Adaptive evolution and then what?

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Introduction

Traits determining ecological interactions and dynamics are generally subject to natural selection. That genetically based individual variation in ecological traits can influence population dynamics has interested population biologist from various perspectives. Population ecologists recognized the need to incorporate individual variation in models of population regulation (1,2), while evolutionary biologists wish to understand genetic and evolutionary dynamics, e.g. of life history traits, in density-regulated populations (3,4).

But how does adaptation in ecological traits affect population dynamics? In this project we investigated how ecological dynamics changes as a consequence of adaptive evolution in ecological traits. We used an individual-based predator-prey model in which average predator phenotype and predator phenotypic plasticity can evolve to increase predations efficiency in two contrasting habitats.

During simulations, four different evolutionary dynamics unfolded: 1) the predator evolves an increased phenotypic plasticity, allowing it to efficiently prey on both prey types; 2) the predator diversifies into one generalist genotype with high degree of plasticity and two specialist genotypes with low degree of plasticity; 3) the predator diversifies into two specialists with low degree of plasticity; and 4) the predator becomes perfectly adapted to the optimal phenotype in one of the two habitats, with low degree of phenotypic plasticity.

Model

The basic model consists of two prey types and one predator with dynamics described by

$$\frac{dN_i}{dt} = r_i N_i \left(1 - \frac{N_i}{K_i}\right) - F_i P$$

$$\frac{dP}{dt} = \left(P \sum c_i F_i\right) - mP$$

where i is an index of the two prey types, F_i the functional response of the predator for prey type i and c_i is conversion efficiency. The functional response is defined as $F_1 = qf_1$ and $F_2 = (1-q)f_2$ where q is the probability that the predator prefers prey type 1 and

$$f_i = \frac{a_i N_i}{V_i + a_i h_i N_i}$$

Here a_i is the attack rate and h_i is the handling time of prey type i The conversion efficiency is defined as $c_i = d_i(1 - yk_i)$ where d_i is the maximal conversion efficiency for prey type i. y is a quantitative genetic trait describing the degree of phenotypic plasticity and k_i is a species specific scaling factor for the cost of plasticity.

The predation preference depends on predator genotype and prey availabilities.

Attack rate and handling time for either prey type i are optimized for a certain phenotype $\hat{u}_i$ ($\hat{u}_1 = -\hat{u}_2$). The predator's performance on prey type i depends on how close the predator's phenotypes (u_1, u_2) match the optimal phenotype ($\hat{u}_1$, $\hat{u}_2$). The further away the predator phenotype is from the optimal phenotype for a given prey type, the lower the predation efficiency. The predator's phenotypes are defined in terms of two quantitative genetic traits x and y, where x is the mean morphology of the predator and y is the phenotypic plasticity around x. Specifically, the predator's phenotypes u_i are given as:

$u_1 = x + y$ and $u_2 = x - y$.

Results

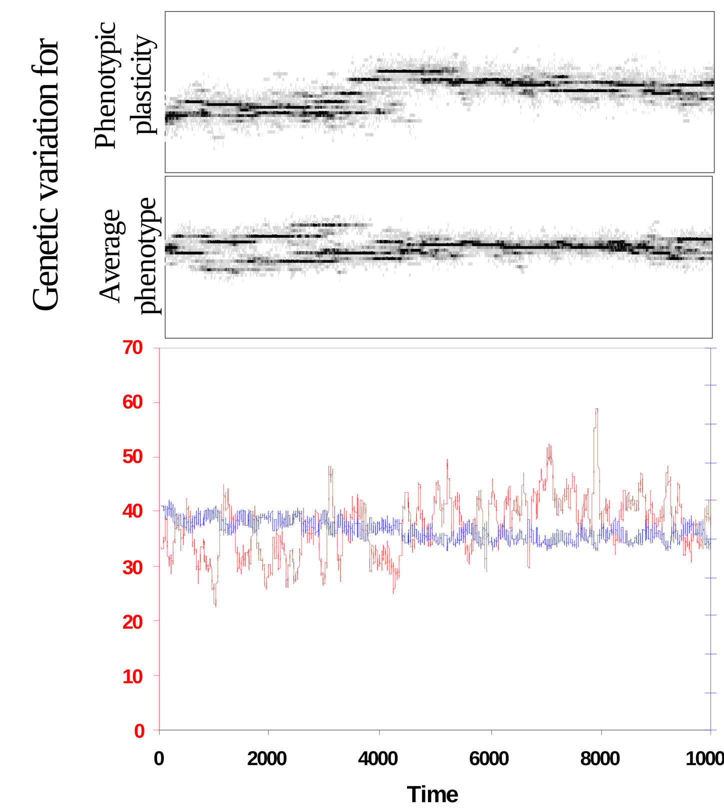

Figure 1. In simulations where phenotypic plasticity was favored and no branching occurred in average phenotype, the average population density declined slightly whereas density fluctuations (CV) remained more or less constant.

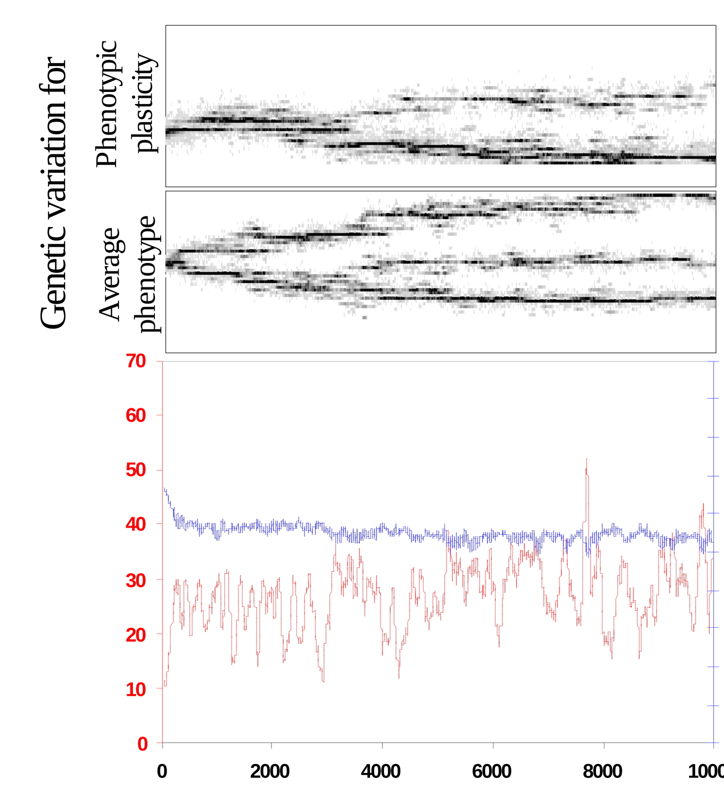

Figure 2. In simulations where two specialists with no plasticity and a generalist with high degree of plasticity evolved, the average population density decreased initially whereas population fluctuations increased initially and then remained high.

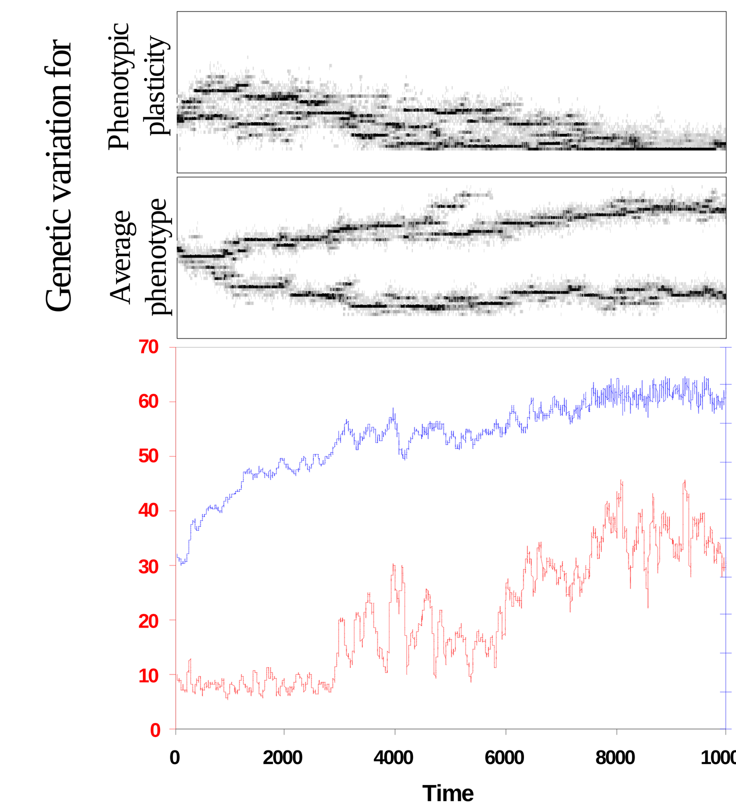

Figure 3. In simulations where two specialists with no plasticity evolved, the average population density decreased initially but then increased. Population fluctuations initially remained low and constant whereas after branching and when phenotypic plasticity started to decline, population fluctuations started to increase to high levels.

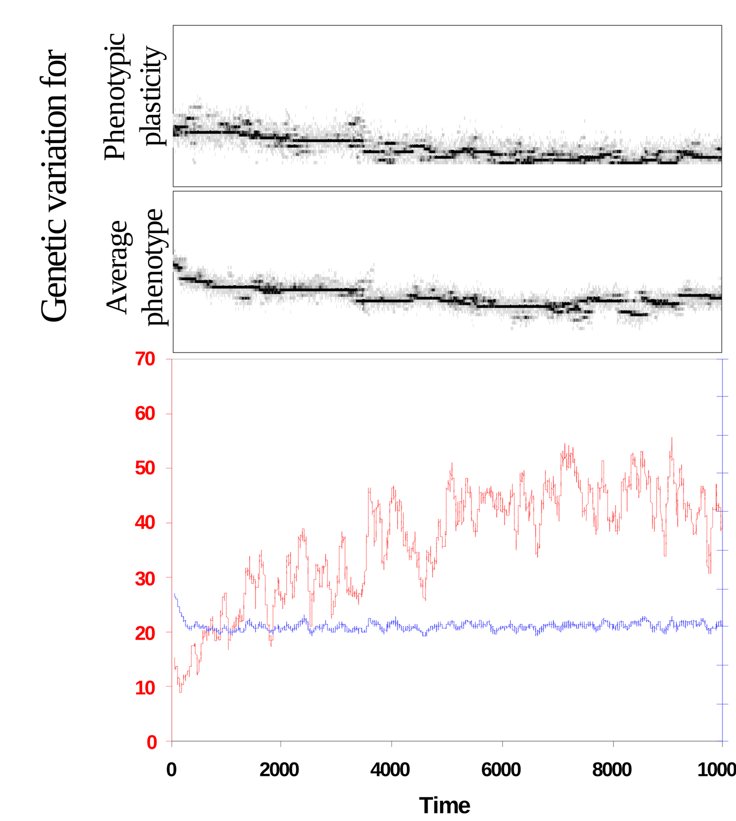

Figure 4. In simulations where the predator population evolved to be adapted to habitat 1, the average population density decreased initially whereas population fluctuations increased to high levels.

Conclusion

Many ecologists interested in population dynamics have been skeptical of the relevance of genetics and natural selection in their research. However, the two main results of our model show that:

1) Population fluctuations are changing with evolutionary dynamics, and

2) Adaptive evolution does not always have to lead to an increase in population density

Our previous work has shown that the type of evolutionary dynamics that occurs in this model depends on the ecological dynamics of the model (5). Here we have shown that there is a feedback in the other direction as well: population dynamics changes as a consequence of evolutionary change in demographic traits. Therefore, further evolutionary dynamics in such systems might depend on the "new" population dynamics created by the concurrent evolutionary dynamics.

References

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For further information

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