The evolution of the mutation rate and the effect of phenotypic plasticity under scenarios of directional environmental change

an individual-based eco-evolutionary model

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INTRODUCTION

A current challenge in ecology and evolutionary biology is to understand and predict how species cope with increasing rates of environmental change (Chevin et al. 2010). Populations of organisms facing these perturbations are expected to respond either by local genetic adaptation or plasticity, an active or passive shift of the distributional range, or (local) extinction (Wiens 2016).

In this project we developed an individual-based model and focused on local adaptation: genetic changes and phenotypic plasticity. We are interested in studying conditions promoting population persistence under directional climate change scenarios.

OBJECTIVES

1. to investigate how the **mutation rate** is influenced by genomic properties and the rate of directional environmental change (climate change).

   Why? Since variation in DNA repair and replication processes exists, the mutation rate might be subject to selection and its evolution might depend on the conditions of environmental change.

2. To study how adaptive and non-adaptive **phenotypic plasticity** affect persistence and performance of different kind of organisms under scenarios of environmental stochasticity or noise color, and of rate of environmental change.

METHODS

In our model, density compensation (α) affected the fecundity of an individual. Fecundity was defined as the number of offspring an individual could contribute to the next generation (Fig. 1A and 1B).

The environment was simulated through a moving optimum ϑ_t representing a continuous environmental variable. The parameter ϑ_t moved at rate r per simulated time step (Fig. 2). Different scenarios of stochasticity (noise color) were considered (Fig. 2).

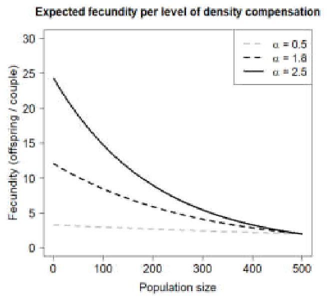


Fig. 1A Expected fecundity (offspring / couple) for each life strategy (levels of α)

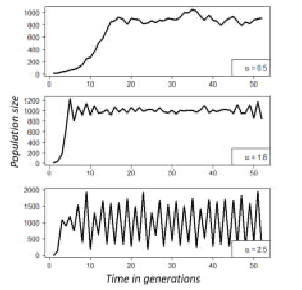


Fig. 1B Population dynamics per life strategy (level of α)

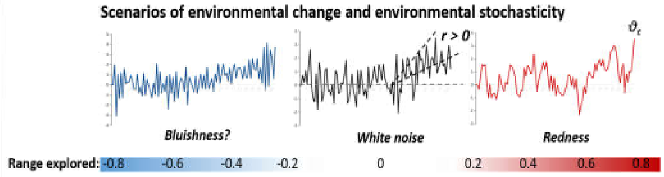


Fig. 2 Examples of scenarios of environmental stochasticity (noise color) and rate of environmental change. A broad range of the level of autocorrelation was explored: negative autocorrelation lead to blue noise, while positive, to red noise

1 RESULTS

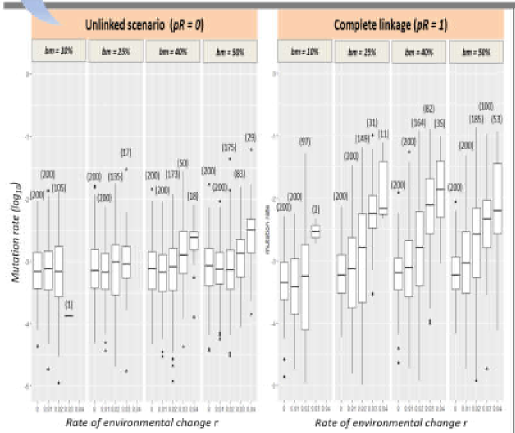


Fig. 4 The evolution of the mutation rate under scenarios of directional environmental change, probability of recombination *pR*, and percentage of beneficial mutations *bm*. Each data point corresponds to the mean mutation rate present in the population at the end of each simulation run (200 generations). The number of data points per box is shown in parenthesis.

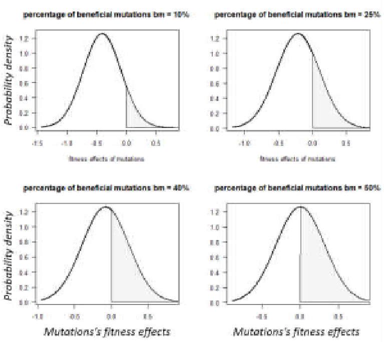


Fig 3 Distribution of fitness effects of mutations according to different scenarios of percentage of beneficial mutations *bm*. Beneficial mutations are shown in light grey color.

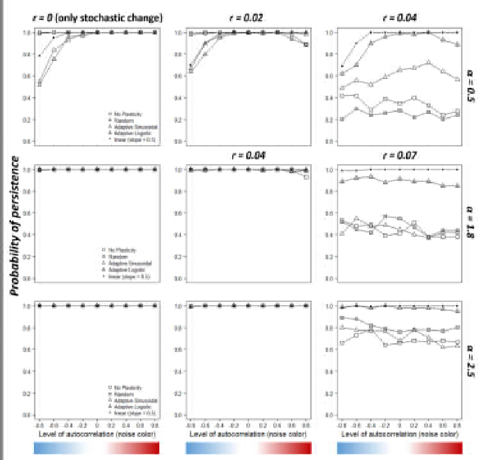
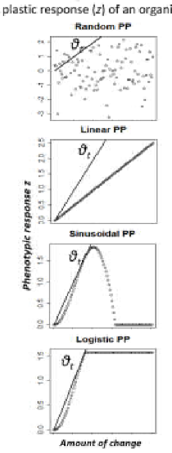


Fig 6 Effect of types of phenotypic plasticity on the probability of persistence of life strategies (levels of α) under different scenarios of stochasticity (noise color) and rate of environmental change r.

Fig 5 Types of phenotypic plasticity. The straight line represents the environmental optimum ϑ_t and the dots, the plastic response (z) of an organism



CONCLUSIONS the evolution of the mutation rate

Considering that 50% beneficial mutations may be an unrealistic assumption, and that recombination is ubiquitous in a sexual species, results suggest that, it is unlikely for the mutation rate to evolve in a sexual species experiencing directional climate change scenarios. Therefore, when the percentage of beneficial mutations is small, and populations are not large enough, sexual species (especially multicellular ones) producing few offspring may be expected to buffer their ability for local adaptation mainly through plasticity, provided that movement opportunities are constrained.

2 CONCLUSIONS phenotypic plasticity

- Adaptive phenotypic plasticity can both promote and hinder evolution, and this depends on the scenario of environmental stochasticity (noise color).
- Linear reaction norms can overestimate probability of persitence
- Organisms that produce relatively few offspring (slow population growth rate, $\alpha = 0.5$) benefit, to a larger extent, from adaptive phenotypic plasticity, as compared to organisms with larger clutch size.

Nature / the Universe inspires all questions, and contains all answers

Always think the world as bigger, so you can give room for surprises

References

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