

Influence of local interaction, mating, and dispersal on adaptive speciation in sexual populations

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Goal

To analyze conditions for evolutionary branching in a sexual population influenced by local interactions between individuals.

Background and motivation

Explaining the origin and development of species diversity is one of the greatest challenges in biology. To meet this challenge, it is necessary to achieve a better understanding of speciation processes: Speciation is the process by which one species splits into two or more daughter species, which evolve as distinct lineages.

Studies of speciation classically focus on its geographical context (Mayr 1942, 1963) ranging from allopatry (speciation observed when a population gets divided by a physical barrier; after accumulating genetic differences reproductive incompatibility may be established) to sympatry (reproductive isolation and speciation occur without geographic isolation). In the case of the sympatry, there are two main explanations of speciation: ecological differentiation through natural selection (Schluter 2001) and mating differentiation through sexual selection.

Several studies have suggested that in the presence of gene flow between subpopulations, the adaptive evolution of prezygotic isolation mechanisms such as assortative mating may prevent the creation of organisms with intermediate phenotype and thus enable speciation (Dieckmann and Doebeli 1999; Higashi et al. 1999; Kondrashov and Kondrashov 1999; Doebeli and Dieckmann 2003). Assortativeness is a well-known phenomenon in nature, and organisms with complex behavioral may be more likely to form new species because they choose among potential mating partners. They distinguish members of their own species among potential mating partners on the basis of their size, shape, ornaments, and behavior. Such discriminations can greatly influence which individuals are most successful in producing offspring and may lead to the rapid reinforcement of reproductive isolation between incipient species.

Past research has highlighted the importance of spatial population structure for the eco-evolutionary processes underlying speciation. A recent study of sympatric/parapatric speciation along environmental gradients (Doebeli and Dieckmann 2003) also showed that evolutionary branching occurs more easily in spatially structured populations owing to the presence of local adaptation and competition among individuals with low mobility.

Research questions

In this project I will examine an individual-based model of organisms with sexual reproduction, to investigate features of speciation process under sympatric conditions. For this I will try:

- To establish in general how conditions for evolutionary branching are influenced by the spatial structure of a population, by comparing structured and well-mixed populations.

This goal can be broken down into three more specific steps by looking, in turn, at the effects of local interactions, local mate choice, and local dispersal.

- To investigate the influence of local interactions on evolutionary branching.
The more well-mixed a population, or the larger the distances over which individuals interact, the more phenotypes will participate in the competition affecting any focal individual. How this affects evolutionary branching will be examined.
- To investigate the influence of local mate choice on evolutionary branching
I expect to obtain more favorable conditions for evolutionary branching when individuals prefer to mate with similar partners that are situated close to their own location. Owing to the restriction of gene flow, spatially proximity implies phenotypic proximity.
- To investigate the influence on evolutionary branching of the local dispersal of offspring around parents.
Recently it has been shown that in natural populations non-random dispersal results in genetic differentiation in fitness-related traits (Garant et al 2005; Postma and van Noodwijk 2005). I would like to study whether the movement of offspring by short distances away from their parents could result in the formation of local groups of individuals with similar phenotype and how such pattern formation could influence the dynamics of local competition and, in consequence, evolutionary branching.

Time permitting, a related additional question will be addressed:

- To study the influence of sex structure on evolutionary branching.
Previous models have considered hermaphroditic individuals, so that the question of how sex structure affects the process of evolutionary branching still remains open.

Methods and work plan

Model description

At the first step I will construct an individual-based model, along the lines of the model presented by Doebeli and Dieckmann (2003), to study evolutionary branching in a sexual population. Disruptive selection in this model arises from competition for a distribution of resources.

The model describes hermaphroditic individuals with sexual reproduction. Alternatively, the population could also be considered as containing separate sexes, provided that the spatial and phenotypic distribution of males and females is equal. For investigating the influence of the sex ratio, I plan to extend this model to describe male and female individuals separately.

Phenotypes in each individual are determined by three sets of diallelic diploid loci. The first trait (ecological character) will determine the resource use, the second one (mating trait) will be responsible for the degree of assortative mating, and the third trait (marker trait) will determine an ecologically neutral trait that serves as a mating signal. Individuals are characterized by the rates at which births, deaths, and movements occur.

Reproduction occurs with constant intrinsic rate, but individuals depend on the existence of suitable partners for mating in their local neighborhood. The assortative mating in the model will be based either on the ecological trait or on the neutral marker trait. Individuals with a mating character of 0 mate randomly. Individuals carrying more ‘minus’ than ‘plus’ alleles at the mating loci mate disassortatively, whereas individuals with more ‘plus’ alleles are more likely to mate with individuals with a similar ecological trait or marker trait. Offspring inherit alleles from both of their parents at each locus independently. Random mutations of alleles occur with a given small probability.

Each newborn offspring undergoes an initial movement event from the location of its parent. Individuals die according to local logistic competition. Movement occurs at a constant rate, with individuals changing their location by a random distance drawn from a normal distribution.

The model is defined in continuous time and continuous space, with periodic boundary conditions in a uniform square environment. The resource that individuals compete for has a unimodal (Gaussian) distribution. Algorithmically, the model will be implemented using the minimal process method (Gillespie 1976).

Work plan

Based on this model, I will investigate processes of evolutionary branching by changing the population’s spatial structure from structured to well-mixed. In particular, I will study the influence on evolutionary branching of the distances over which individuals interact, mate, and disperse, as described in more detail above.

June: During this month I plan to construct the model and run preliminary computer simulations to test it.

July: I will then establish how conditions for evolutionary branching are influenced by the spatial structure of a population, by running computer simulations to investigate the influence of local interactions, mate choice, and offspring dispersal. If the previous steps will be completed quickly, I will also study the influence of sex structure on evolutionary branching.

August: The first half of this month will be focused on summarizing the results. During the last two weeks, I will concentrate on preparing a manuscript describing these results.

Relevance and link to EEP’s research plan

The proposed research will extend previous studies of mechanisms underlying, and factors influencing, processes of adaptive speciation carried out by EEP (e.g., Dieckmann and Doebeli 1999; Doebeli and Dieckmann 2003).

Expected output and publications

This work will constitute an important part of my PhD thesis and is destined for publishing as a co-authored article in a research journal.

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