OLM 9.5. The dynamical role of spatial constraints in competitive interactions

We compared two versions of the single-species site occupancy model in Figure 6.10b (TBE, p.103). While reproduction is possible to any empty site in the Levins model (TBox 6.2; p.102), dispersal is limited to the neighbouring sites in its spatially explicit version. The spatial constraint of dispersal is increasingly detrimental to a population, when it becomes rare. On the other hand, we have learnt that coexistence is based on rare advantage in Ch9Coex (p.170), therefore rare disadvantage by limited dispersal should decrease the propensity for coexistence. Here, we study this effect by a specific example.

We define first a spatially explicit, dispersal limited model version of competition. Suppose that the individuals of two populations (of "Species 1" and "Species 2") interact on a 2D square lattice in continuous time. Each individual occupies a single lattice site, thus the sites may take one of three possible states: occupied by Species 1, Species 2 or none (empty). Individuals reproduce to an empty site in the Moore neighbourhood (the 8 adjacent sites) and die with specified rates, which are affected by their neighbours.

The rate of reproduction is chosen to be 1 for both species. Competitive differences are realized only in the death rates. Competition takes place against the neighbours of the focal individual of Species *i*, of which d_{0i} is the death rate without competitive pressure; d_{ii} is additional death rate due to the presence of a conspecific competitor; d_{ij} quantifies the effect of a competitor from the other species. d_{0i} and d_{ii} are fixed for both species at 0.05 and 0.30, respectively, and we scan the d_{ij}-d_{ji} parameter plain through the 0.10-0.50 range in steps of 0.05, to map the cases with interspecific competitive effects weaker, equal or stronger than intraspecific competition.

This model is spatially explicit in reproduction and competition: in both cases two adjacent sites are involved. We compare this spatial model with its non-spatial equivalent, often called as *mean field* model, in which both reproduction and competition has infinite range. (For instance, the Levins model of TBox 6.2 is the mean-field version of the dispersal limited model in Figure 6.10.b.) The mean field version of our current model corresponds to a competitive Lotka-Volterra model; its derivation is similar to the one used in TBox 9.4 (p.189).

Figure 9.5.1.a presents the outcomes of the spatially explicit simulations on the d_{ij}-d_{ji} parameter plain. Comparing this to Figure 9.5.1.b, which shows the results for the mean field model, reveals that the parameter range allowing coexistence is substantially smaller in the spatial model.

We conclude that limited dispersal is detrimental to coexistence, at least in this model. The result can be seen, as counterintuitive, because limited dispersal slows down the exclusion process. However, we are interested in the final outcome, instead of the process; therefore the speed is irrelevant. Limited dispersal is detrimental to coexistence because it imposes disadvantage on the rare variant, while coexistence of competitors is based on rare advantage. This is why we expect our results to be relevant beyond this simple model. See Mágori et al. (2005) for a more detailed analysis of a similar model.

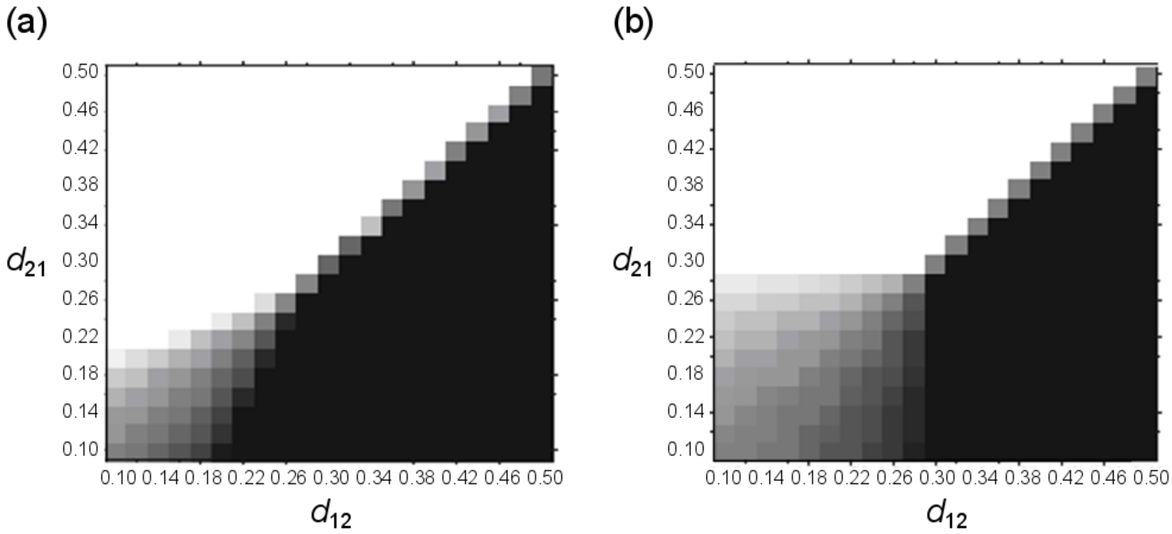

Figure 9.5.1 Effect of spatial constraints on coexistence of two competing species.

Axes represents parameters d_{12} and d_{21}; d_{ij} denotes the competitive effect by Species *j* on Species *i*. Fixed parameters: d_{ii} = 0.3 and d_{0i} = 0.05 for both species. Initial relative frequency is 0.1 for both species. Colour code: white: Species 1 outcompetes Species 2; black: Species 2 outcompetes Species 1; gray: coexistence, shade represents equilibrium ratio. a) spatial model, with dispersal to the neighbourhood; b) mean-field model without spatial constraints (Czárán and Magyar 2007).

We find the opposite effect of dispersal limitation in TBox 10.3 (p.214) in Ch10Niche. In that situation there are two ecologically different locations and two species adapted to different locations. They coexist via spatial niche segregation provided, their dispersal rates are not too large. In the model presented in this OLM space is homogeneous, therefore spatial niche segregation is impossible and coexistence stems from local interactions. In more complicated situations dispersal limitation may have both kinds of consequence. Its net effect cannot be predicted without detailed analysis of each special case (Czárán 1998).

References

Czárán, T. (1998). *Spatiotemporal Models of Population and Community Dynamics*, Springer.

Czárán, T. and Magyar, G. (2007). Együttélés térben és időben. In E. Pásztor and B. Oborny, eds. *Ökológia*, pp. 124-42. Budapest, Nemzeti Tankönyvkiadó.

Mágori, K., Szabó, P., Mizera, F. and Meszéna, G. (2005). Adaptive dynamics on a lattice: role of spatiality in competition, co-existence and evolutionary branching. *Evolutionary Ecology Research*, 7(1): 1-21.