

# Speciation Through the Learning of Habitat Features<sup>1</sup>

Consider two habitats,  $A$  and  $B$ . The viability within a habitat is determined by one diploid locus with two alleles. The three possible genotypes are denoted by  $g_A g_A$ ,  $g_A g_B$  and  $g_B g_B$ . Individuals are further characterized by a cultural trait that is determined by the habitat they are born into,  $c_A$  or  $c_B$ . There is female demographic dominance and dynamics of females and males are equal. Generations are discrete and non-overlapping. Mating is polygynous, and female preferences depend on both male frequencies and cultural traits. After or during production of young there is local density regulation, and then viability selection takes place.

Each female in the population is characterized by its genotype, cultural trait, and two real-valued parameters,  $\alpha$  and  $p$ . Parameter  $\alpha$  determines mating preferences of the female. The value  $1 - p$  is the habitat preference.

Let  $N_1, N_2, N_3$  be the number of females with cultural trait  $c_A$  and genotypes  $g_A g_A, g_A g_B, g_B g_B$ , and let  $N_4, N_5, N_6$  be the number of females with cultural trait  $c_B$  and genotypes  $g_A g_A, g_A g_B, g_B g_B$ . The total number of females with cultural trait  $c_A$  is denoted by  $N_A = N_1 + N_2 + N_3$ . The value of  $N_B = N_4 + N_5 + N_6$  is introduced similarly. The total population size is  $N = N_A + N_B$ .

Denote the probability that a female that was born in habitat  $X$  mates with a male from the same habitat by  $\rho_X(\alpha)$ , where  $0 < \alpha < 1$  is the strength of the mating preference. Put

$$\rho_A(\alpha) = \frac{\alpha N_A}{\alpha N_A + (1 - \alpha) N_B}, \quad \rho_B(\alpha) = \frac{\alpha N_B}{(1 - \alpha) N_A + \alpha N_B}.$$

Thus, the functions are non-negative, increasing in  $\alpha$ , approaching 0 as  $\alpha \rightarrow 0$  and approaching 1 as  $\alpha \rightarrow 1$ . If  $\alpha = \frac{1}{2}$ , we have  $\rho_A(\frac{1}{2}) = \frac{N_A}{N_A + N_B}$ ,  $\rho_B(\frac{1}{2}) = \frac{N_B}{N_A + N_B}$ , and the female shows no mating preferences.

A female produce their young in the same habitat as they were born in with probability  $1 - p$ , so the value  $1 - p$  is referred to as the habitat preference. In each habitat there is local density regulation that depends on the density in the habitat. Denote by  $E$  female fertility,  $K$  carrying capacity (higher  $K$  implies higher carrying capacity),  $N'_A$  and  $N'_B$  numbers of females choosing habitats  $A$  and  $B$  for producing young. Local density regulation is governed by the following probabilities of survival for each young,

$$Q_A = \frac{K}{K + (E - 1)N'_A}, \quad Q_B = \frac{K}{K + (E - 1)N'_B}.$$

Thus, if  $N'_A = K$ , then one young survives in average in habitat  $A$ . If  $N'_A$  is less/more than  $K$ , more/less than one young survives in average in habitat  $A$ .

Each young inherits mother's values of  $\alpha$  and  $p$  with small random changes such that the values of  $\frac{1-\alpha}{\alpha}$  and  $\frac{1-p}{p}$  perform additive random walks on the log-scale. So, that  $\alpha$  is transformed into  $\alpha'$  such that

$$\frac{1 - \alpha'}{\alpha'} = \frac{1 - \alpha}{\alpha} e^\xi,$$

where  $\xi$  is normally distributed with zero mean and standard deviation  $\text{sd}_\alpha$ . The value of  $p$  is transformed similarly.

Survived young are subject to viability selection depending on their genotype and the habitat they exploit. In habitat  $A$ , individuals carrying more  $g_A$  alleles have a higher viability than other individuals, while in habitat  $B$  this is the case for individuals carrying more  $g_B$  alleles. The values of viability are the probabilities of survival for each young.

Young survived local density regulation and viability selection form the next generation.

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<sup>1</sup>This is a modified individual-based model borrowed from the paper by J.B.Beltman, P.Haccou. Speciation Through the Learning of Habitat Features.// Theoretical Population Biology, 67 (2005), p.189-202.