dispersal connections tend to enhance the overall stability of a system.

1. A. Turing, *Phil. Trans. R. Soc. Lond. B*, **237**, 37-72 (1952).
2. V. Castets, E. Dulos, J. Boissonade and P. De Kepper, *Phys. Rev. Lett.*, **64**, 2953-2956 (1990).
3. Q. Ouyang and H. L. Swinney, *Nature*, **352**, 610-612 (1991).
4. J. D. Murray, *Mathematical Biology* (Springer, 2003).
5. S. Kondo and A. Asai, *Nature* **376**, 765-768 (1995).
6. H. G. Othmer and L. E. Scriven, *J. Theor. Biol.*, **32**, 507-537 (1971).
7. W. Horsthemke, K. Lam and P. K. Moore, *Phys. Lett. A*, **328**, 444-451 (2004).
8. H. Nakao and A. S. Mikhailov, *Nature Physics*, **6**, 544-550 (2010).
9. I. Hanski, *Nature*, **396**, 41-49 (1998).
10. M. D. Holland and A. Hastings, *Nature*, **456**, 792-795 (2008).