Evolutionary Cycles

(Adaptive Dynamics Project 2016)

Consider a trait (such as body size) that influences success in competitive contests with other members of the population. The evolution of such a trait is determined by two opposing forces: Being larger than the opponents is advantageous for winning the contests, but a large size is also costly in terms of maintenance and thus may affect reproduction and survival in a contest-independent way as well. In this project, we explore the evolution of body size in an ecological model that admits multiple attractors.

Consider a resident population with traits $x_1, \ldots, x_k$ (denoting log-body size) and corresponding population densities $n_1, \ldots, n_k$, and let the population dynamics be given by

$$\dot{n}_i = r(x_i)n_i \left(1 - \sum_{j=1}^{k} \alpha(x_i - x_j)n_j\right) - \frac{\beta P n_i}{c^2 + \left(\sum_{j=1}^{k} n_j\right)^2},$$

where $r(x) = b(x) - d(x)$ is the difference of density-independent birth and death, and $\alpha(\Delta x)$ is the strength of interference competition which depends on the difference Δx of the log-body sizes (and hence on the ratio of the true body sizes), and where the last term is the loss to predation. The population density P of the predator is constant (presumably because it is largely regulated by other factors that have no impact on the model). The predator has a Holling type III functional response with respect to total prey density.

As a large body size is costly in terms of reproduction or survival, we assume that r is a decreasing function of x. Large body size by itself does not help winning a contest but being larger than the opponent does. We therefore assume that the competition coefficient α is a decreasing function of the size difference.

Study the adaptive dynamics of $x \in \mathbb{R}$. This can be done partially analytically. For numerical work, assume that r is a linearly or exponentially decreasing function, and that the competition coefficient is of the form

$$\alpha(\Delta x) = c\left(1 - \frac{1}{1 + \nu e^{-k\Delta x}}\right).$$

The key to this project is to understand the population dynamics of the monomorphic resident population: for certain parameters and resident strategies, there may be two stable equilibria. When this is the case, a PIP must be developed for each attractor separately.

Here are some further suggestions you may want to consider:

(1) Find parameter values that give opposite signs of the selection gradient on the respective attractors. This can lead to evolutionary cycles by periodic switching of resident attractors.

(2) Find parameters that give a branching point, and investigate the dimorphic evolution.