Effects of resource competition on evolution and adaptive radiation

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Plan of talk

- Introduction
  - Lotka-Volterra equations
  - Motivation
- Introducing the model
  - Resource contest
  - Mutations model
- Results

Introduction

Lotka-Volterra equations

The competitive Lotka-Volterra equation reads

$$\frac{dn_\mu}{dt} = n_\mu r_\mu \left(1 - \sum_{\mu'=1}^{N} \alpha_{\mu\mu'} n_{\mu'} \right)$$

where n_μ are abundances, r_μ are per capita growth rates and $\alpha_{\mu\mu'}$ is interaction matrix

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L-V equations are very extensively studied in the case of static coefficients. No evolution and its feedback on population dynamics.

Goals of present study

- Incorporate the resources which are shared contested by all species (but not in so complex way as in food-web models)
- Introduce reasonable ecological scenarios for the time behavior of the resources
- Make the coefficients of the interaction matrix α_{ij} experience the evolutionary motivated alterations (but not in so complex way as in genome simulators like SimuPOP)
- Stay within population abundances n_{mu} formalism and not go to Individual Based Models (IBM)

The model

Population dynamics

L-V equations can be rewritten via resource surplus Δ_μ as

$$\frac{dn_\mu}{dt} = n_\mu f(\Delta_\mu)$$

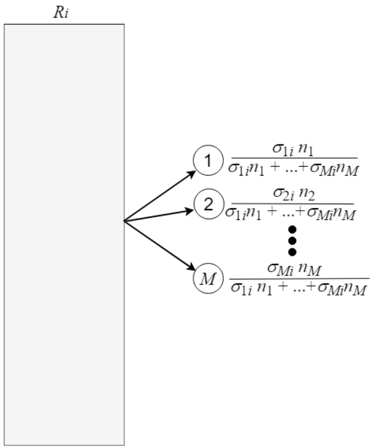
Function $f(\Delta)$ should grow with Δ and $f(0) = 0$. The surplus

$$\Delta_\mu = \sum_i \sigma_{\mu i} h_{\mu i} - 1,$$

where $h_{\mu i}$ is availability of resources i for species μ

$\sigma_{\mu i}$ is the **gaining effectiveness** of the resource of type i by species μ. In another words $\sigma_{\mu i}$ is an investment of species μ into harvesting resource i.

Common resource distribution model



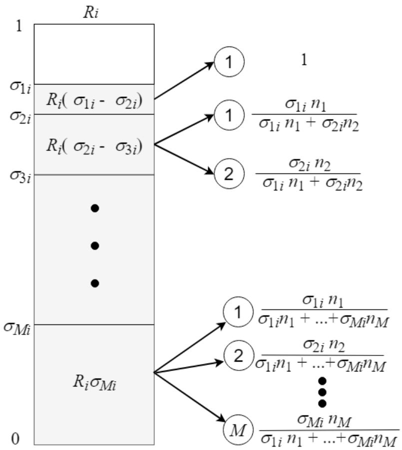
Common formula for resource i availability calculating:

$$h_i = \frac{R_i}{\sum_\mu n_\mu \sigma_{\mu i}}$$

Total abundance in ecosystem is restricted by resource influx R_i.

There is no strong motivation to enhance $\sigma_{\mu i}$ thanks to beneficial mutations.

Developed resource distribution model



The species can not gain more than $R_i\sigma_{\mu i}$ of resource. It is favorable to **increase the gaining effectiveness** $\sigma_{\mu i}$.

Abundance is restricted by $R_i\sigma_{\mu i}$

Evolutionary aspects

No specialists in everything: we restrict $\sum_{i=1}^{R} \sigma_{\mu i} < 1$

Deleterious mutations
At each step we subtract from $\sigma_{\mu i}$ some small *uniformly* distributed random value

Beneficial mutations
Rarely we add some large *exponentially* distributed values to $\sigma_{\mu i}$.
Parameter D controls strength of beneficial mutations

- $D = 0$ - no beneficial mutations
- $D = 1$ - deleterious and beneficial mutations fully compensate at large times

Reproductive isolation: forking/speciation time T to split the species μ into species μ and ν

The **Molecular clock** as a randomly alternated bit array like "0001000110000" is used to trace the phylogeny

Results

Verification of the model

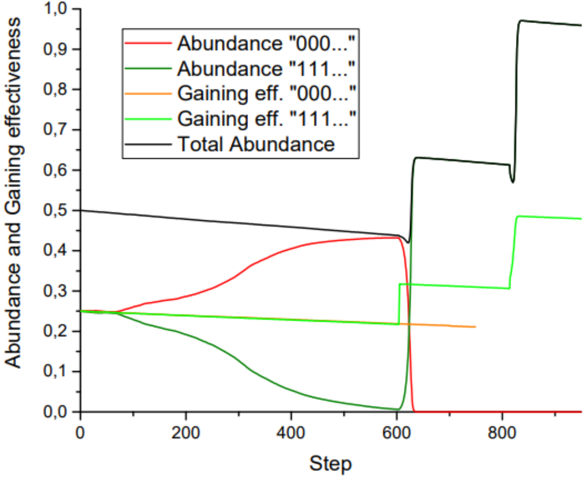
The model should obey the following ecological axioms:

- Competitive exclusion principle
- Resistance to genomic decay
- Absence of vacant ecological niches

The model should obey the following ecological scenarios:

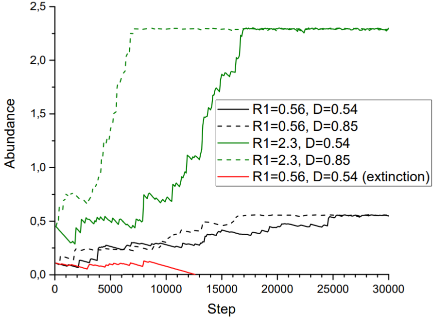
- **Specialization in constant** environment (constant resource influx R_i for several resource types)
- **Omnivory** in rapidly changing environment (**randomly alternating** resource influx R_i)

Competitive exclusion principle

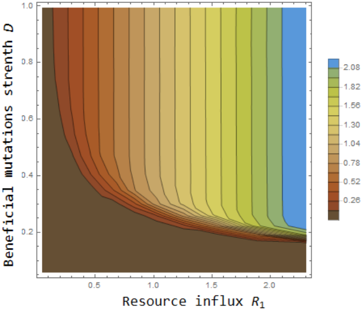


Due to strong beneficial mutation at 600-th step "green" species survives and "red" species is extincts.

Genomic decay resistance

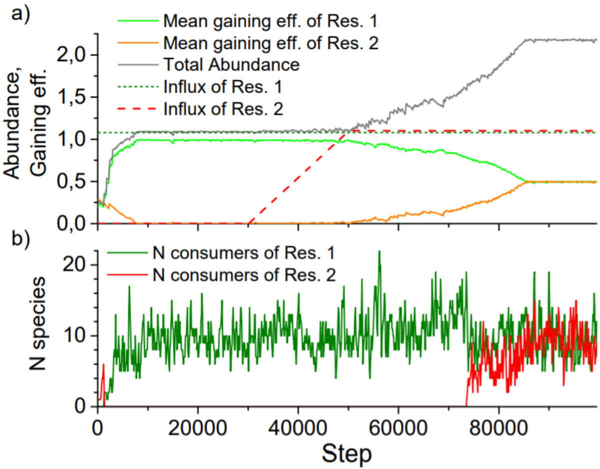


Abundance vs time step at various levels of resource influx R_1 and level of beneficial mutaions D



Survival phase diagram: abundance after 100000 steps at various levels of resource influx R_1 and level of beneficial mutaions D

No vacant ecological niche

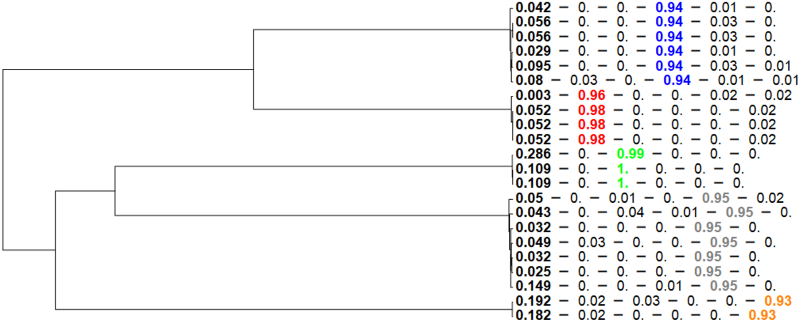


From 30000 to 50000 step the influx of second resource R_2 grows from 0 to 1. As a result, its "red" consumers appear at ≈ 75000 step.

Ecosystem in stable environment

$$R_1 = R_2 = R_3 = R_4 = R_5 = \text{const}$$

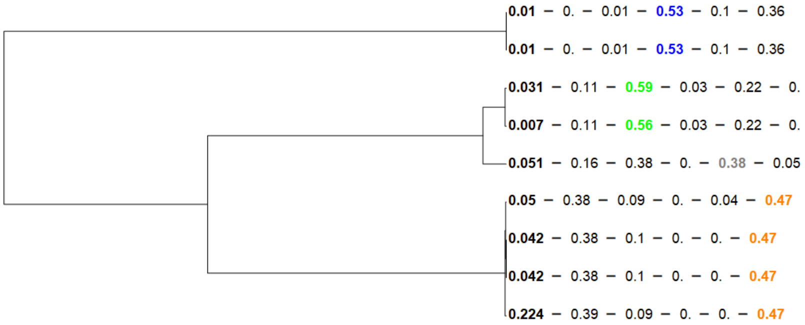
. **Abundance** – $\sigma_{\mu 1}$ – $\sigma_{\mu 2}$ – $\sigma_{\mu 3}$ – $\sigma_{\mu 4}$ – $\sigma_{\mu 5}$



Strong **specialization**: for each species some of $\sigma_{\mu i} \approx 1$

Ecosystem in unstable environment

$$R_1 + R_2 + R_3 + R_4 + R_5 = \text{const}; \qquad R_{1,2,3,4,5} = \text{random}$$



No specialization: no dominating gaining effectiveness $\sigma_{\mu i}$

Conclusions

- The model bringing evolutionary aspects to population dynamics is introduced
- The model reproduces main ecological concepts

Thanks for your attention!