Dispersal-induced resilience to stochastic environmental fluctuations in populations with Allee effect

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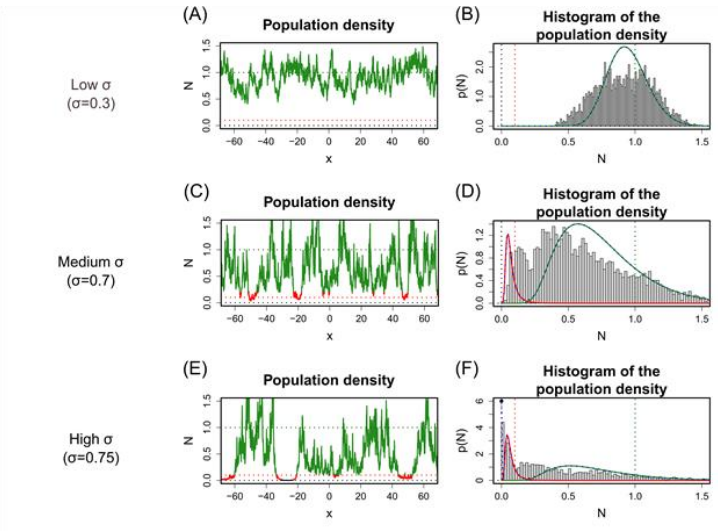
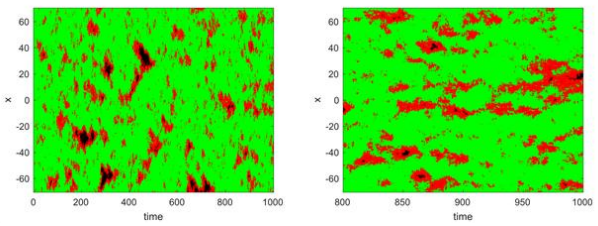
Many species are unsustainable at small population densities (Allee Effect), i.e., below a threshold named Allee threshold, the population decreases instead of growing. In a closed local population, environmental fluctuations always lead to extinction. Here, we show how, in spatially extended habitats, dispersal can lead to a sustainable population in a region, provided the amplitude of environmental fluctuations is below an extinction threshold. We have identified two types of sustainable populations: high-density and low-density populations (through a mean-field approximation, valid in the limit of large dispersal length). Our results show that patches where population is high, low or extinct, coexist when the population is close to global extinction (even for homogeneous habitats). The extinction threshold is maximum for characteristic dispersal distances much larger than the spatial scale of synchrony of environmental fluctuations. The extinction threshold increases proportionally to the square root of the dispersal rate and decreases with the Allee threshold. The low-density population solution can allow understanding difficulties in recovery after harvesting. This theoretical framework provides a novel approach to address other factors, such as habitat fragmentation or harvesting, impacting population resilience to environmental fluctuations. Environmental fluctuations can create population-depleted areas and even extinct areas for the population. This effect is more severe in the presence of the Allee effect (decreasing growth rate at low population densities). Dispersal inside the habitat provides a rescue effect on population-depleted areas, enhancing the population resilience to environmental fluctuations. Habitat reduction decreases the effectiveness of the dispersal rescue mechanism. We report here how the population resilience to environmental fluctuations decreases when the dispersal length or the habitat size are reduced. The resilience reduction is characterized by a decrease of the extinction threshold for environmental fluctuations. The extinction threshold is shown to scale with the ratio between the dispersal length and the scale of environmental synchrony, i.e., it is the dispersal connection between non-environmentally-correlated regions that provides resilience to environmental fluctuations. Habitat reduction also decreases the resilience to environmental fluctuations, when the habitat size is similar to or smaller than the characteristic dispersal distances. The power laws of these scaling behaviors are characterized here. Alternative scaling functions with spatial scales of population synchrony are found to fit the simulations worse. These results support the dispersal length as the critical scale for extinction induced by habitat reduction.





References

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[2] R. Crespo-Miguel, J. Jarillo, F. J. Cao-García, Scaling of population resilience with dispersal length and habitat size. J. Stat. Mech. Theory Exp., 2022(2), 023501 (2022).