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Adaptive advantage of aggregation in a population with Allee effects

Aggregation is often believed to be advantageous in populations with positive density dependence at small population size (i.e., Allee effects). Many species of non-social animals aggregate to acquire resources for survival and reproduction. By aggregating, organisms may create a more favorable environment, reduce per capita predation risk, or procure resources, none of which is likely attainable for individuals acting alone. However, when resources are scarce or population density is high, aggregation likely results in overcrowding and severe competition. Moreover, aggregation behavior can affect the collective reproductive success of the population and thus can alter population dynamics and population density. Because benefits to aggregation behavior may be density dependent, its adaptive advantage can be more properly examined by explicitly accounting for the feedback loop between behavior and population dynamics. The objective of this project is to investigate the conditions under which aggregation is advantageous. We constructed a minimal model that incorporates aggregation, Allee effects, and scramble competition. The part of the model describing the dynamics of group formation by preferential attachment is based on analytical solutions of the stochastic birth and death processes of groups of different sizes. We then used the methods from adaptive dynamics and performed invasion analysis to examine the invasion fitness of various aggregation tendencies. We found that, although a strong tendency to join larger groups is advantageous for establishing a population from a small size, it is generally not advantageous. This is due to high population density produced by effective aggregation. A strategy where individuals pick a group randomly is overall more advantageous and able to invade populations with a stronger aggregation tendency. In some regions of parameter space, we observe evolutionary suicide where invaders go extinct after successfully invading the resident population. Strong tendencies for aggregation become advantageous enough to persist when some mechanisms regulating group size are included or when the population frequently experiences a low density (e.g, dispersal, stochastic high mortality events). We conclude that aggregation alone is mostly not advantageous and needs some additional mechanisms to either regulate group size or suppress population density.