To adapt and persist in a changing environment

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Introduction

- Habitats are undergoing unprecedented rates of fragmentation and change
- Isolated populations respond to a changing environment by altering both traits and abundance
- By including both we capture the nature of the race: hurry up and adapt before you go extinct

Evolutionary rescue

- Maladapted populations will rapidly decline to extinction if they do not evolve
- Populations which evolve fast enough to prevent extinction are “rescued” by evolution

Questions

- What is the maximum rate of environmental change a population can withstand?
- Which aspects of a population does this maximum rate depend on?

Model

- We model the evolution and abundance of a population as the environment changes gradually
- Abundance $p_i$ of phenotype $i$ grows logistically and experiences Lotka-Volterra competition:

$$\frac{dp_i}{dt} = p_i R(1 - \frac{1}{K} \sum_j a_{ij} p_j)$$

- One quantitative trait $s_i$ determines fitness, through competition $a_{ij}$ and carrying capacity $k_i$:

$$s_{ij} = e^{-(s_i - s_j)^2/2\sigma_i^2}$$

- Trait-dependent competition $a_{ij}$; similar values compete strongest.

- Trait-dependent carrying capacity $k_i$; maximum at optimal trait value $s_{opt}$.

Analysis

- To persist, a population must evolve as fast as the environment changes.
- Maximum rate of evolution increases with:
  - mutational rate $\mu$
  - mutational variance $\sigma_i^2$
  - population size (carrying capacity) $K$
  - reproductive rate $R$
  - strength of stabilizing selection $\sigma_k$

$$\frac{ds}{dt} |_{max} = \frac{\pm \mu \sigma_i^2 K R}{\sigma_k \sqrt{\epsilon/2}}$$

Figure 2. The rate of evolution $\frac{ds}{dt}$ as a function of the distance from the optimal $|s - s_{opt}|$. It is maximal $\frac{ds}{dt}_{max}$ at an intermediate distance. See Box 1 for details.

Simulations

- We have formulated an expression for the maximum rate a population can evolve
- In the long-run, a population must evolve as fast as the environment changes, or go extinct
- Conservation efforts should therefore take the above variables into account when assessing risk

Directions

- Compare maximum rate of evolution with quantitative genetic models
- Test predictions with experiment: expose yeast to increasing salt concentrations
- Examine extinction risk when the environment changes abruptly

References