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A Parent-Offspring Trade-Off Limits the Evolution of an Ontogenetic Niche Shift

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Appendix A from H. ten Brink and A. M. de Roos, “A Parent-Offspring Trade-Off Limits the Evolution of an Ontogenetic Niche Shift” (Am. Nat., vol. 190, no. 1, p. 45)

Canonical Equation

The canonical equation of adaptive dynamics is a deterministic approximation describing the rate of evolution in a population that is mutation limited and where mutation steps are small (Dieckmann and Law 1996; Durinx et al. 2008). The evolutionary rate of change of a trait is proportional to the selection gradient and depends, furthermore, on the production rate of mutants, their establishment chance, and the mutational covariance matrix. Because the degree of food specialization ψ is a morphological trait while food choice ϕ is a behavioral trait, we assumed the traits to be completely independent of each other; therefore, the mutational covariance matrix, which in this case equals the identity matrix, does not play a role in the evolutionary trajectories. The rate of change of traits \mathbf{y} in a monomorphic, size-structured population can then be described as

$$\frac{d\mathbf{y}}{d\tau} = \frac{T_f \hat{n} \mu}{T_s \sigma^2} \frac{\partial s(\mathbf{y}'|\mathbf{y})^\top}{\partial \mathbf{y}'} \bigg|_{\mathbf{y}'=\mathbf{y}}, \quad (\text{A1})$$

where τ spans the evolutionary timescale (Durinx et al. 2008). In this equation T_s is the expected life span of an individual, T_f the average age at giving birth, \hat{n} the size of the population in equilibrium, μ the mutation probability per birth event, σ^2 the variance of the offspring trait distribution, and

$$\frac{\partial s(\mathbf{y}'|\mathbf{y})^\top}{\partial \mathbf{y}'} \bigg|_{\mathbf{y}'=\mathbf{y}} \quad (\text{A2})$$

the selection gradient. Because we have an explicit expression for R_0 , we use this as a measure of invasion fitness. The relation between R_0 and the invasion fitness $s(\mathbf{y}'|\mathbf{y})$ is given by

$$s(\mathbf{y}'|\mathbf{y}) = \frac{\log(R_0(\mathbf{y}'|\mathbf{y}))}{T_f} \quad (\text{A3})$$

(Durinx et al. 2008). Because we studied the evolutionary change of two traits in a single population, T_s and \hat{n} are equal for both equations and scale only the evolutionary rates but do not change the evolutionary endpoints.

Furthermore, when it is assumed that the size and variance of the mutations are equal for both traits, the mutation rates and the selection gradients are the only factors that determine the evolutionary trajectories. The food source preference ϕ of an individual can evolve rapidly, and this could even happen on an ecological timescale because of learning (e.g., Slagsvold and Wiebe 2007). On the other hand, ψ probably evolves more slowly, since it is a morphological trait. We assume, therefore, that the mutation rate of trait ϕ is higher than the mutation rate of trait ψ . The canonical equation for the two traits now simplifies to

$$\begin{aligned} \frac{d\phi}{d\tau} &= C_1 \frac{\partial R_0(\phi'|\phi)}{\partial \phi'} \bigg|_{\phi'=\phi}, \\ \frac{d\psi}{d\tau} &= C_2 \frac{\partial R_0(\psi'|\psi)}{\partial \psi'} \bigg|_{\psi'=\psi}, \end{aligned} \quad (\text{A4})$$

where we choose C_1 to be 10 times as high as C_2 . Decreasing (increasing) C_1 decreases (slightly increases) areas 1 and 2 in figure 4 but does not qualitatively change the evolutionary outcomes. The evolutionary time units can be considered arbitrary, since they are freely adjustable through the choice of the constants C_1 and C_2 .