Species Diversity in Coupled Habitats: Going Beyond Homogeneous and Deterministic Models

Tatjana Thiel, Michaela Hamm, Barbara Drossel

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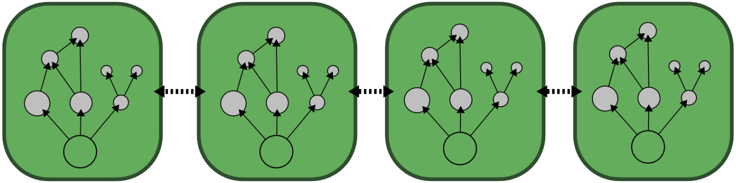
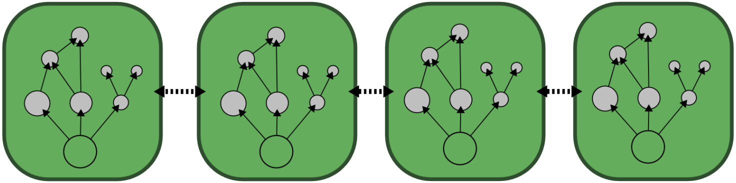
Introduction
Networks on networks

- How does migration alter diversity of species on local and regional scales?



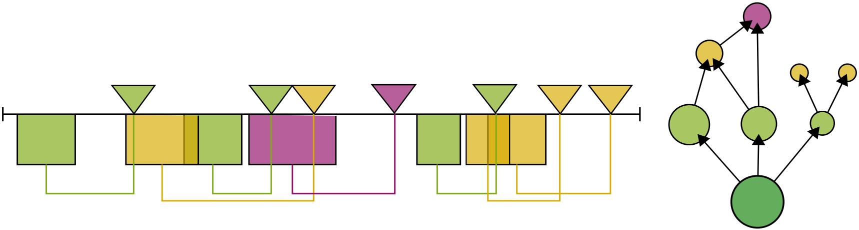
Introduction
Networks on networks

- How does migration alter diversity of species on local and regional scales?
- Research approach: Modelling explicit population dynamics of metafoodwebs.



Basics
Niche model

- Usage of niche model for foodweb construction [1].



Basics
Population Dynamics

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\frac{\mathrm{d}B_i^u(t)}{\mathrm{d}t} =& \lambda m_i^{-0.25} \sum_{j \in R_i} \frac{a f_i^u B_j^u}{1 + \sum_{l \in R_i} a f_i^u h B_l^u} B_i^u \\
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References: [2, 3]

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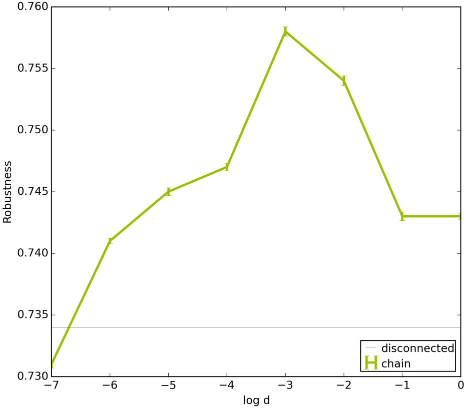
Former Results
Deterministic and Homogeneous Approach [3]

- Robustness: Fraction of persisting species.



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- Robustness: Fraction of persisting species.
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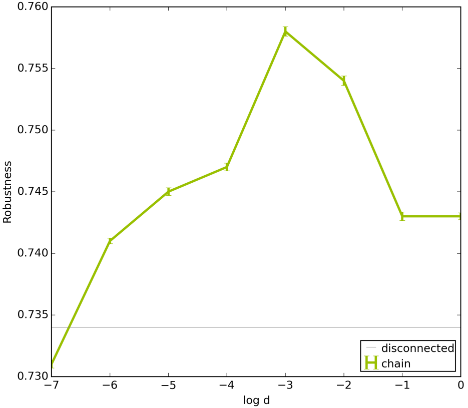

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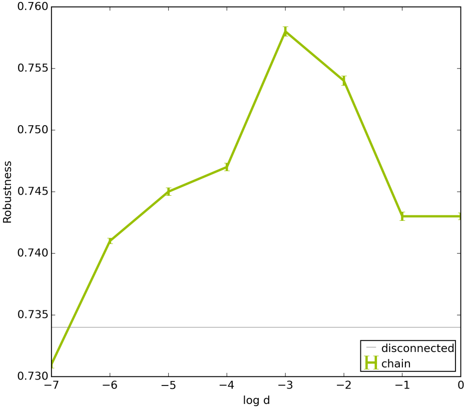

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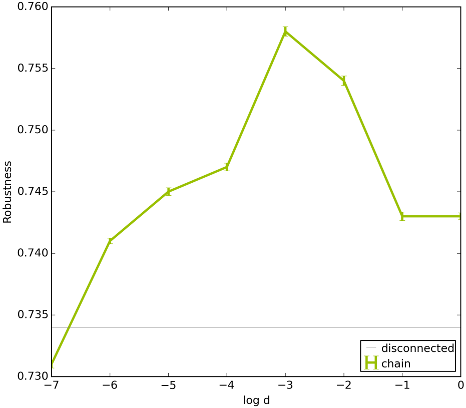

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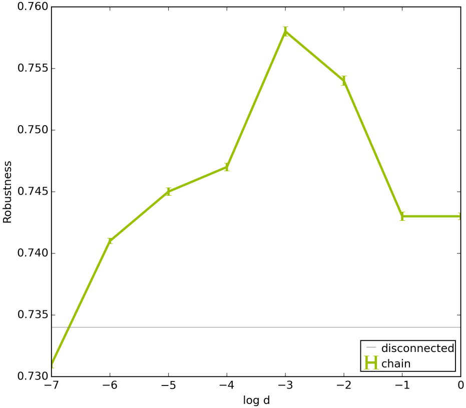

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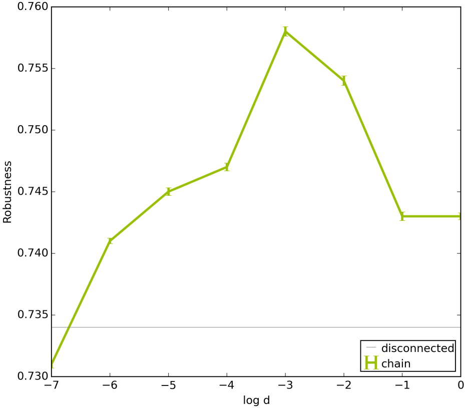

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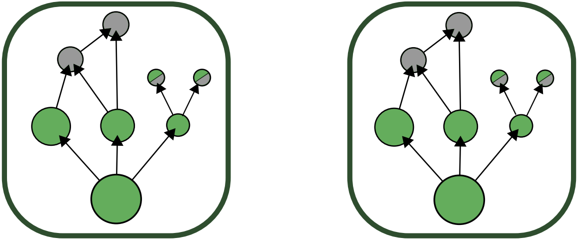

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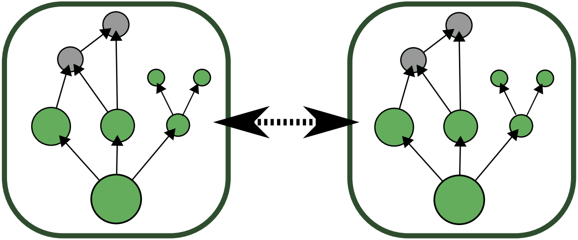

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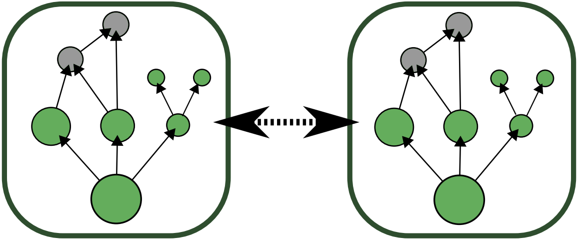

- Species survives in spite of unfavourable initial conditions.

Former Results
Deterministic and Homogeneous Approach [3]

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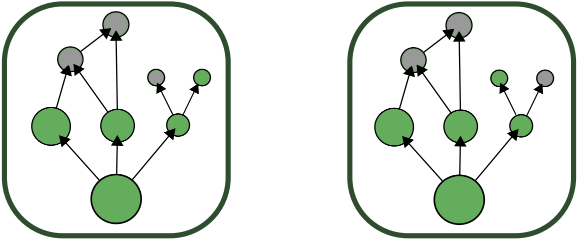
Dynamic coexistence



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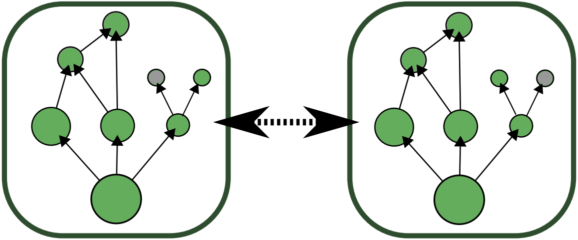

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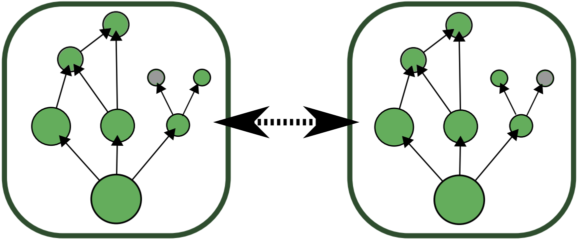

- Additional species to unconnected case.

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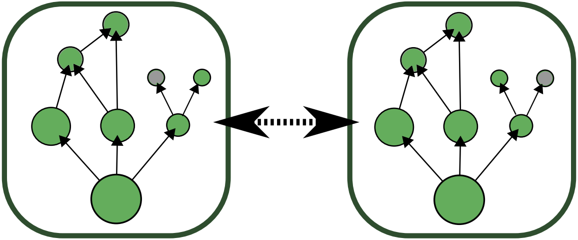

- Additional species to unconnected case.
- Migration stopped ⇒ species go extinct.

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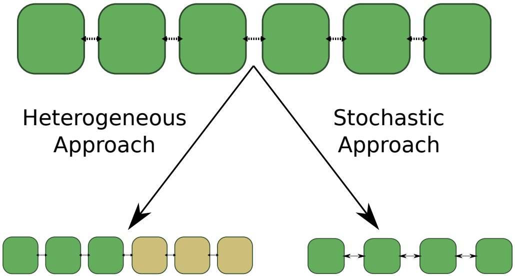
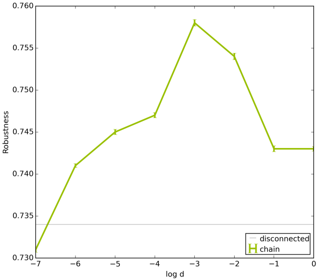
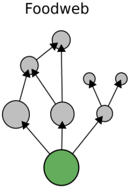
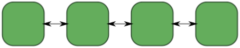




Stochastic Approach
Modifications to Homogeneous Model

- Migration events rare $\Rightarrow$ Migration is a stochastic process.





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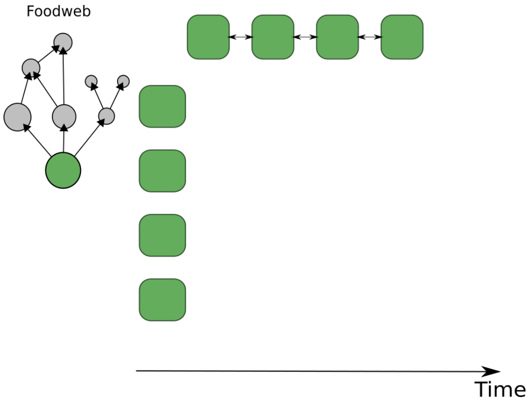

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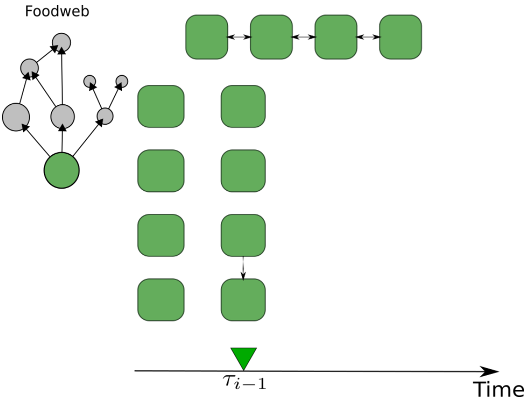

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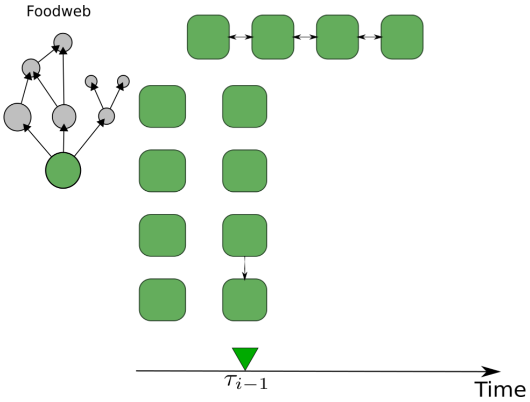

- Consider migrating biomass unit B_{migr}.

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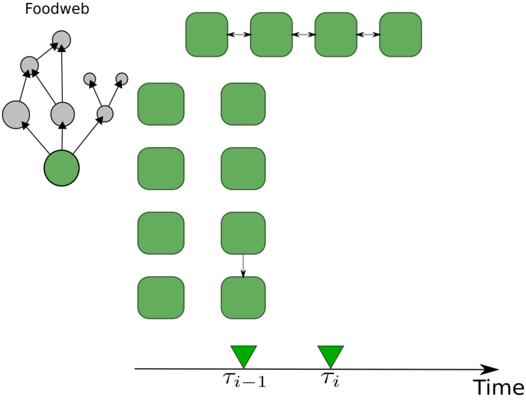

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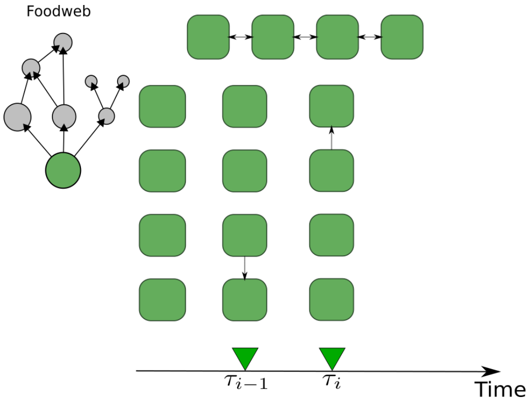

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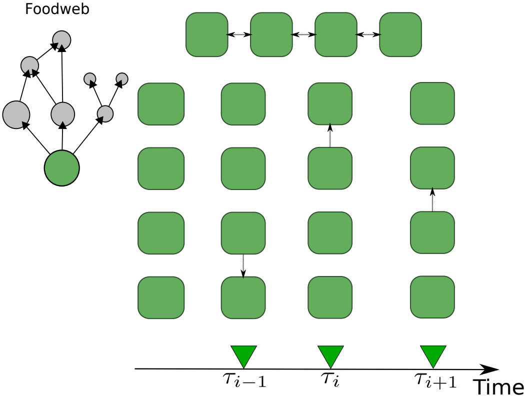

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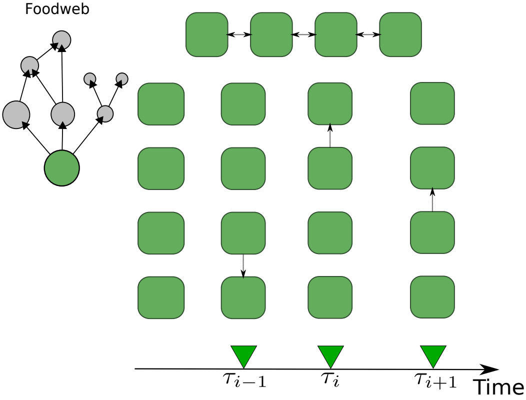

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- Mean time between two migration events: $\bar{\tau} \propto \frac{B_{\text{migr}}}{d}$

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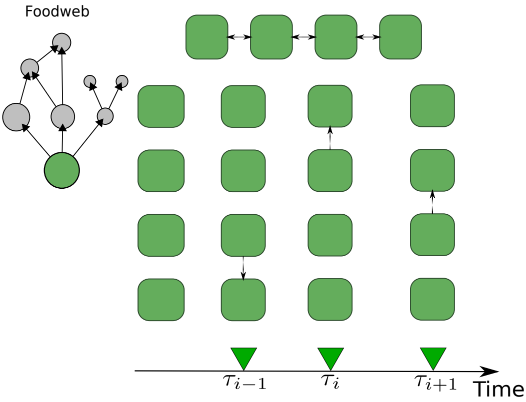
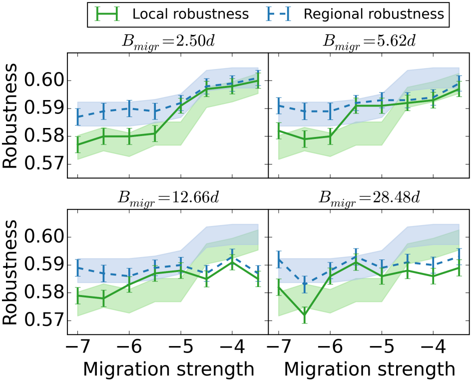


- Consider migrating biomass unit B_{migr}.
- Mean time between two migration events: $\bar{\tau} \propto \frac{B_{\mathrm{migr}}}{d}$
- Regional robustness: Fraction of species persisting anywhere.

Stochastic Approach
Results



- Increasing migrating biomass unit leads to:

Stochastic Approach
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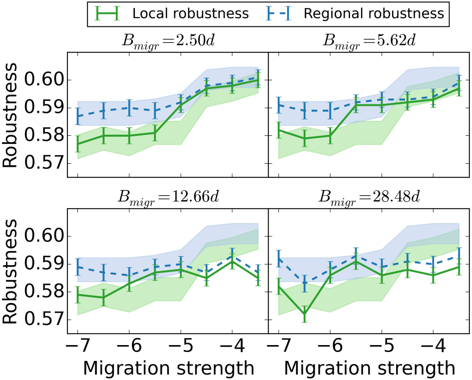

- Increasing migrating biomass unit leads to:
  - Intermediate migration strength: Local and regional robustness decrease.

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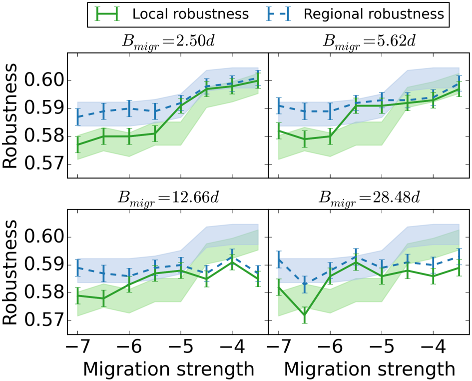
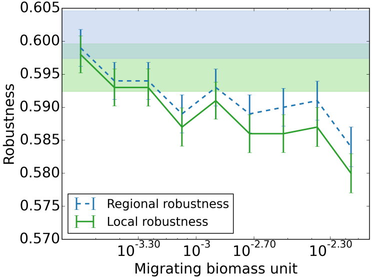


- Increasing migrating biomass unit leads to:
  - Intermediate migration strength: Local and regional robustness decrease.
  - Small migration strength: Local and regional robustness increase.

Stochastic Approach
Results



- $\log(d) = -4$: Local and regional robustness decrease due to:

Stochastic Approach
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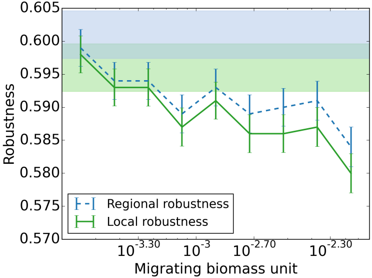

- $\log(d) = -4$: Local and regional robustness decrease due to:
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Stochastic Approach
Results

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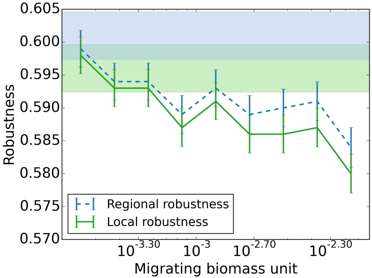

- $\log(d) = -4$: Local and regional robustness decrease due to:
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Stochastic Approach
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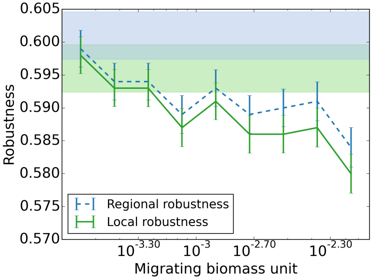

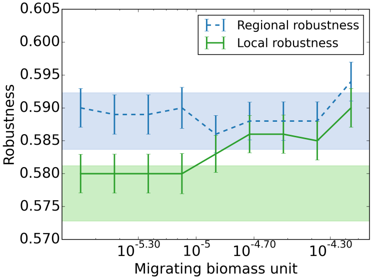

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Stochastic Approach
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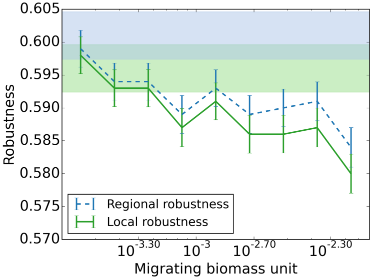

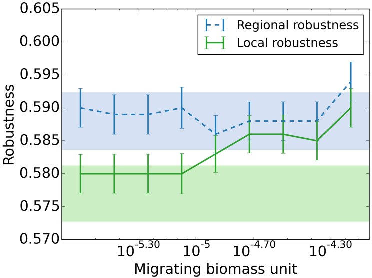

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Stochastic Approach
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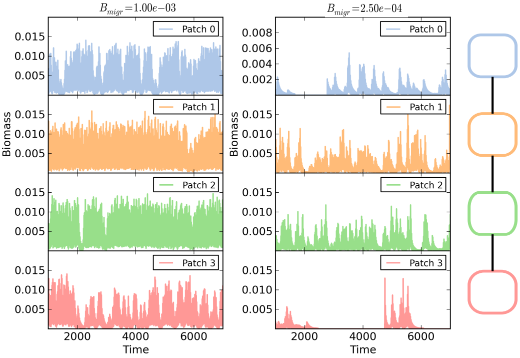

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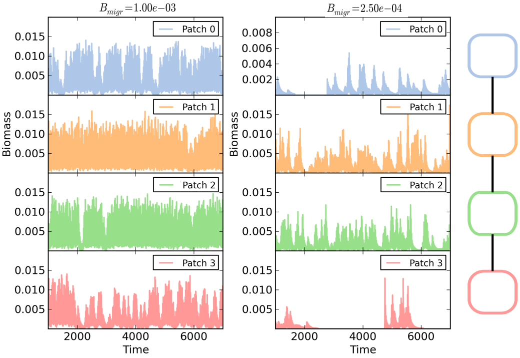

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Stochastic Approach
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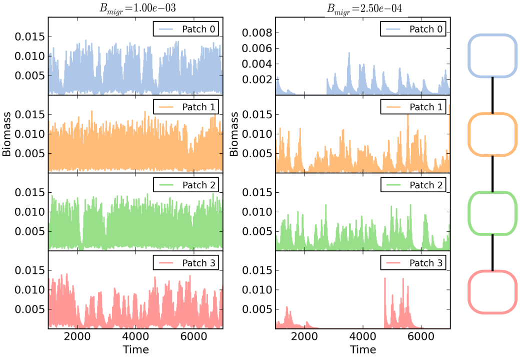
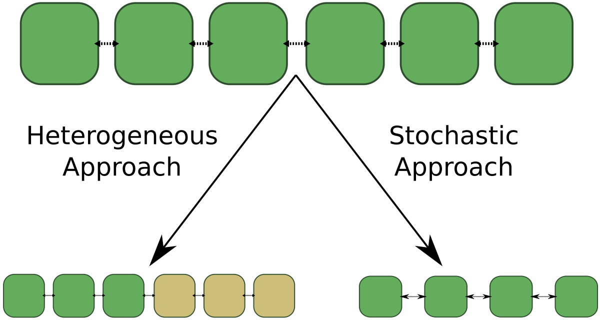


- Sufficiently frequent migration events enables survival.
- Sufficiently frequent migration events become less probable if time between two migration events increases.

Heterogeneous Approach
Modifications to Homogeneous Model



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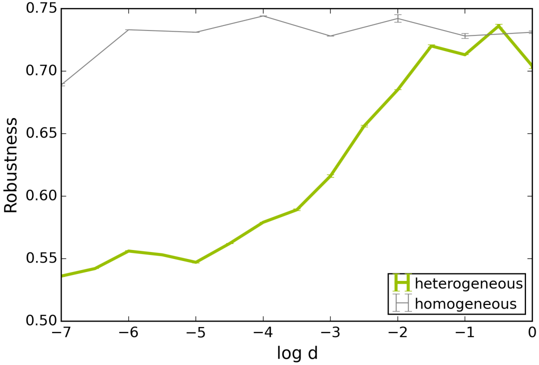
Robustness

Compare heterogeneous system to homogeneous system (same amount of resource in total) regarding robustness:

- Weak migration: Smaller robustness.



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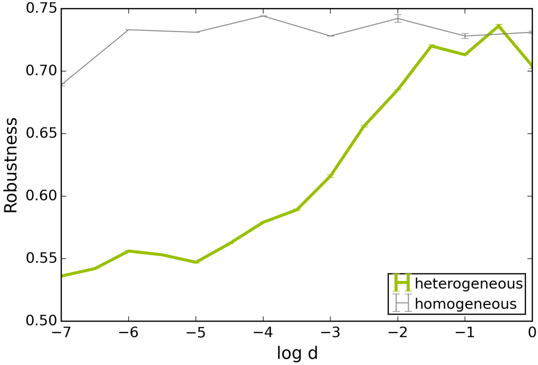

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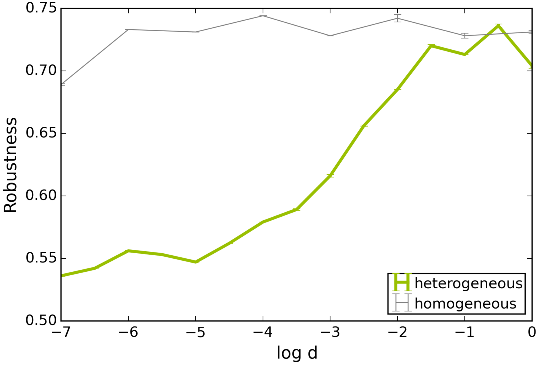
- Strong migration: Reaching value of homogeneous system.



Heterogeneous Approach
Biomass Distribution

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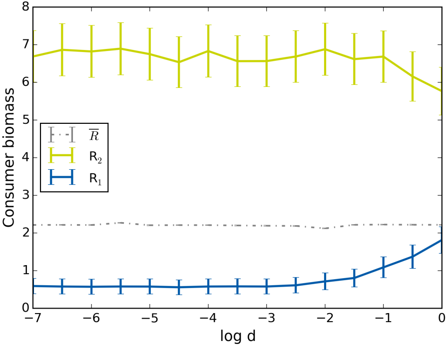
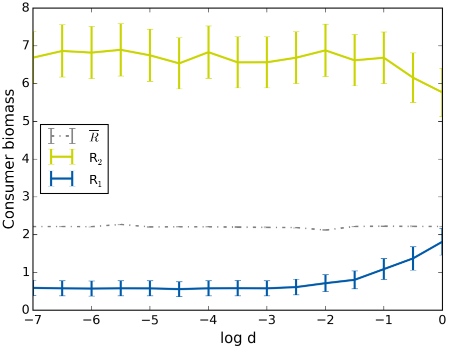
- Biomass in R_1 patches smaller than in R_2 patches.



Heterogeneous Approach
Biomass Distribution

- Biomass in R_1 patches smaller than in R_2 patches.
- R_2 patches contain significant more biomass than patches of the homogeneous system (same amount of total resource).



Heterogeneous Approach
Edge Effects

What happens at the edge between patches of different resource abundance?

Heterogeneous Approach
Edge Effects

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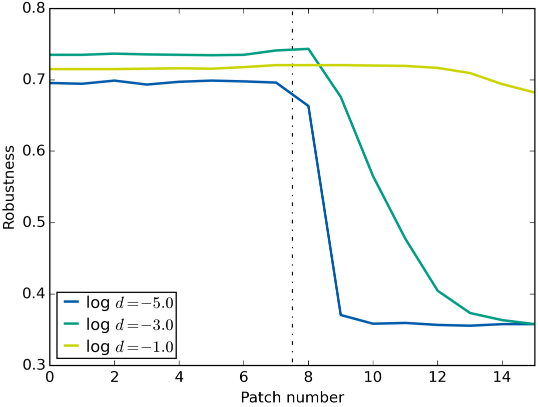
What happens at the edge between patches of different resource abundance?

- Evaluate robustness for each habitat separately:



Heterogeneous Approach
Edge Effects

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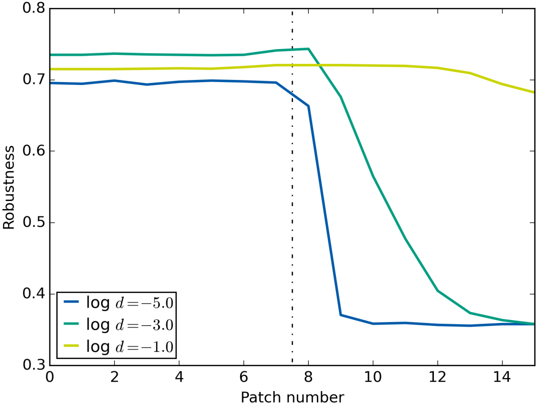
What happens at the edge between patches of different resource abundance?

- Evaluate robustness for each habitat separately:
- Robustness depicts resource abundance for small migration.



Heterogeneous Approach
Edge Effects

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What happens at the edge between patches of different resource abundance?

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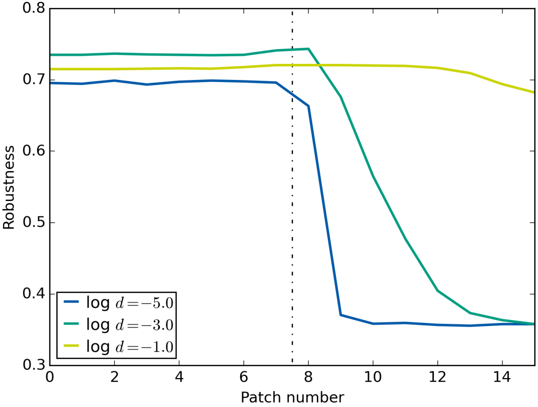
- Higher migration strength allows immigrant species to persist in foreign habitats.



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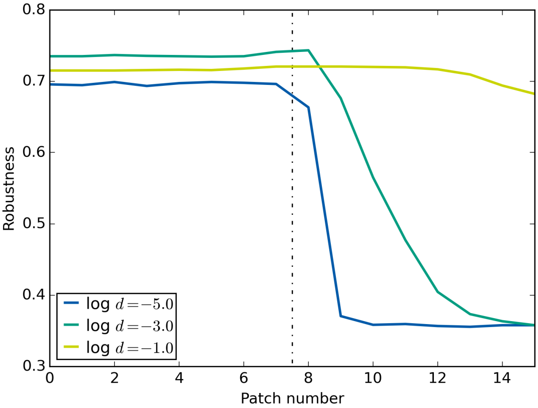
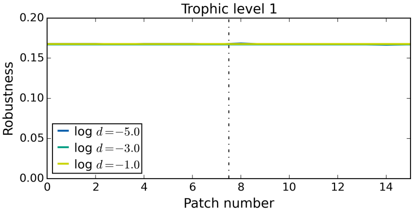
  - **Source-sink effect**



Heterogeneous Approach
Edge Effects

Which trophic levels participate in source-sink effect?

- Trophic level 1:
  - Robustness is not affected by resource abundance.



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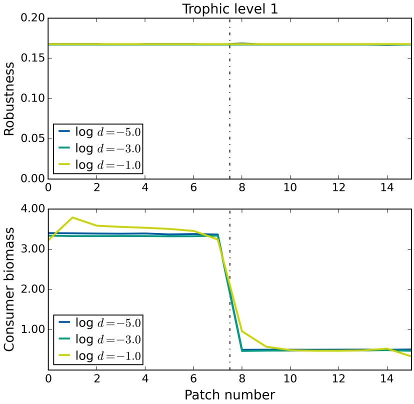

Heterogeneous Approach
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Which trophic levels participate in source-sink effect?

- Trophic level 1:
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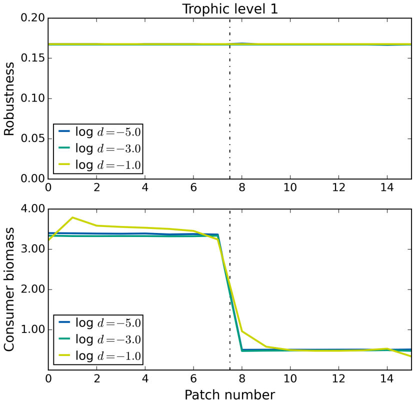
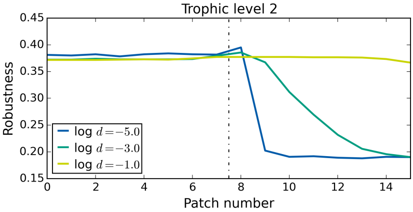
  - Biomass distribution depicts resource distribution for small migration strength.
  - Biomass flow from high resource area to low resource area for larger migration strength.



Heterogeneous Approach
Edge Effects

Which trophic levels participate in source-sink effect?

- Trophic level 2:
  - Depicts result from total robustness.



Heterogeneous Approach
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Which trophic levels participate in source-sink effect?

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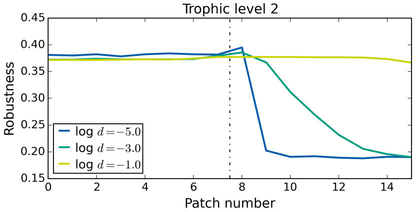
  - Robustness peak at edge (low resource side).



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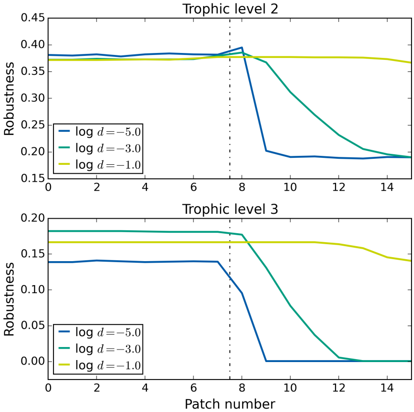

Heterogeneous Approach
Edge Effects

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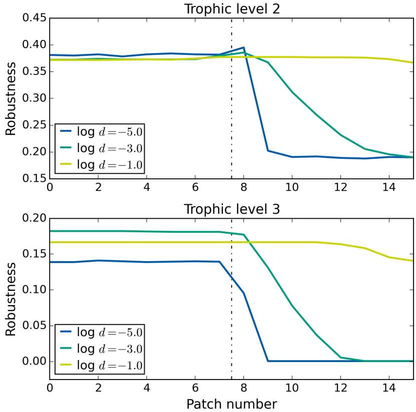
  - Source-sink effect from high to low resource area.



Summary

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- Heterogeneous environments:

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Summary

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TECHNISCHE UNIVERSITÄT DARMSTADT

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TECHNISCHE UNIVERSITÄT DARMSTADT

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UNIVERSITÄT
DARMSTADT

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- Stochastic migration:
  - Increasing migrating biomass units:
    1. Rescue effect can occur for smaller migration strengths.
    2. Dynamic coexistence happens less frequently.

       $\Rightarrow$ Sufficiently frequent migration events enable survival.
    3. For small migration strengths, diversity can be higher than for deterministic approach.

Thank you for your attention!

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