Fragmented metapopulations in dynamic and correlated landscapes

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We consider a spatially explicit patch-occupancy metapopulation where colonization rates decrease with patch separation. We allow the patches to be distributed at random in space, according to some statistical distribution. The patch occupancy deviates from the predictions of the deterministic Levins model due to fluctuations in local spatial structure, and due to local correlations in the stochastic patch occupancy dynamics. However, these deviations will be small if the if the colonization range is large, so that each patch effectively interacts with a large number of other patches.

The inverse colonization range can be used as a small parameter in a perturbation expansion about the deterministic limit. We calculate the dominant term in this expansion, which allows us to quantify the contributions of demographic stochasticity and spatial structure for random, dynamic, and correlated landscapes. It turns out that truncating the expansion at this order provides a very good analytical approximation (relative to numerical simulations of the underlying model), even when the colonization range is comparable to the mean patch separation.

The robustness of our results illustrate the advantage of asymptotically exact approximations, which are guaranteed to give good results in some parameter regime and consequently can fare surprisingly well outside this regime. They also show how stochastic differential equations can be used beyond the linear diffusion limit. This method promises to be a very powerful technique for studying spatially structured stochastic populations.

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