Evolution of Network Structure and Species Diversity in an Evolutionary Foodweb Model

Tobias Rogge

Thanks to Barbara Drossel and Korinna T. Allhoff

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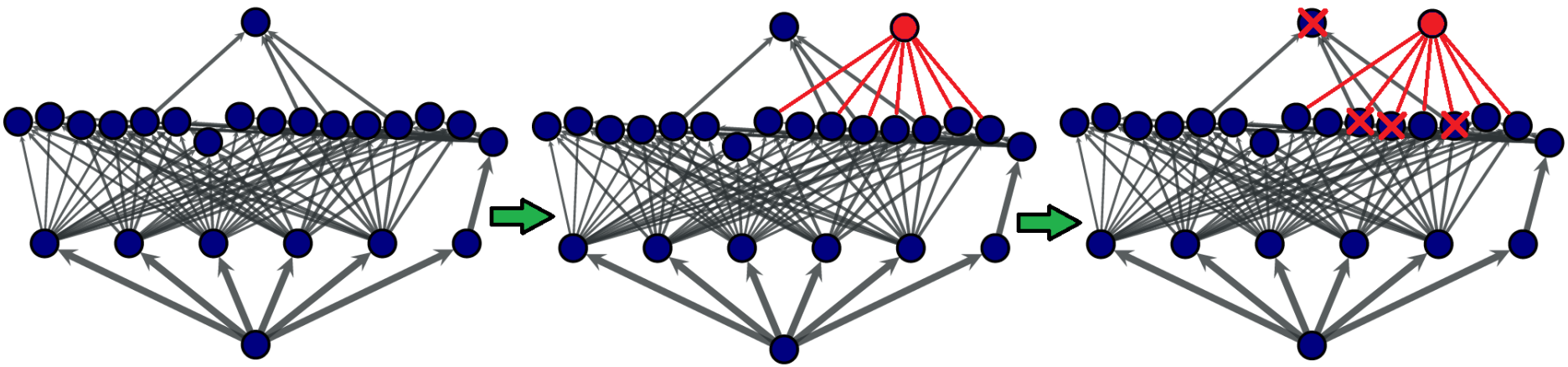

Questions

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- Which structures emerge in a system with ongoing species addition and extinction?

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- Which structures emerge in a system with ongoing species addition and extinction?
- What is the long term behaviour of the network dependent on the parameters of the model?
- How do networks evolve in a spatial setting with migration?

Evolutionary foodweb model
Overview

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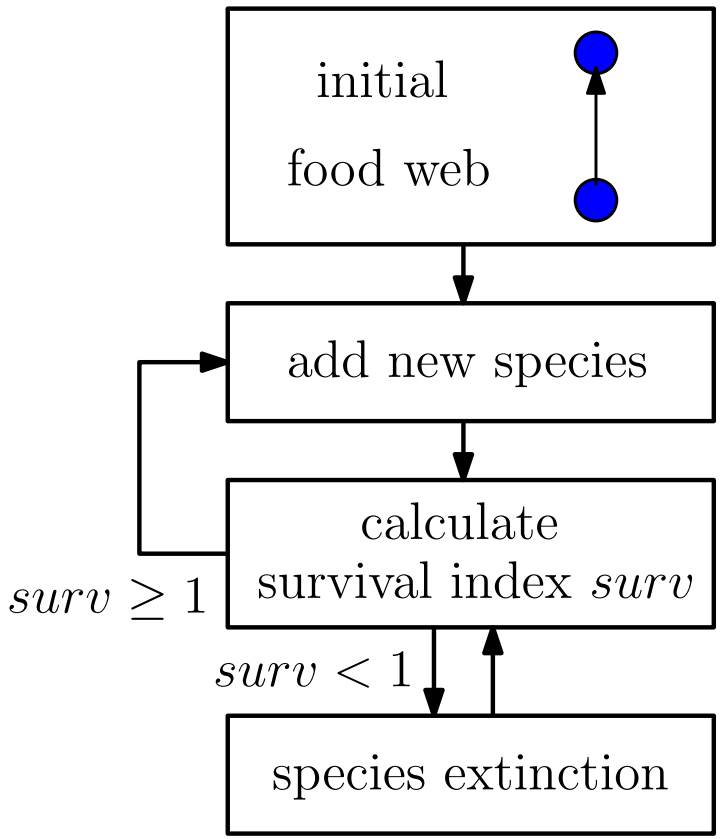

Evolutionary foodweb model
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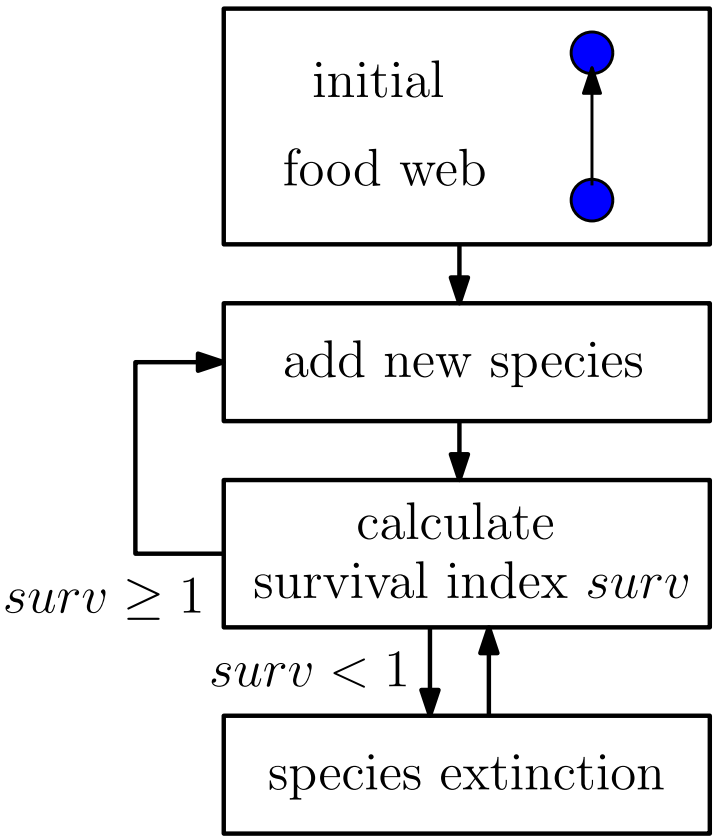
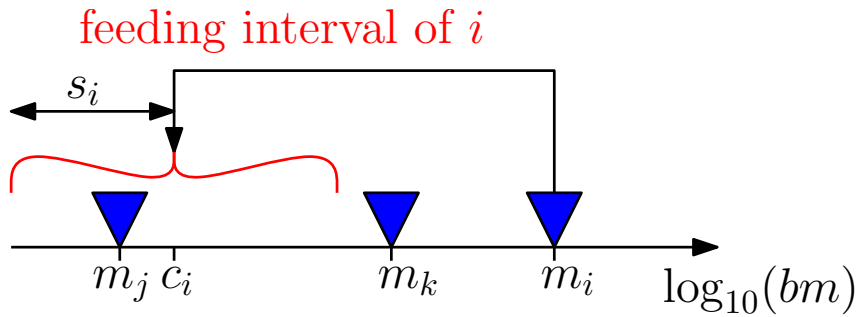


- Each species *i* has three key traits:
  - body mass m_i
  - feeding center c_i
  - feeding range s_i



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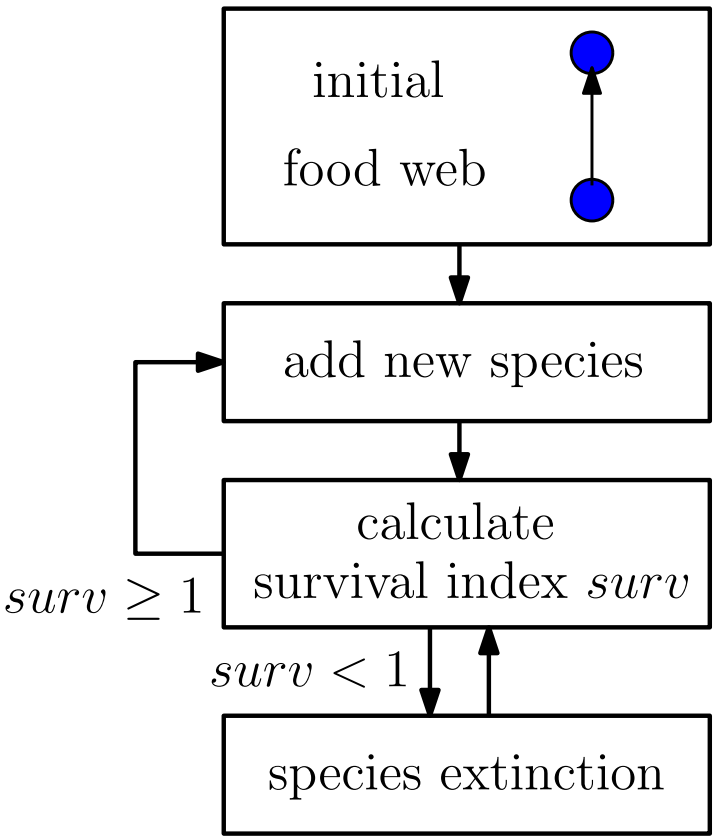

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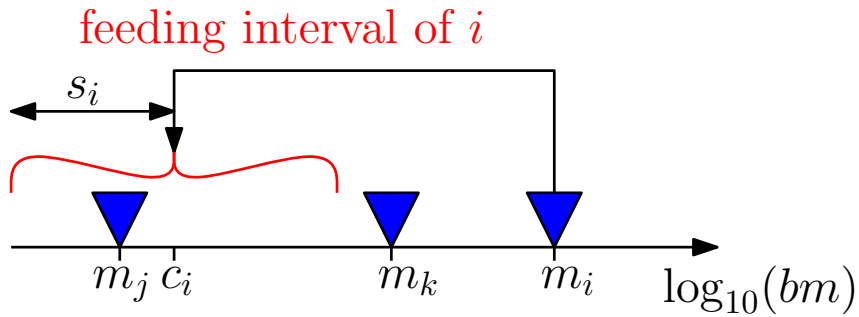
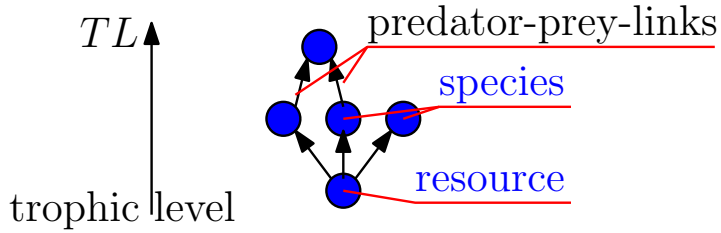


- Species traits determine the trophic structure of the food web.



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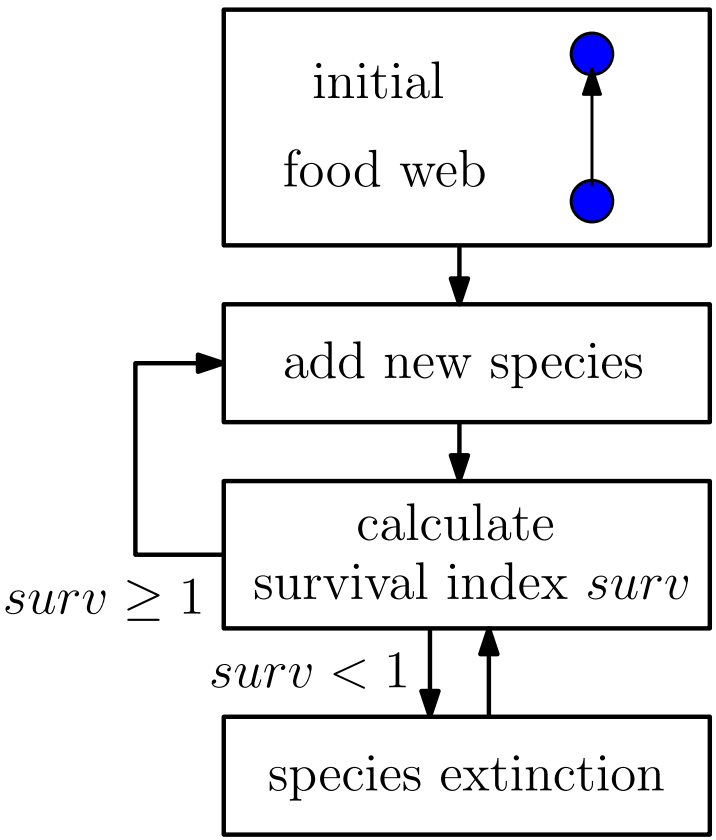

- Random mother species i with $p_i \propto m_i^{-\frac{1}{4}}$
- Faster metabolism and shorter generation time of small species.

Evolutionary foodweb model
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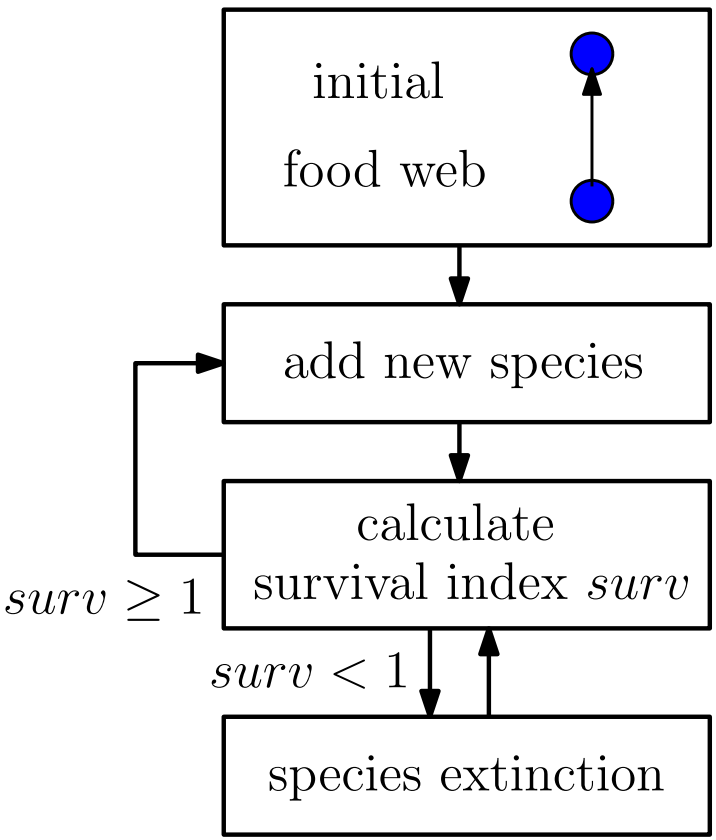

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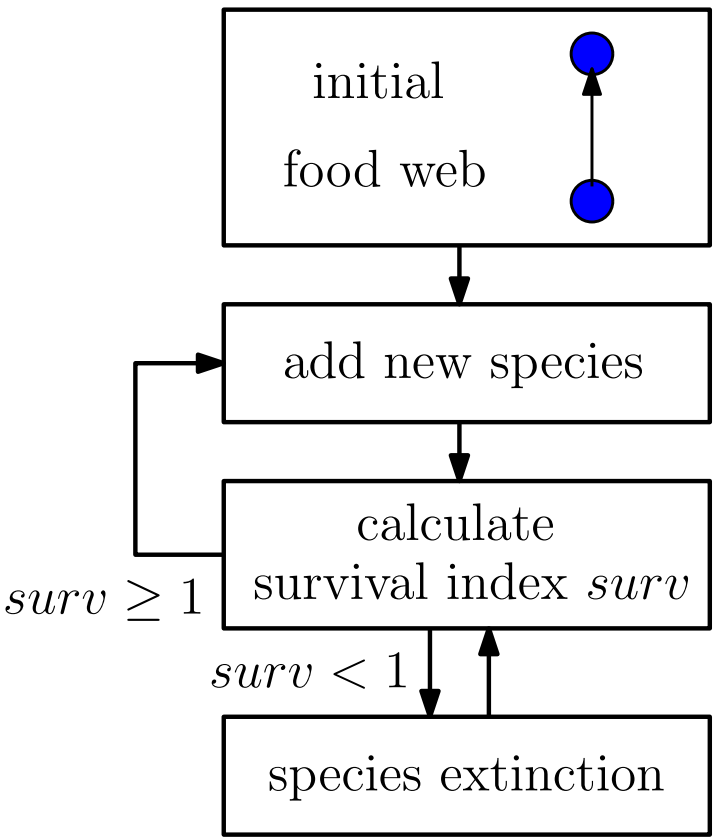

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- Faster metabolism and shorter generation time of small species.
- Body mass m_j of mutant j in an interval around m_i.
- Choose feeding parameters randomly according to model parameters.
- Avoid cannibalism.

Evolutionary foodweb model
Overview

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- Species should compete for common prey.
- Define competition function:

$$C_j = \frac{ck_j^2}{1 + ck_j^2}$$

with competition parameter c.

Evolutionary foodweb model
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Evolutionary foodweb model
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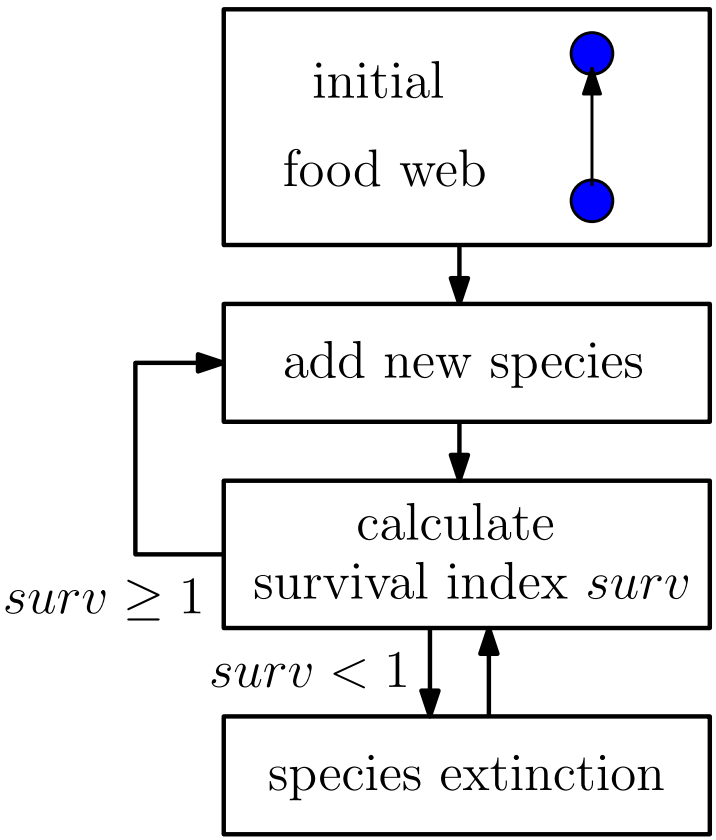

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Evolutionary foodweb model
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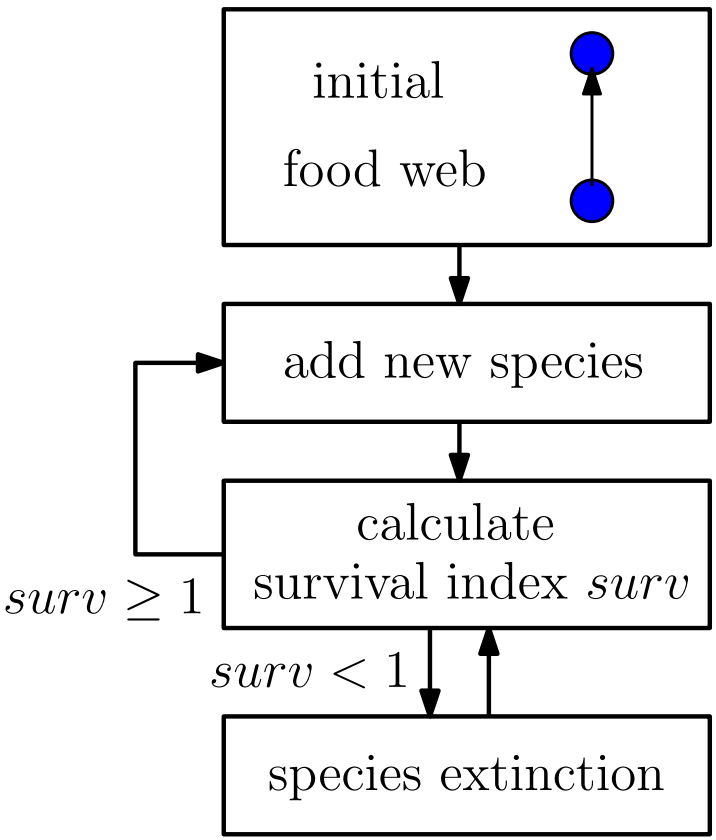

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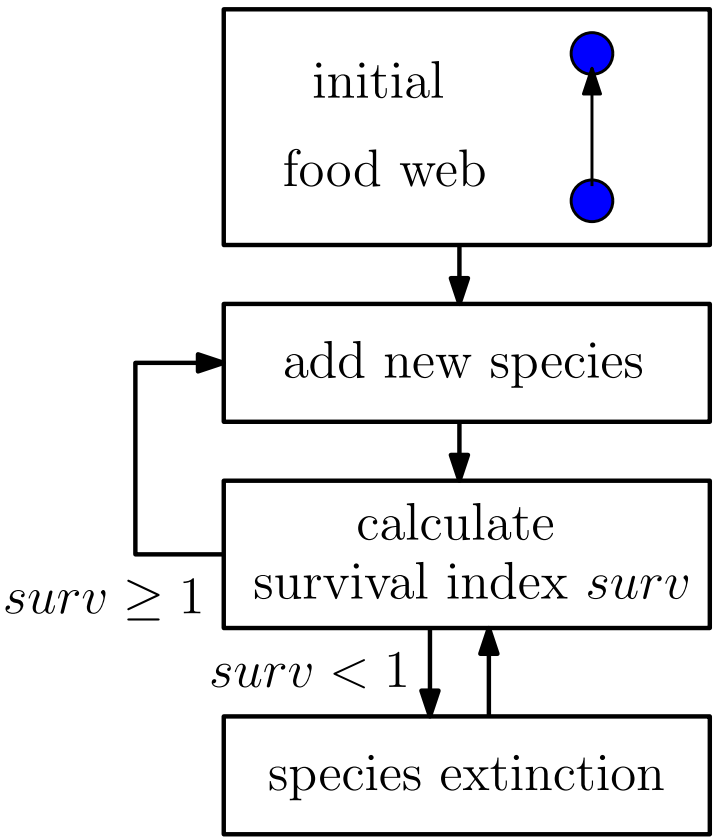

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$$\text{surv}(i) = \frac{\sum_j \alpha_{ij}}{\sum_k \alpha_{ki} + d}$$

with mortality parameter d.

Evolutionary foodweb model
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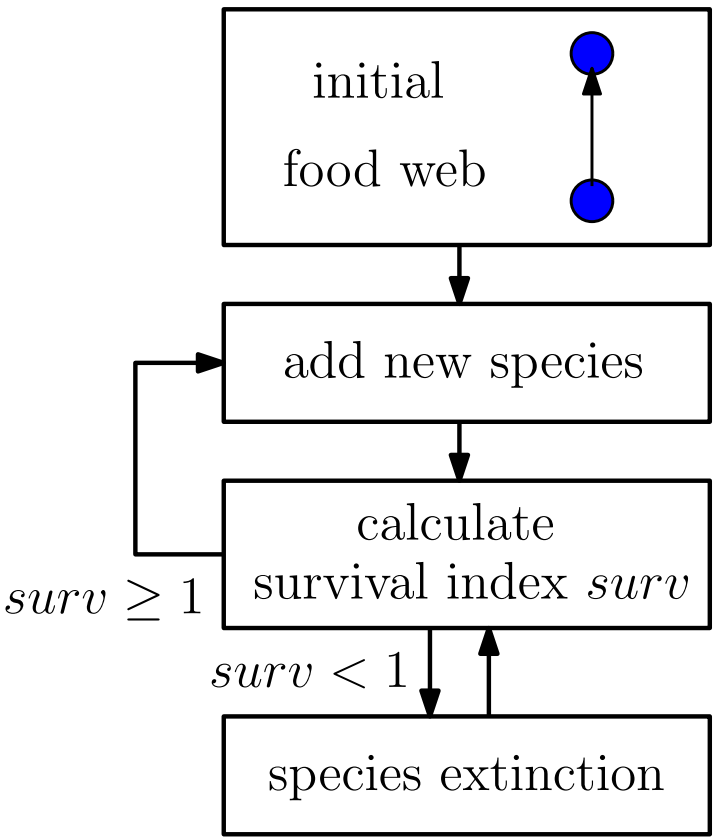

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- $\text{surv}(i) \geq 1$ for all species i are surviving configurations.

Evolutionary foodweb model
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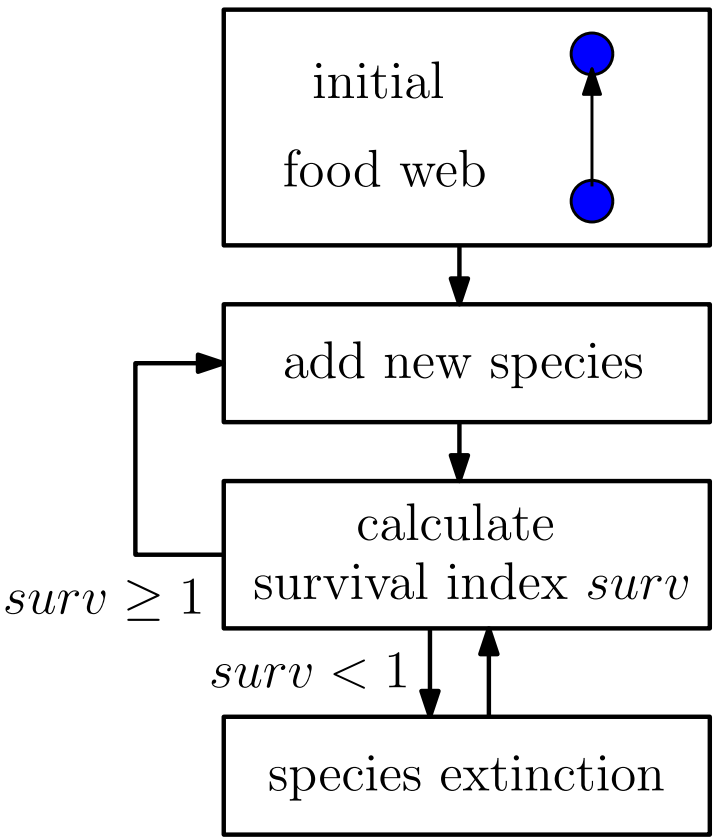

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Evolutionary foodweb model
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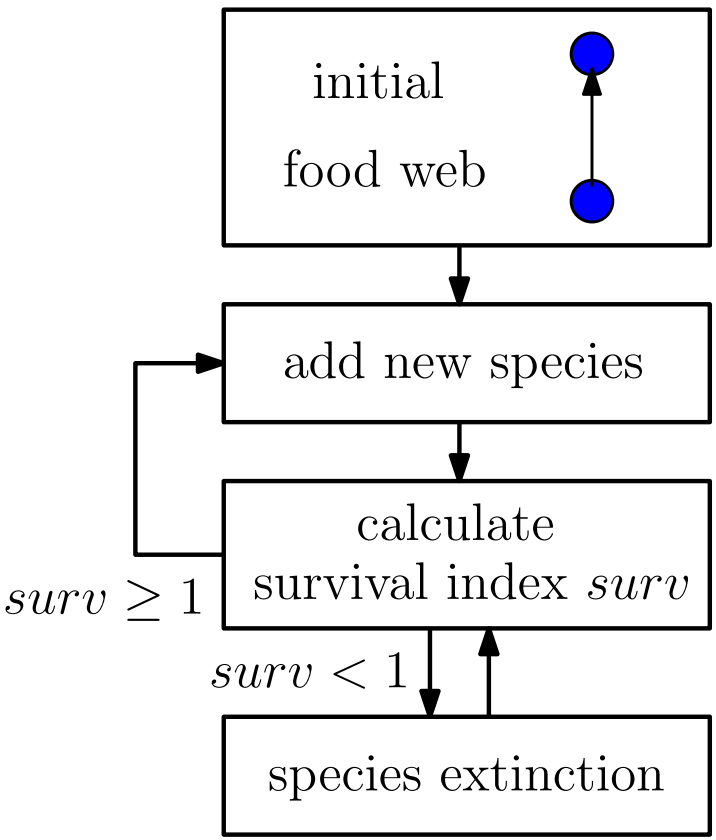

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- Some species may go extinct due to the survival criterion simultaneously.

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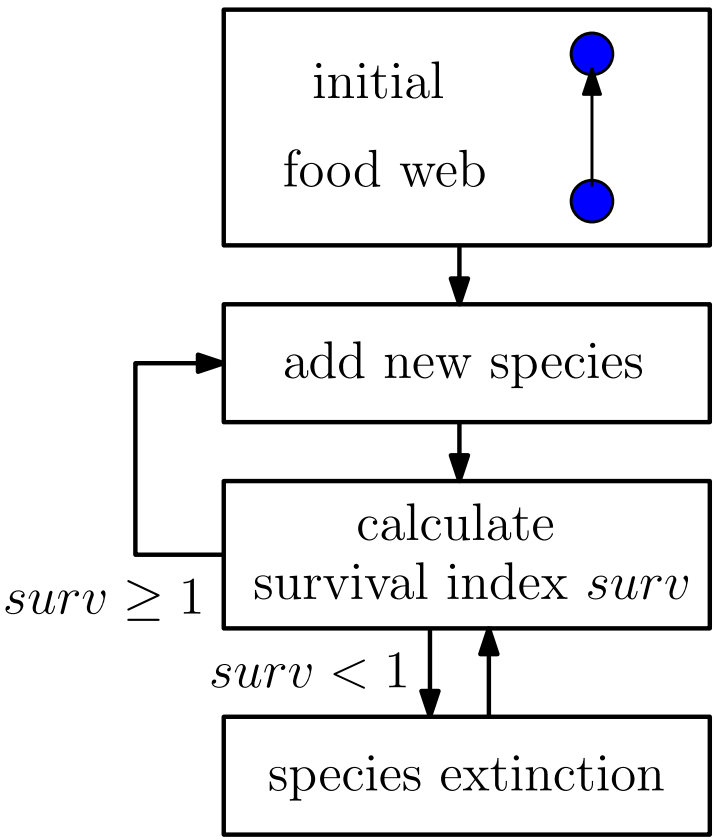

- Remove species with lowest survival index.
- Some species may go extinct due to the survival criterion simultaneously.
- Recalculate survival index after removing randomly one species with minimal $surv(i)$.

Results
Different emerging foodwebs

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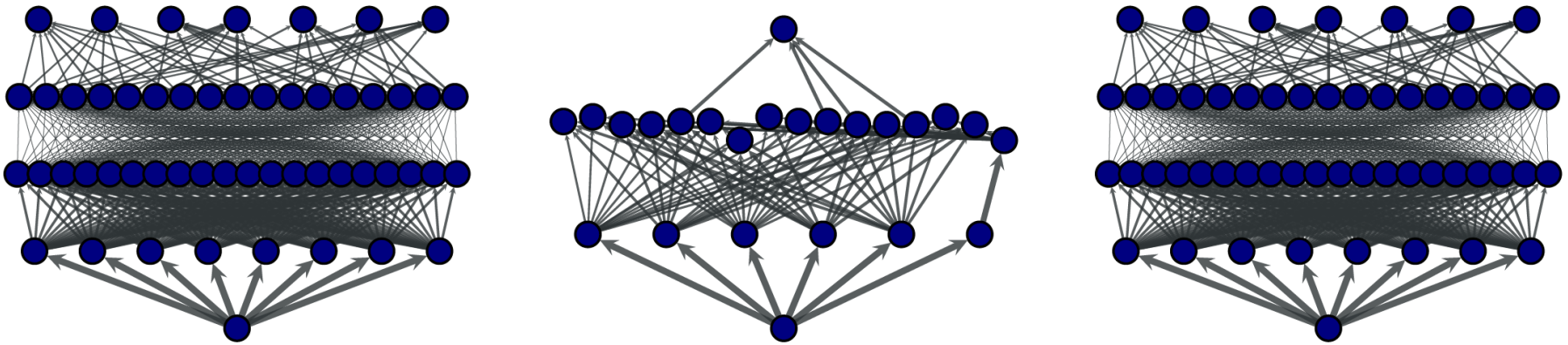

time
$\rightarrow$

Results
Different emerging foodwebs

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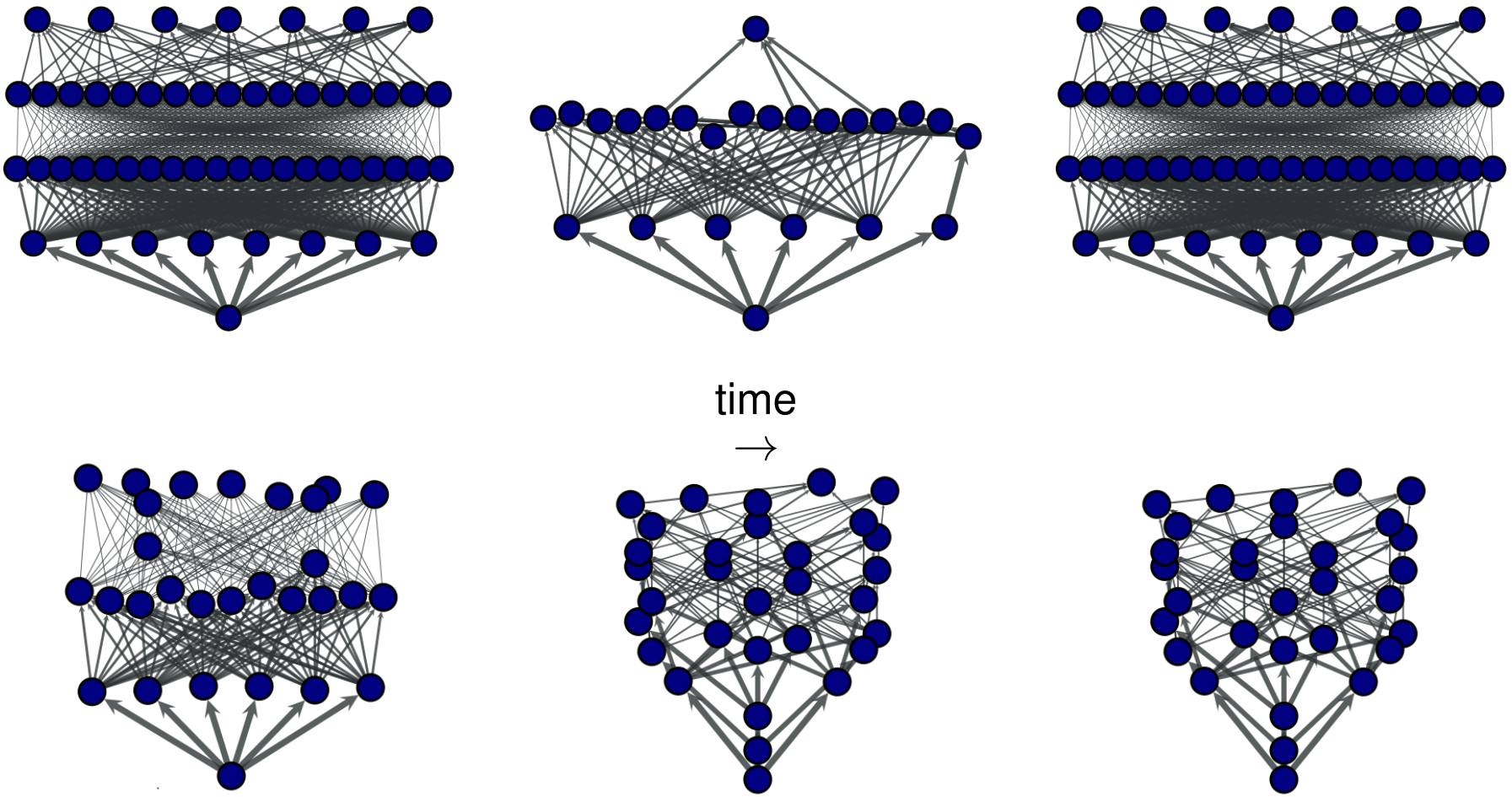

Results
Capacity of Trophic Levels

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- Assume strict trophic levels
- Calculate maximum capacity, i.e. species per trophic level

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- L_i: Number of species in level i.

$$surv(i) = \frac{L_{i-1} \frac{x^i}{1+cL_{i-1}^2}}{L_{i+1} \frac{x^{i+1}}{1+cL_i^2} + d}$$

- Set boundary conditions.
- Solve surv(i) = 1 for L_i with recurrence relation.

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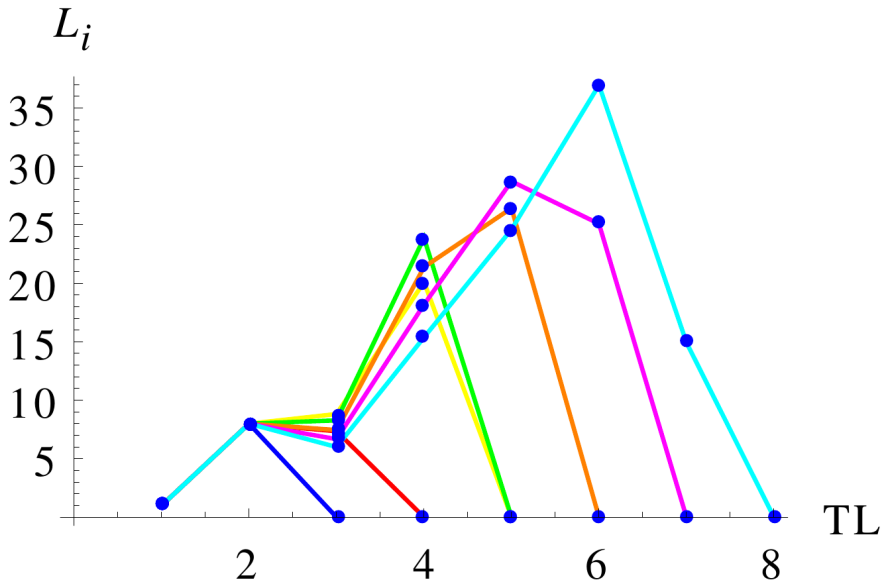

- Variation of efficiency parameter x.

Results
Building up

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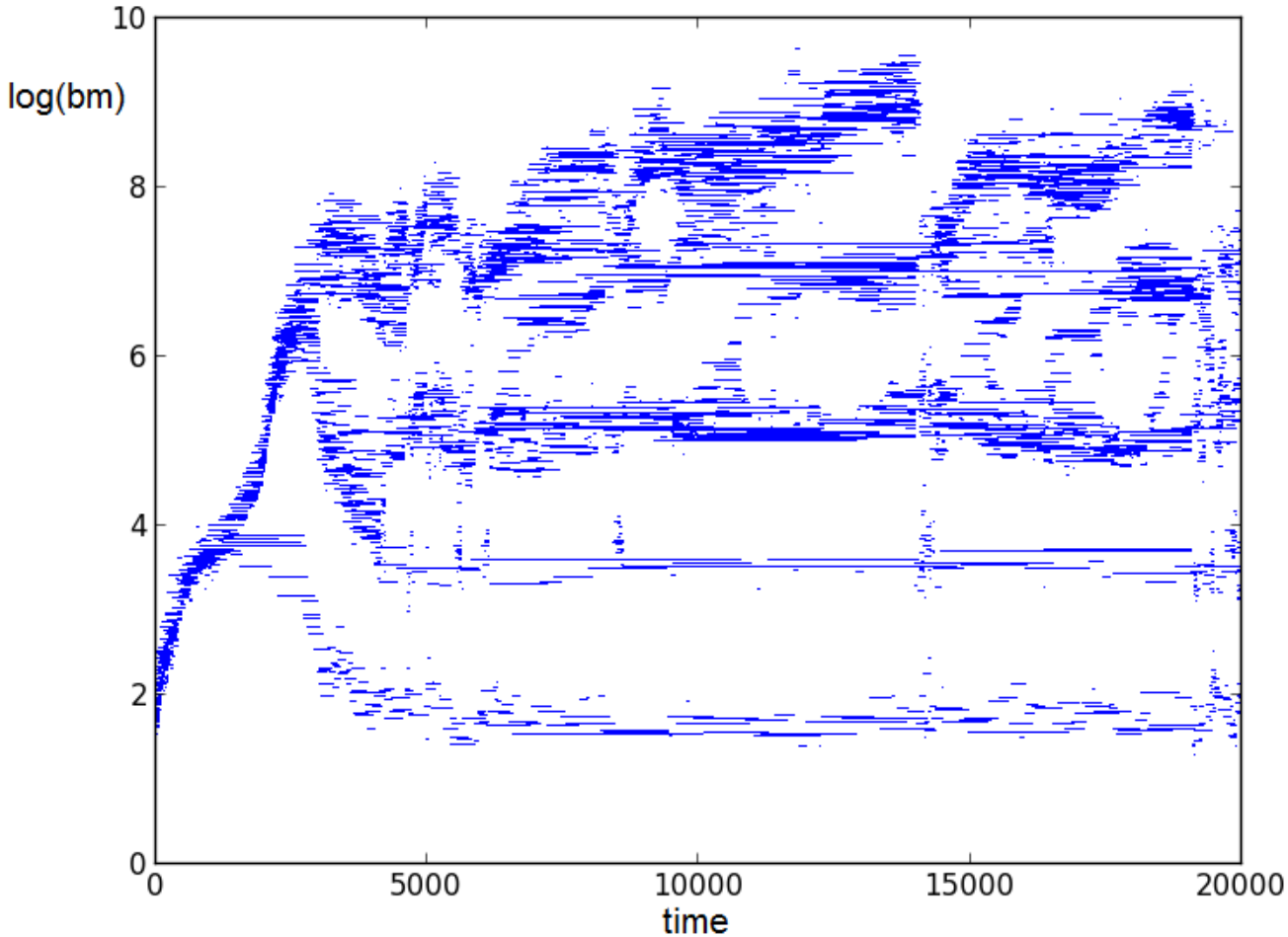

- Trophic levels emerge
- Ongoing species turnover

Results
Frozen States

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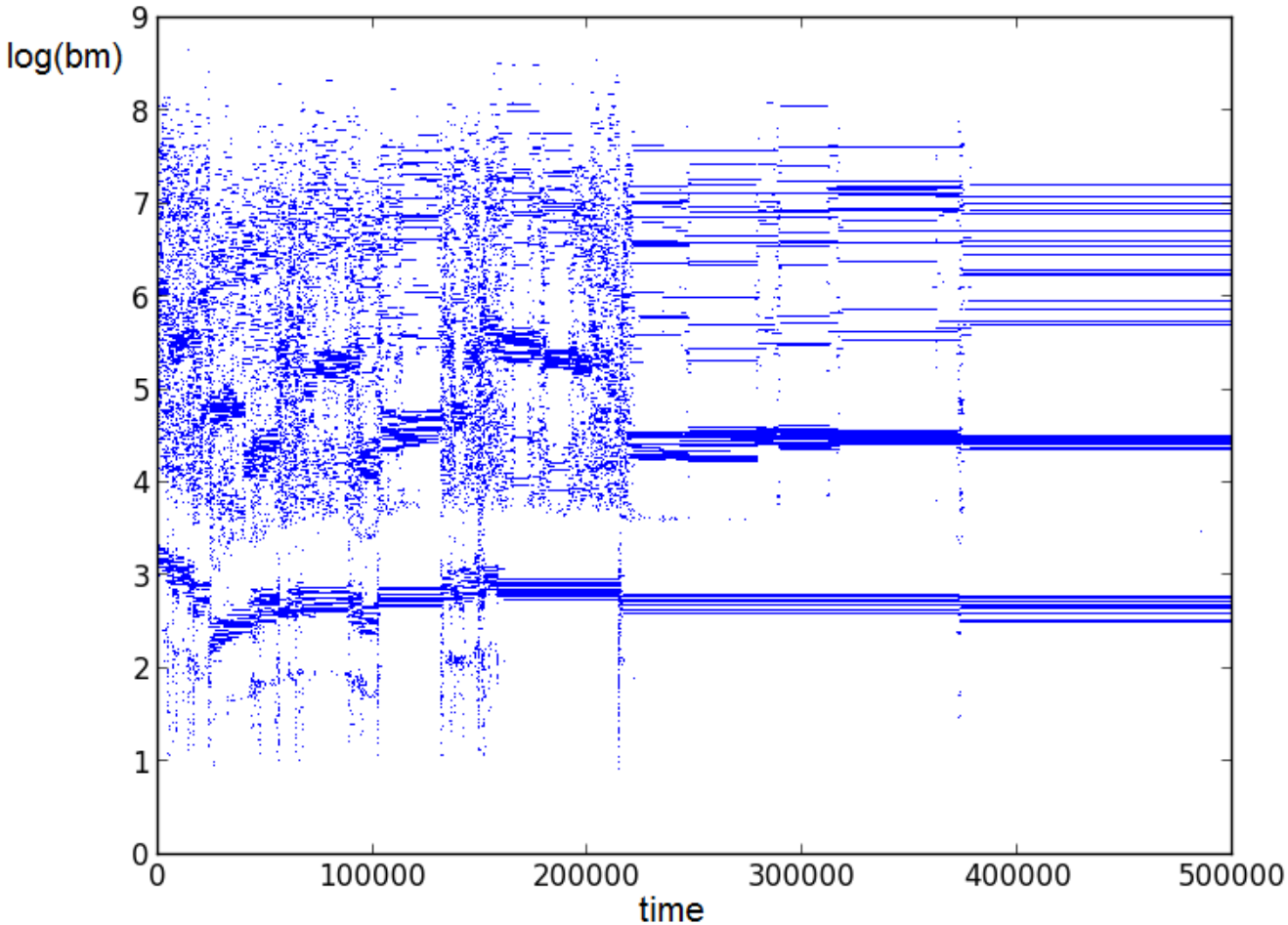

- Evolutionary Dynamic may get slower and stop.
- Frozen State
- Impossible for mutants to survive

Results
Extinction Avalanches

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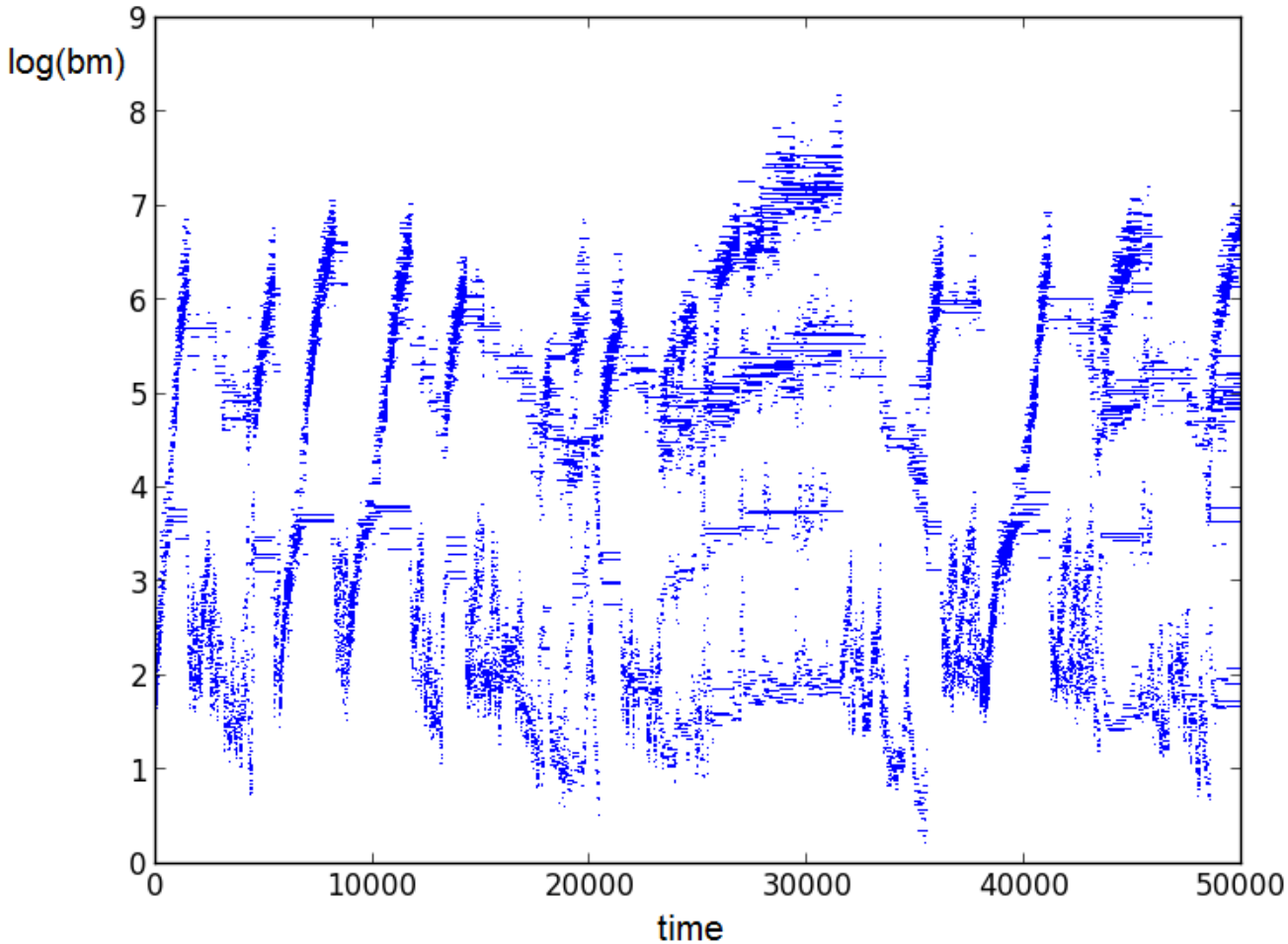

- Different simulation parameters
- Repeated extinction avalanches

Results
Dynamical Patterns

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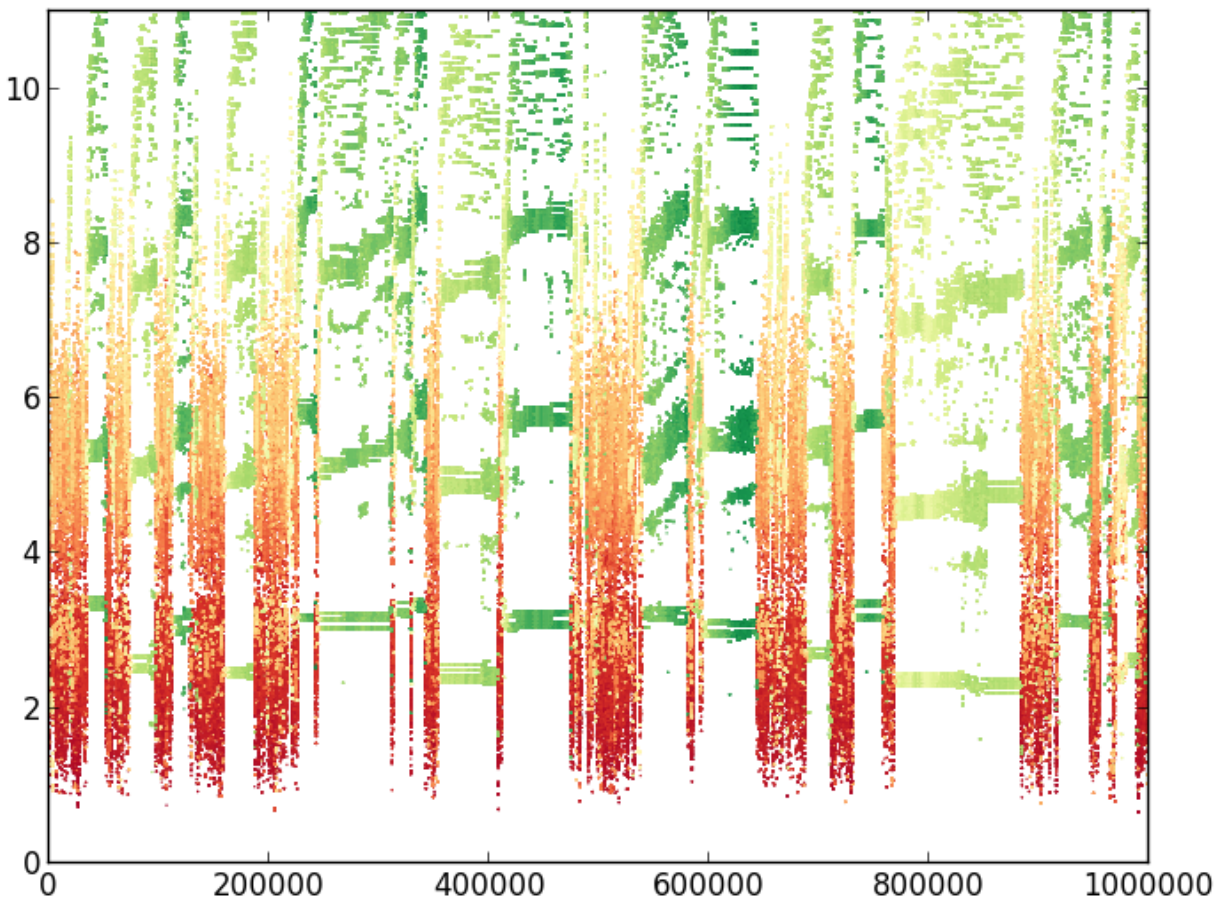

- Switch between dynamical phases in a single simulation
- Fast evolutionary dynamic (red)
- Strong trophic structur (green)

Results
Dynamical Patterns

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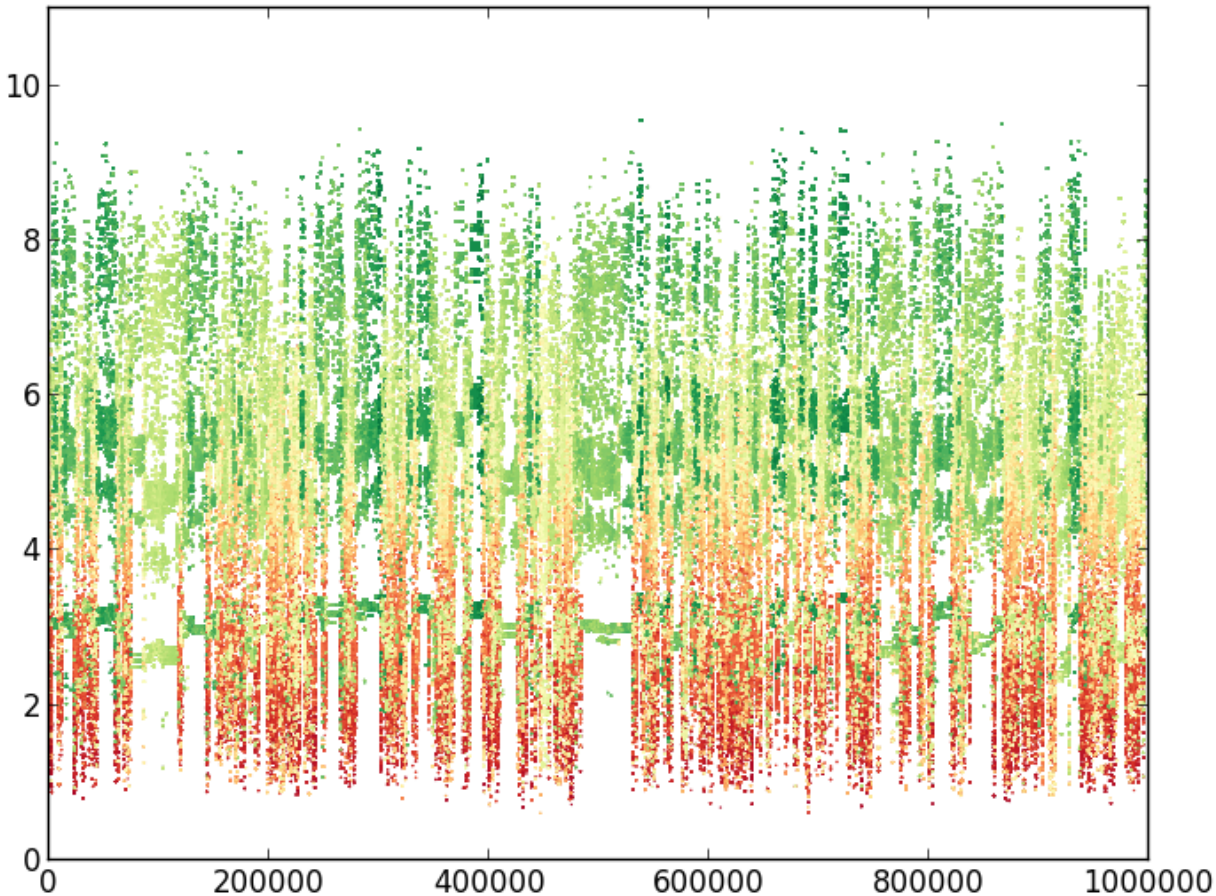

- Same timescale
- Lower efficiency parameter
- High frequency of alternating dynamical phases

Results
Dynamical Patterns

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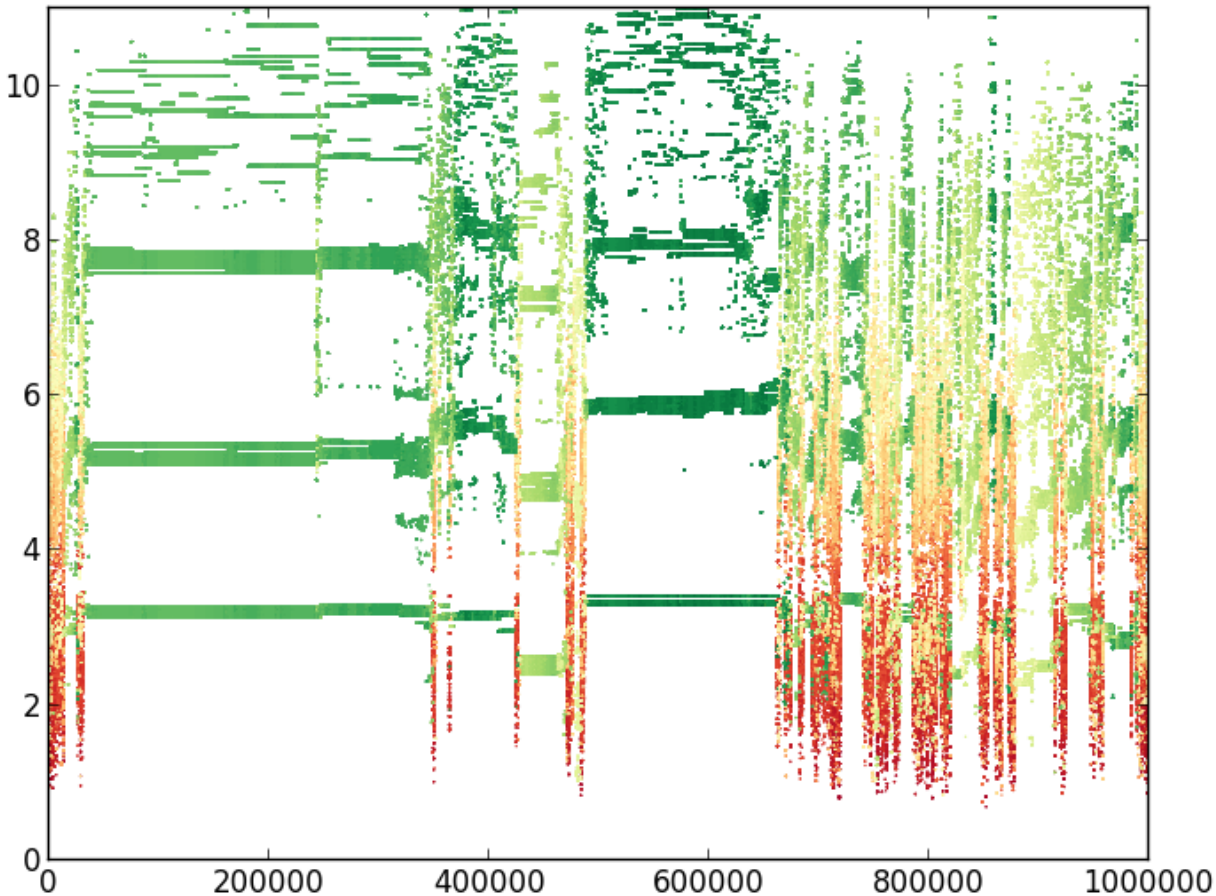

- Long static phase
- Stable configuration in lower trophic levels
- Alternating phases at $t \approx 670000$

Results
Dynamical Patterns

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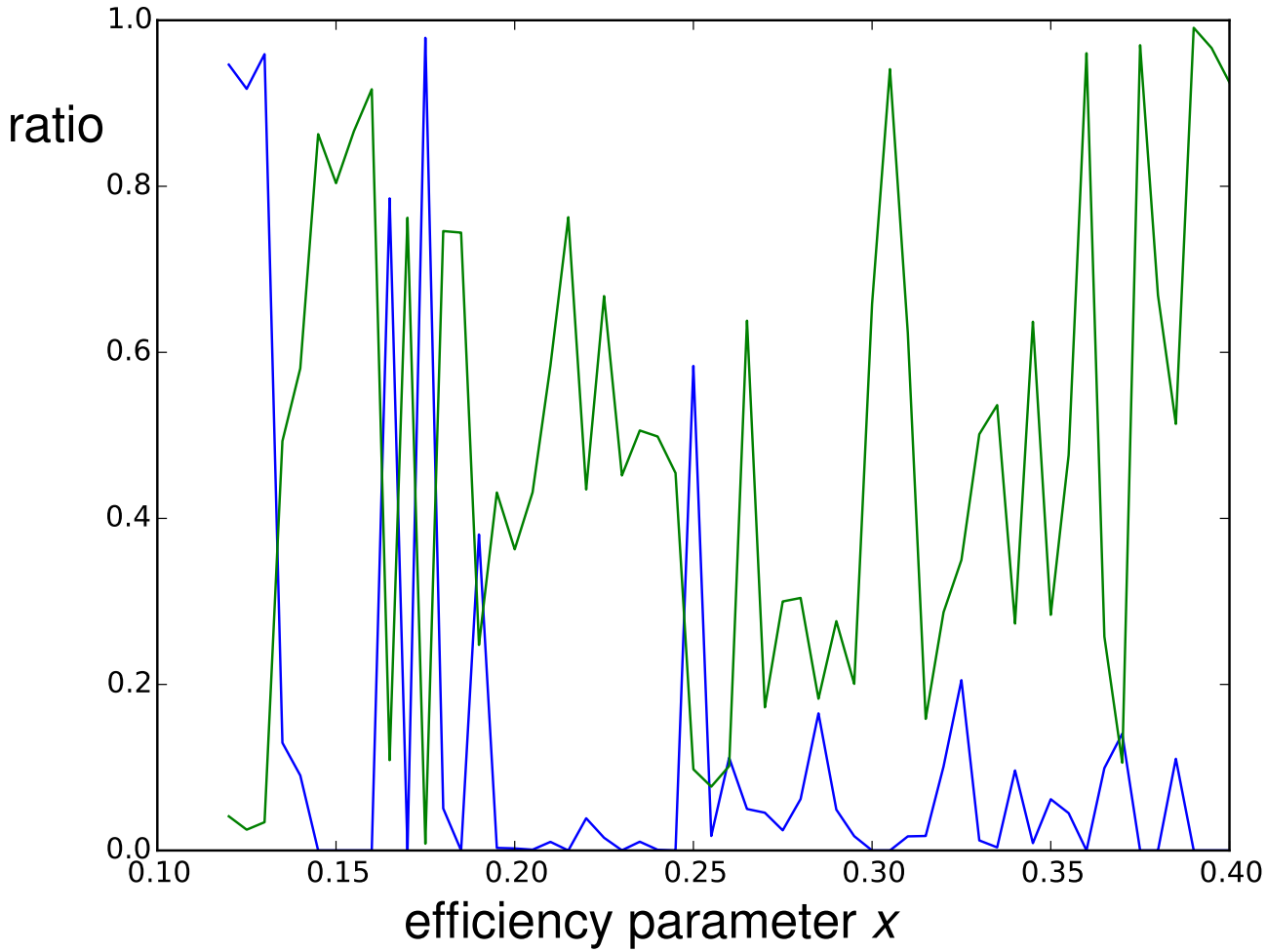
- Frozen configurations (blue)
- Ratio of dynamic phases (green)
- Large fluctuations



Several Patches Coupled by Migration

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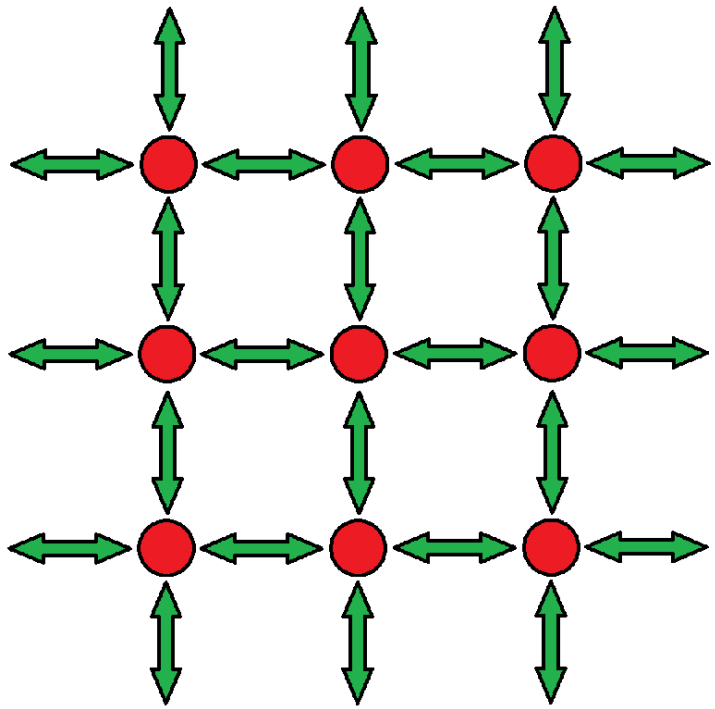

- Bachelor thesis of Johannes Reinhard and David Lehmann

Several Patches Coupled by Migration

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Parameters are:

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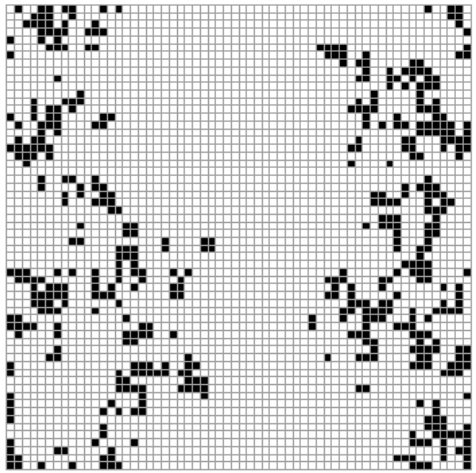
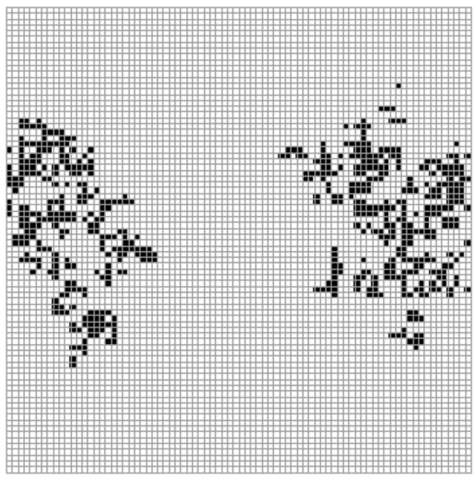


- Without spontaneous extinction: Frozen configurations



- With spontaneous extinction and high migration rates: Species distribute over grid.

Distribution of Species over Patches

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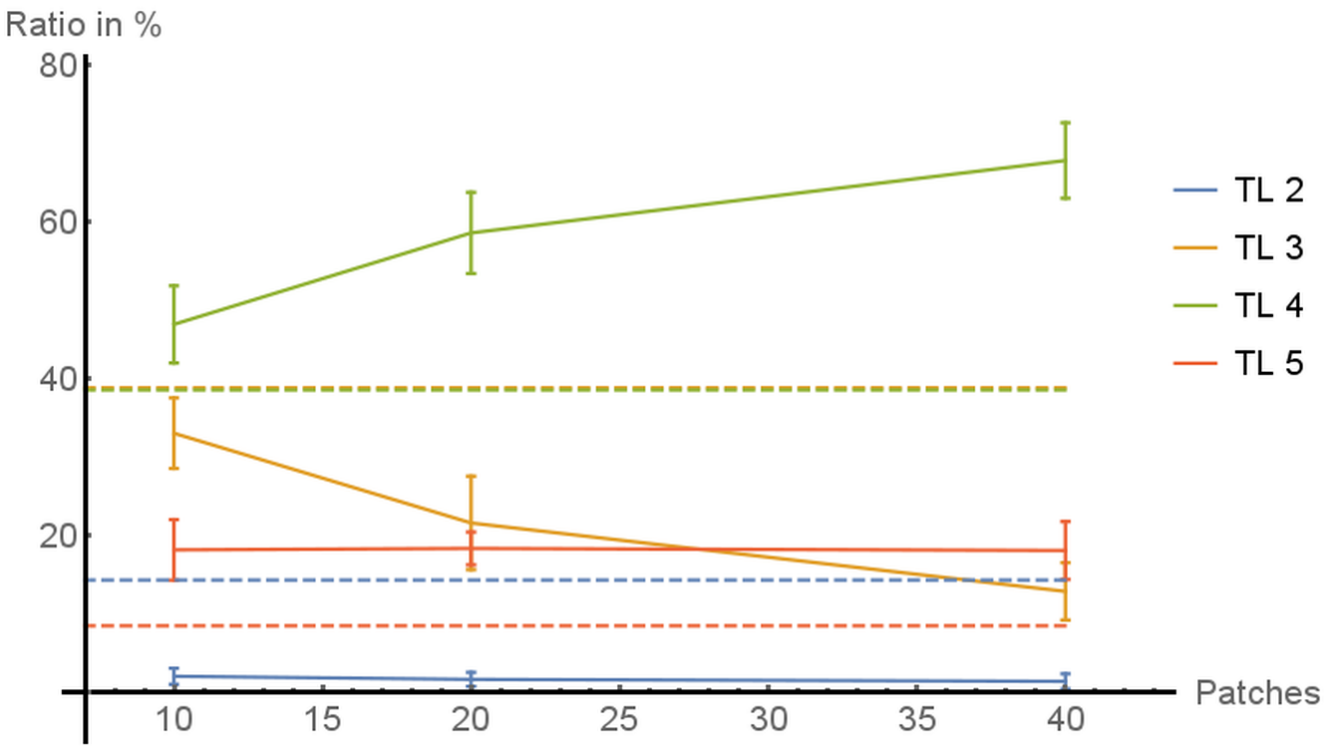

- Species on higher trophic levels occupy more patches.
- Basal species do not spread because of omnipresent resource.
- Mut. rate: 1
- Mig. rate: 4
- Ext. rate: 0.001

Summary

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- The model is able to generate a large variety of complex, multi-trophic networks

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- Long-term dynamics can show layered structures, highly dynamical configurations with frequent extinctions, or frozen configurations.
- In the spatial model species diversities and distributions dependent on trophical level can be analysed

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Thank you for your attention!