A stochastic theory of ecology

Demography of individuals to abundances and diversity

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A stochastic community theory


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Stochastic community theory

Biology of individuals		**Community patterns**
Mortality	predict	Abundance
Reproduction	==>	Diversity
Dispersal		Extinction
Growth		Geographic patterns
Species input		Species-area curve

Stochastic community theory

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Community properties of broad interest emerge from the model without any direct assumptions

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Community properties of broad interest emerge from the model without any direct assumptions

(ie, no assumption about diversity required to produce diversity, etc.)

Outline

Demographic theory of diversity and abundance

- Predicting community traits from individuals

Abundance distribution

- Power-law form observed and predicted
- Rare species dominance

Role of species input

- Causes rare species tail
- Over-rides species differences

Demographic theory of spatial niches

- Interaction of dispersal with fitness differences
- Interaction of species input with fitness differences

Demographic model of a community

1	2	1	2	1
1	1	1	4	1
1	3	1	1	2
4	1	1	3	1
1	1	2	1	1

Demographic model of a community

death

1	2	1	2	1
1	1	1	4	1
1	3	X	1	2
4	1	1	3	1
1	1	2	1	1

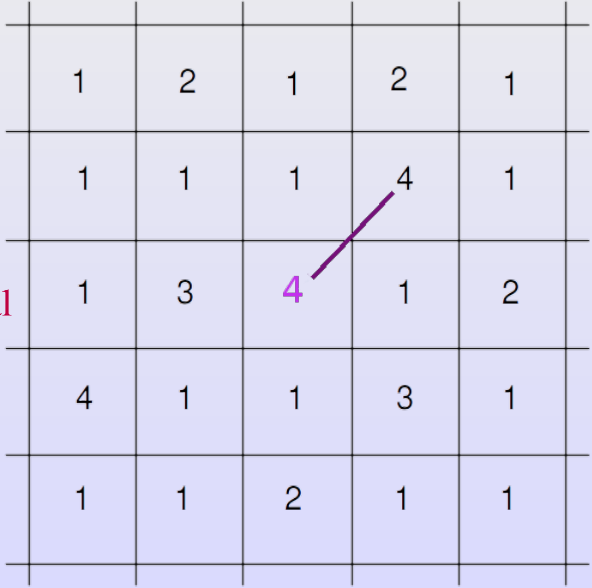
Demographic model of a community

parent

1	2	1	2	1
1	1	1	4	1
1	3		1	2
4	1	1	3	1
1	1	2	1	1

Demographic model of a community

dispersal

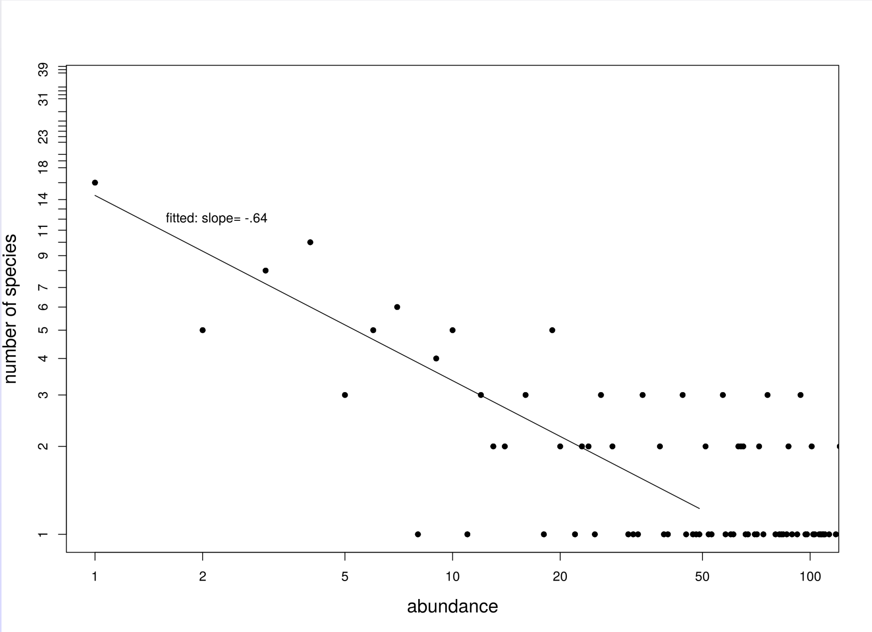


Demographic model of a community

1	2	1	2	1
1	1	1	4	1
1	3	6	1	2
4	1	1	3	1
1	1	2	1	1

input

Species abundance: theory vs. BCI 50-ha plot



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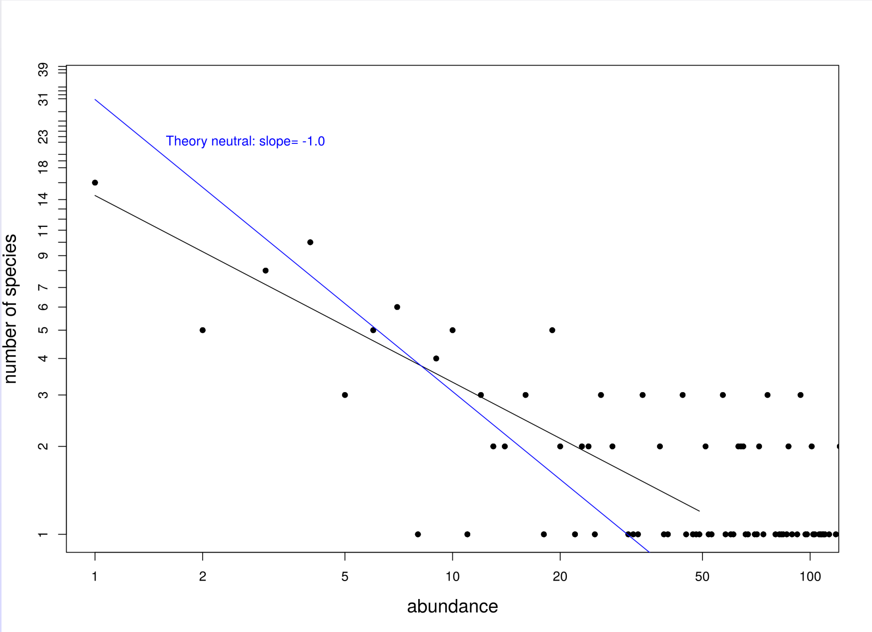

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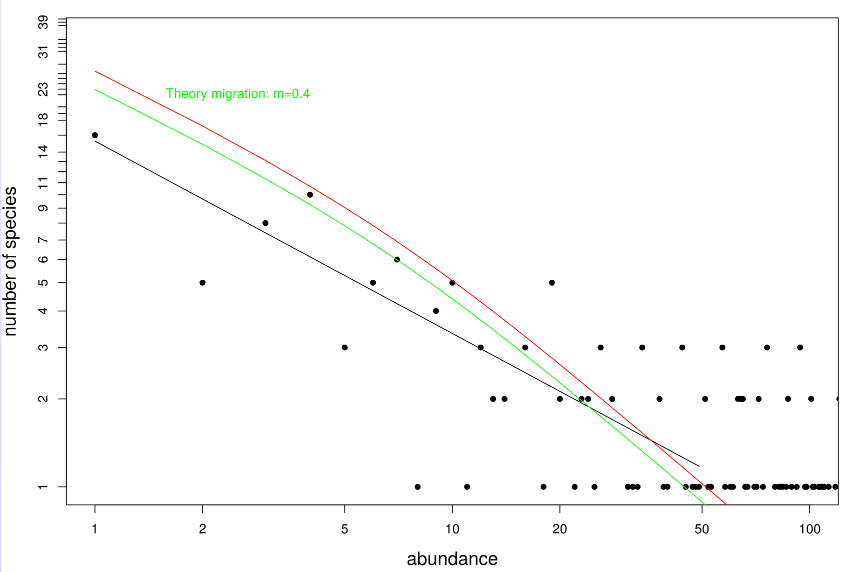
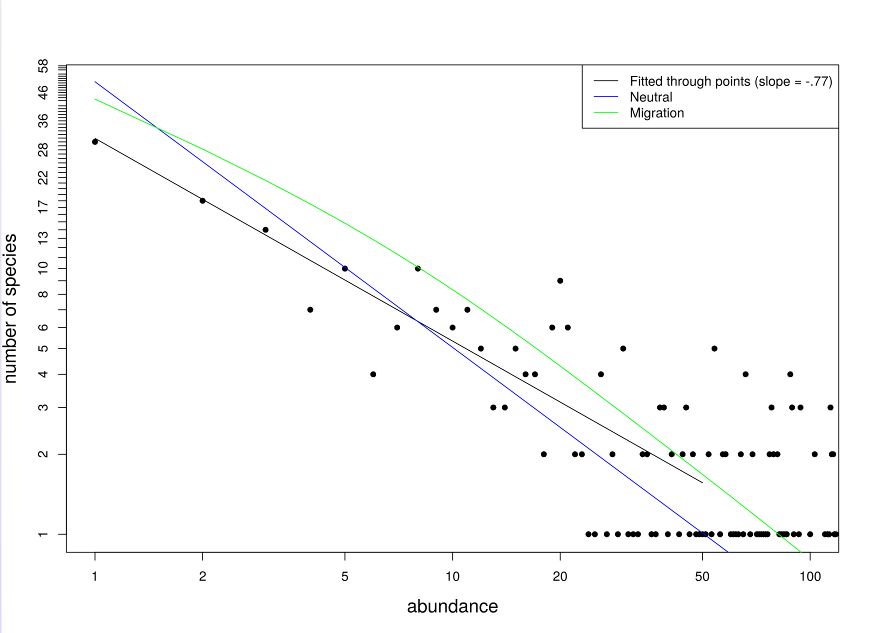
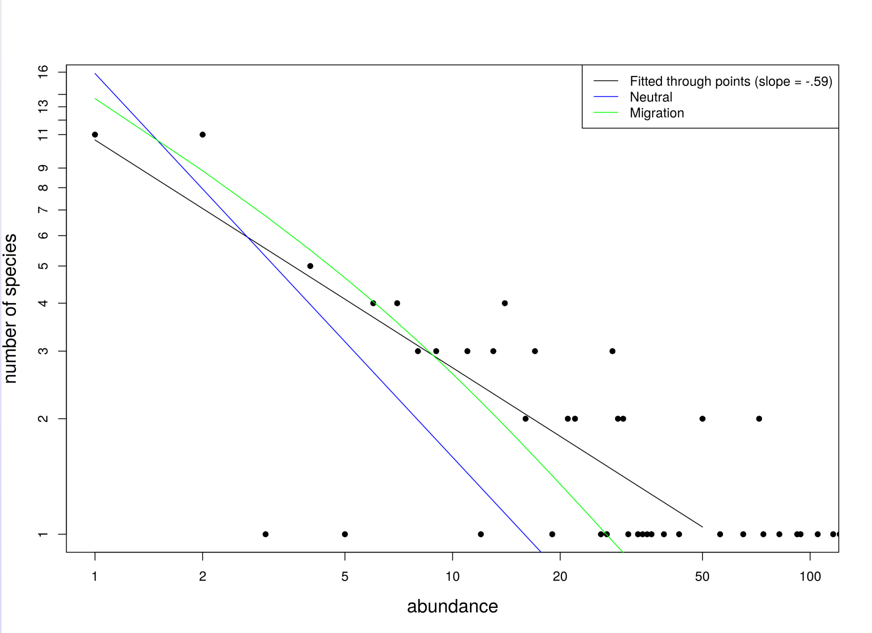


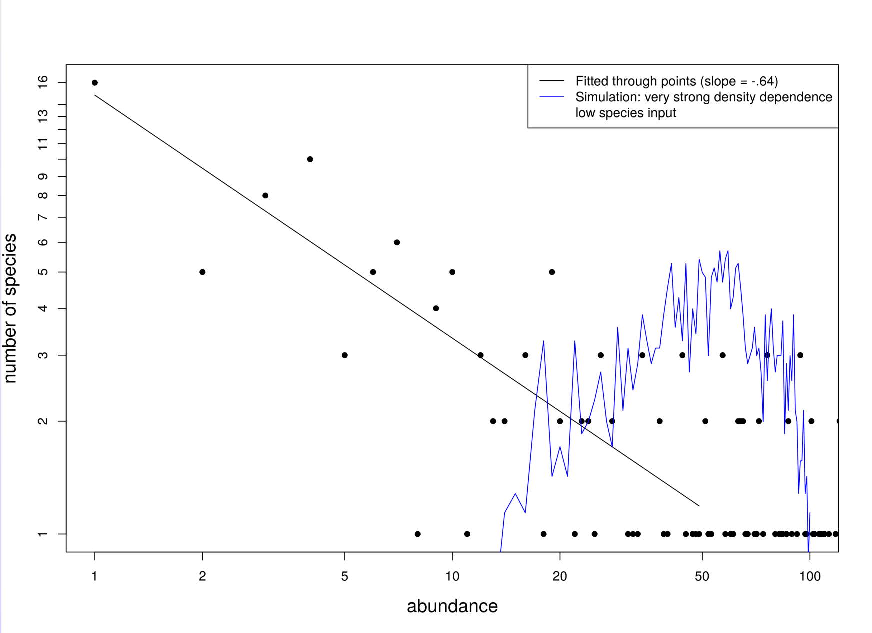
Species abundance: theory vs. Korup 50-ha plot



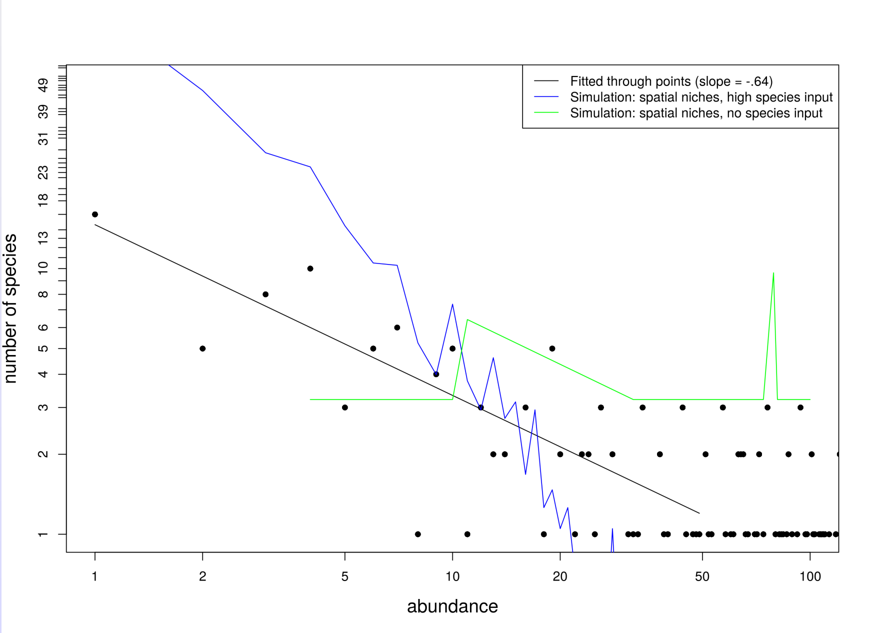
Species abundance: theory vs. Gutian plot



Species abundance: density-dependence theory vs. BCI plot



Species abundance: niche theory vs. BCI 50-ha plot



Predicted abundance distribution I

- The stochastic model with
  1. speciation
  2. without dispersal limitation
  3. without species differences

  leads to a log-series abundance distribution
- Species vs. abundance follows power-law with slope $= -1$
- Rare species tail, singletons always the most frequent category

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- Species vs. abundance follows power-law with slope $= -1$
- Rare species tail, singletons always the most frequent category
- **The dominance of singletons is driven by species input**

Predicted abundance distribution II

- A variant is a power-law with slope shallower than -1 (ie slope ~ -0.7)
- Many model variants predict this flattening
  1. Limited dispersal
  2. Density-dependence (rare species advantage)
  3. Strong intra-specific competition

Predicted abundance distribution II

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- Many model variants predict this flattening
  1. Limited dispersal
  2. Density-dependence (rare species advantage)
  3. Strong intra-specific competition
- **All these models predict a rare-species tail caused by species input**

Observed abundance distributions

Diverse forests

- Singletons always most frequent species
- Abundances follow a power-law
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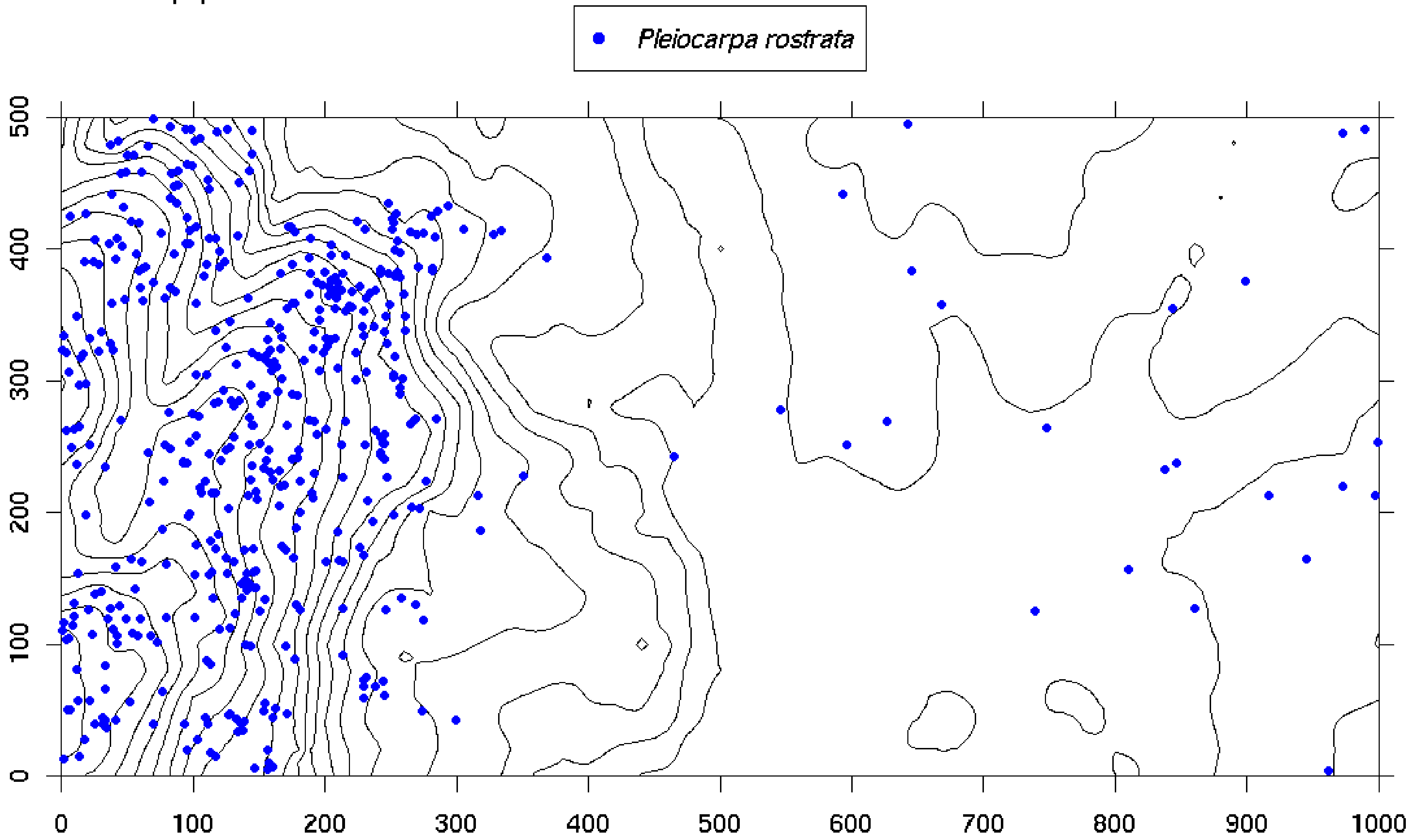
- The slope is always shallower than -1
  (ie slope ~ -0.7)
- **Theories with species input match these predictions**
  (with or without niche differences)
- **Theories with strong density-dependence do not match observations**

Spatial theory of niche differences

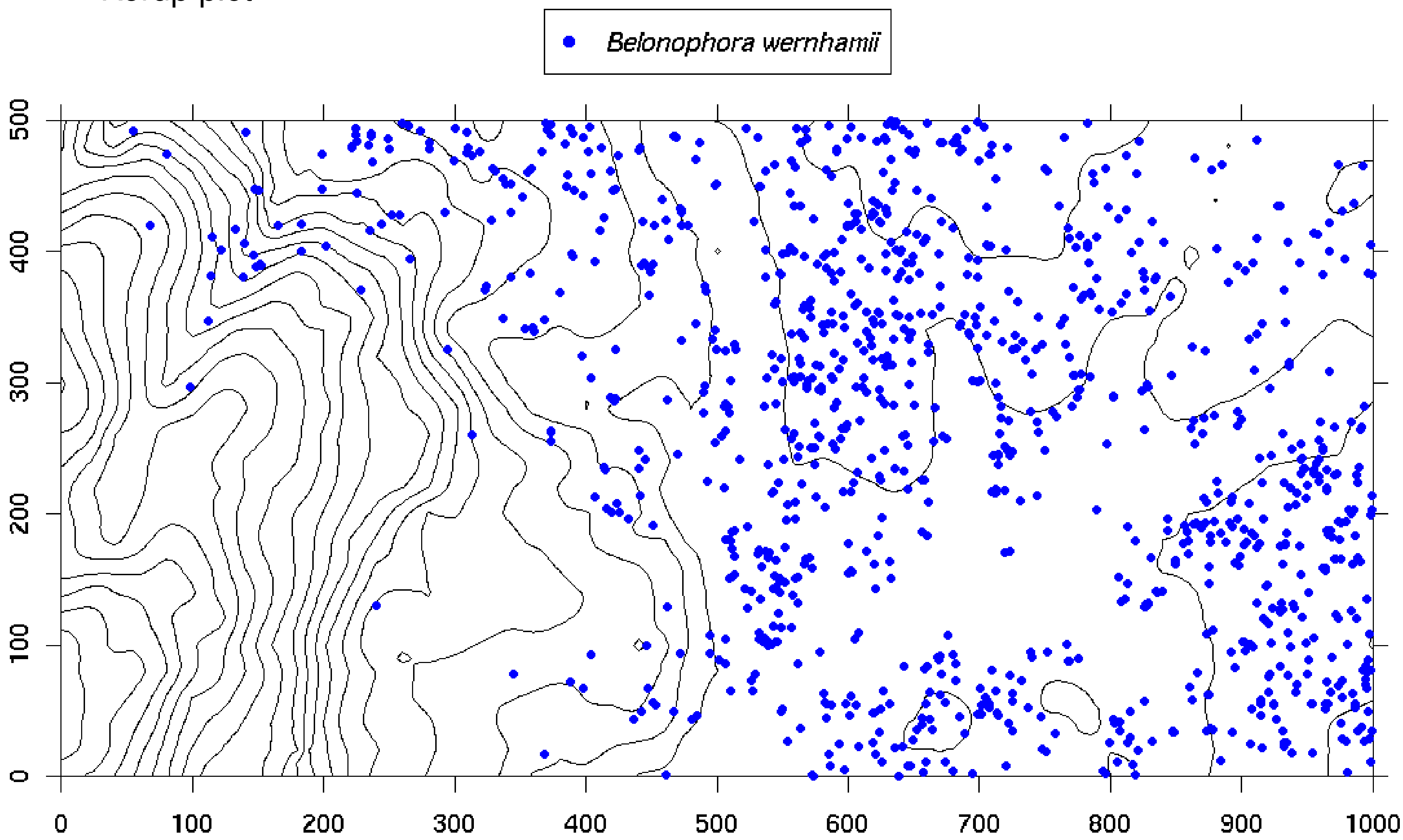
Observed and simulated maps –>

Korup plot



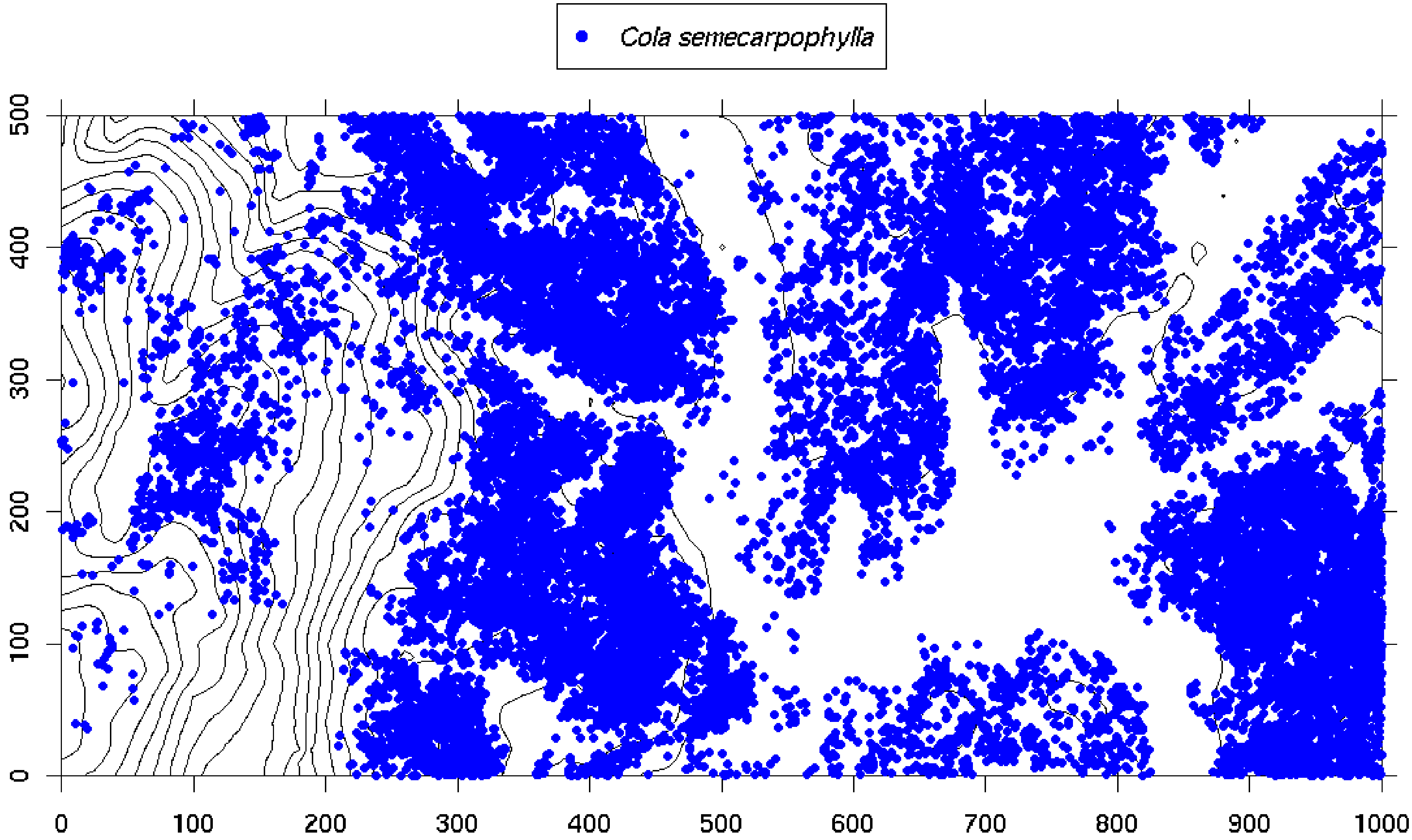
Pleiocarpa rostrata
0
100
200
300
400
500
600
700
800
900
1000
0
100
200
300
400
500

Korup plot


Belonophora wernhamii
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000

Korup 50 ha plot (Cameroon)

494 species,329000 individuals in full census ≥1 cm dbh



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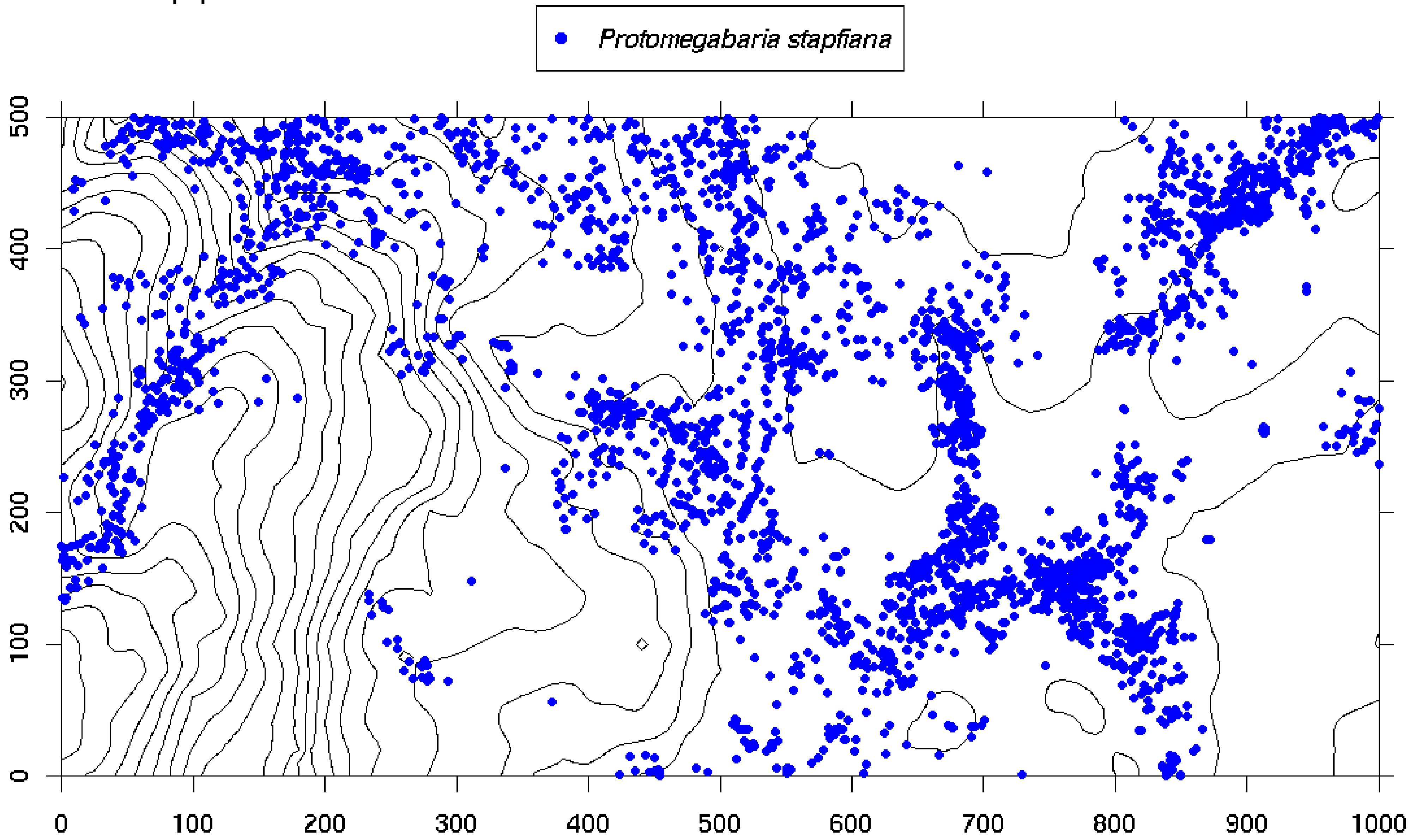
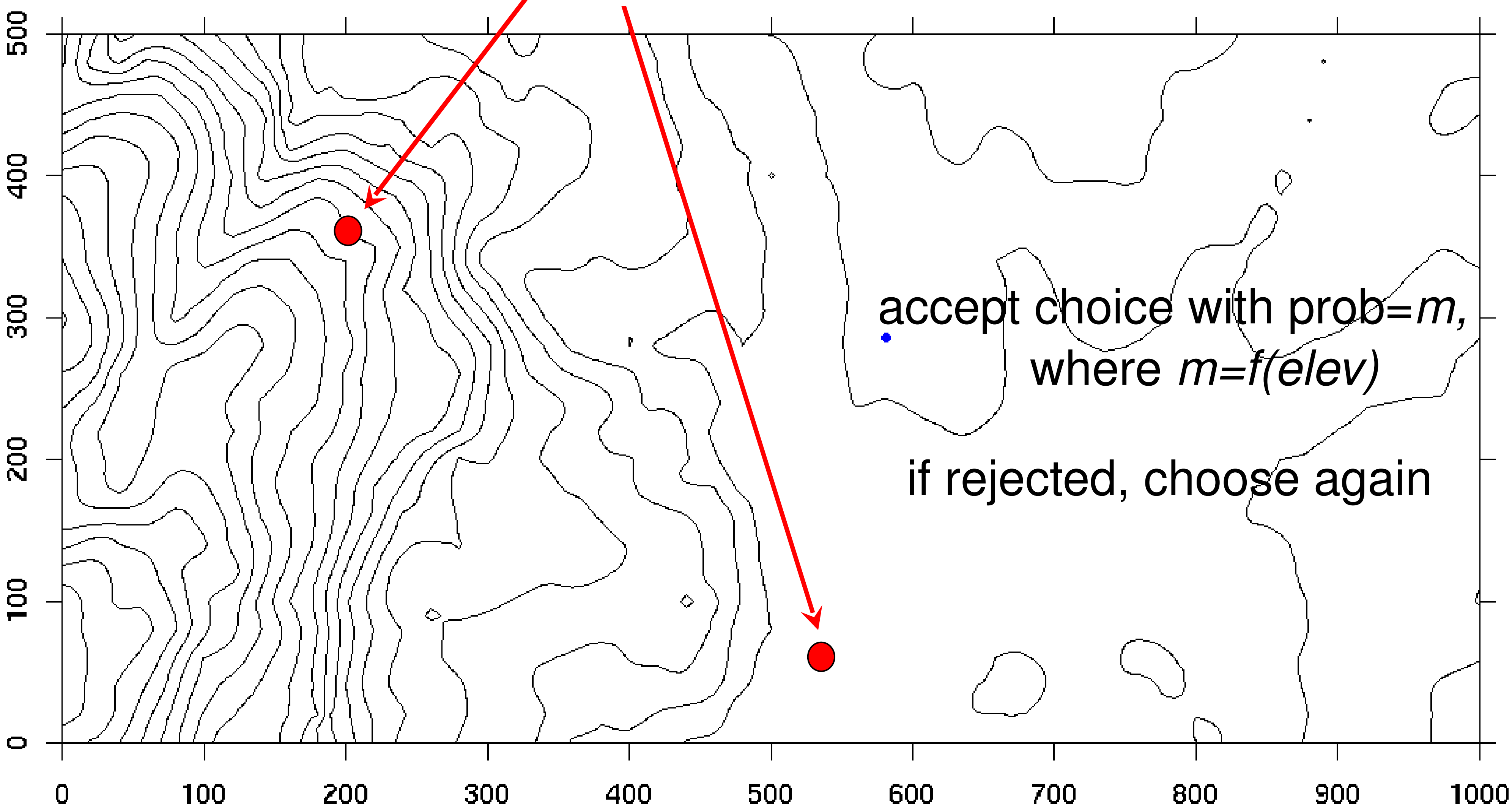
Korup plot



Protomegabaria stapfiana
0
100
200
300
400
500
600
700
800
900
1000

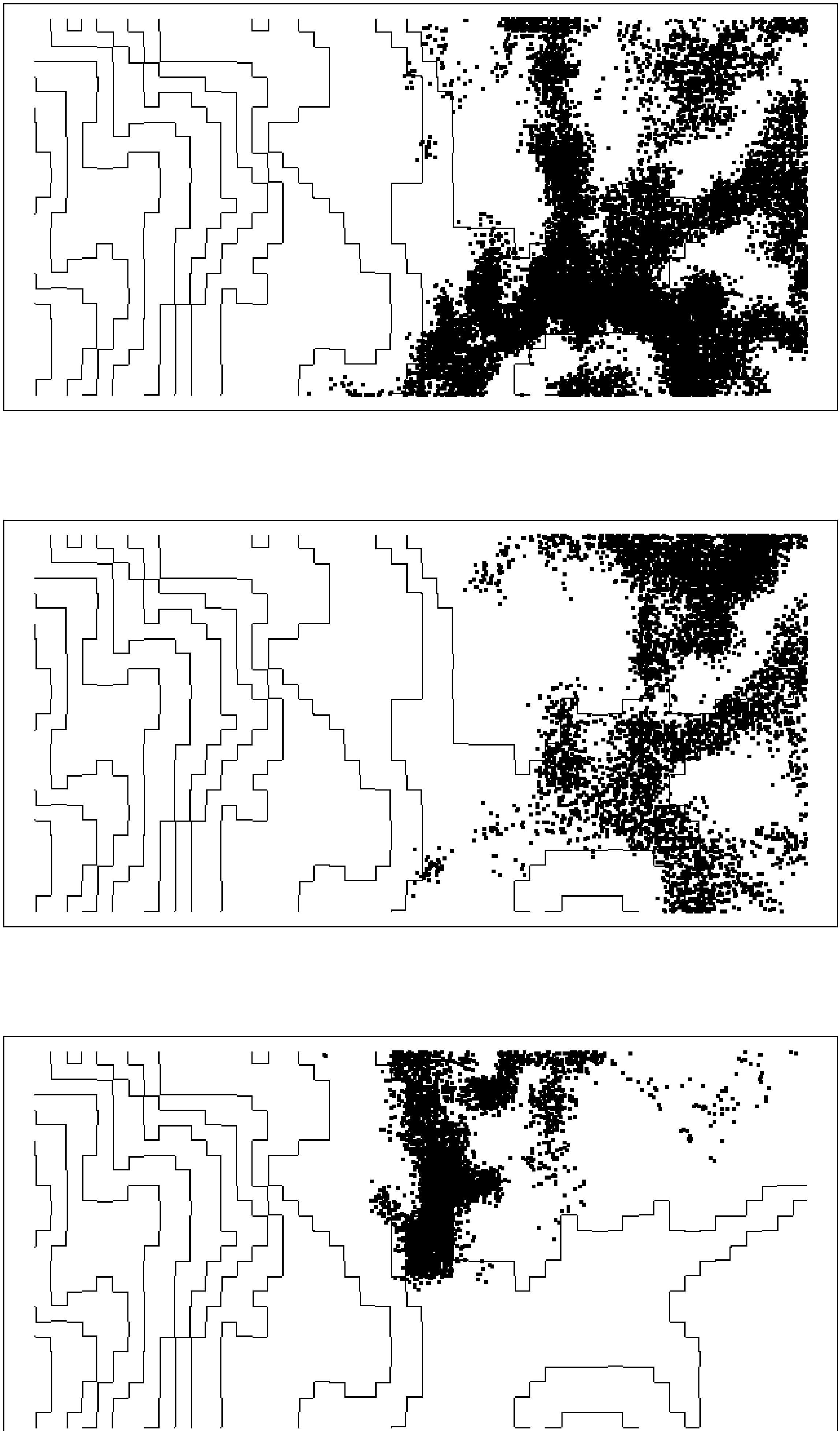
Incorporating niche differences into the stochastic model

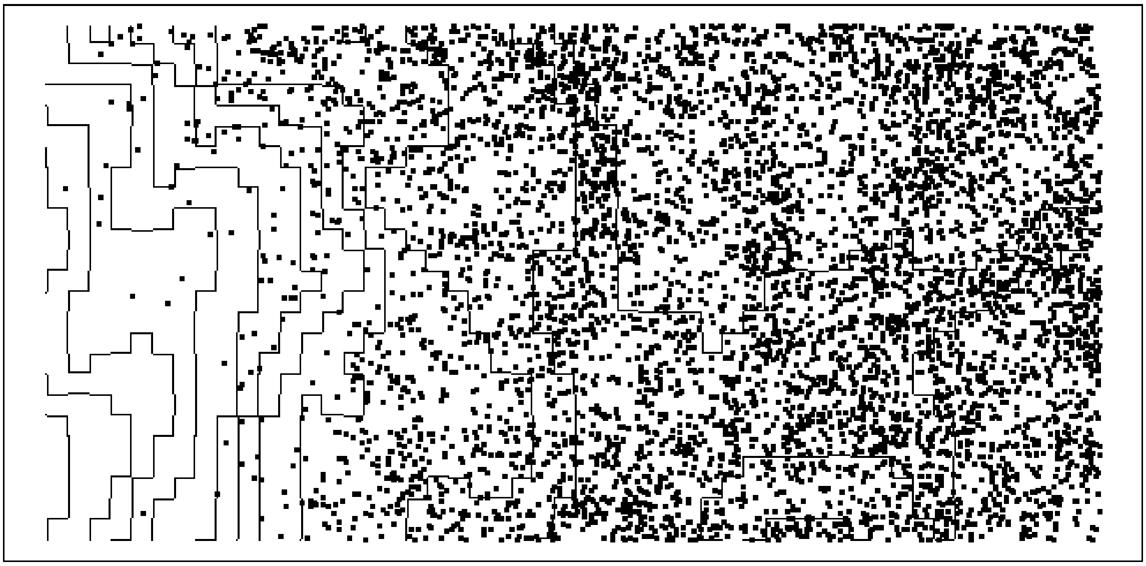
choose tree to die at random

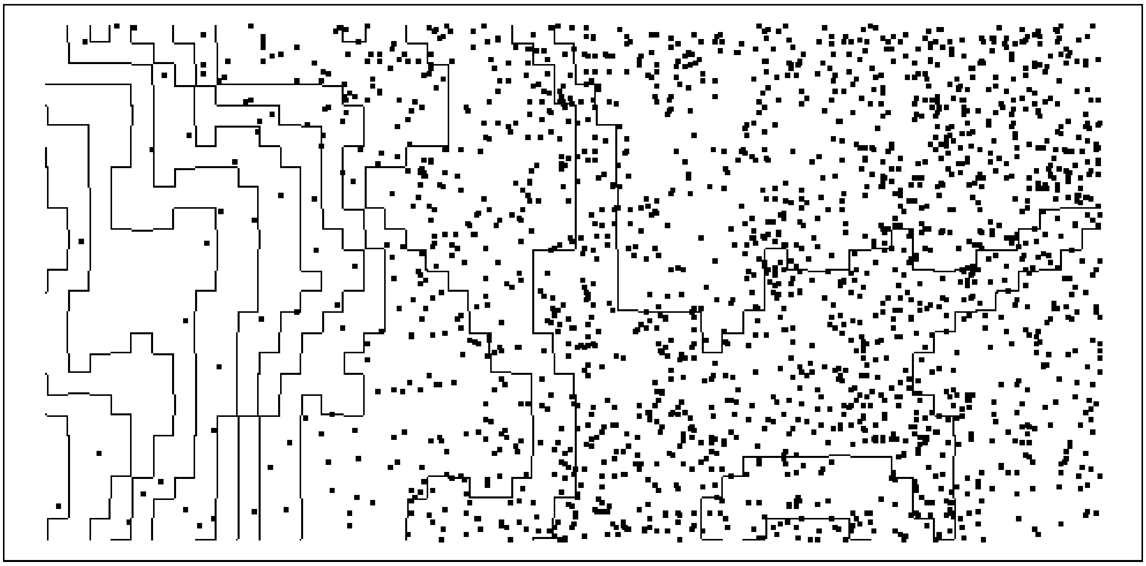


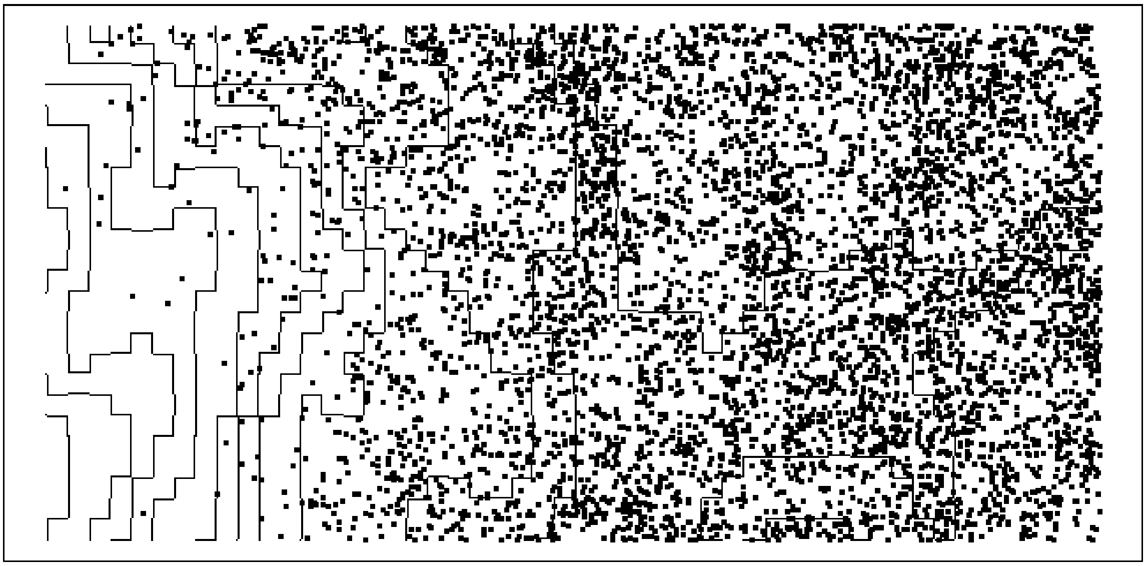
accept choice with prob=*m*,
where *m=f(elev)*

if rejected, choose again

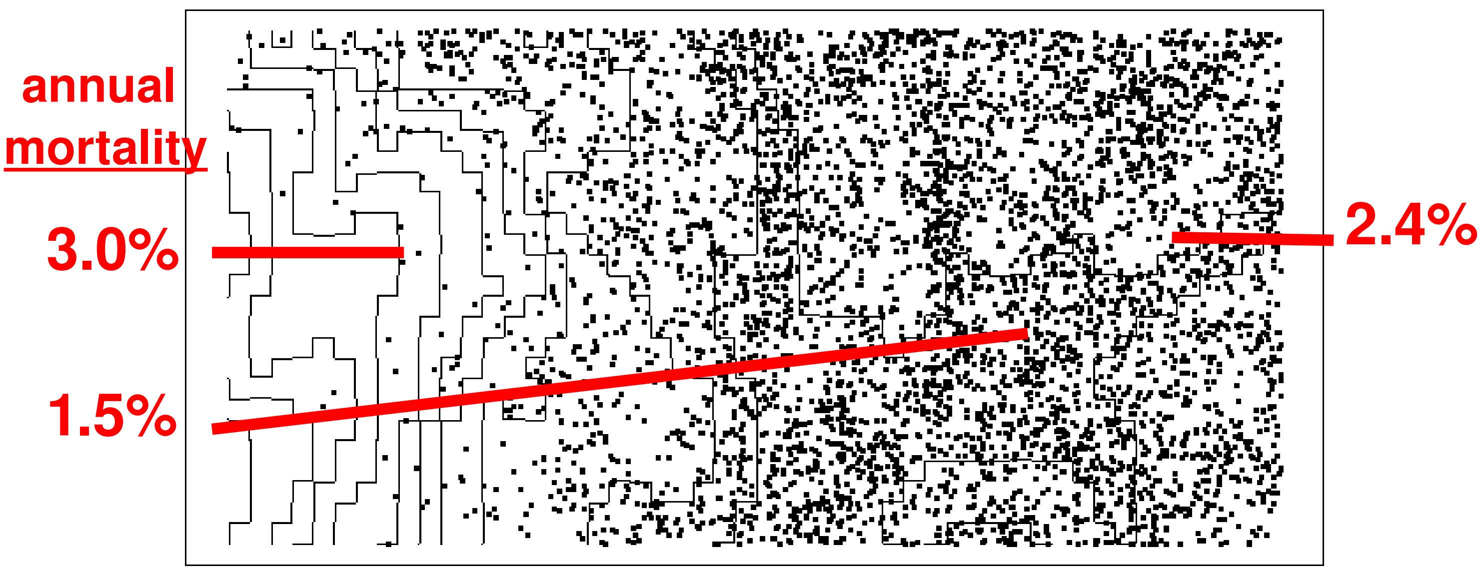




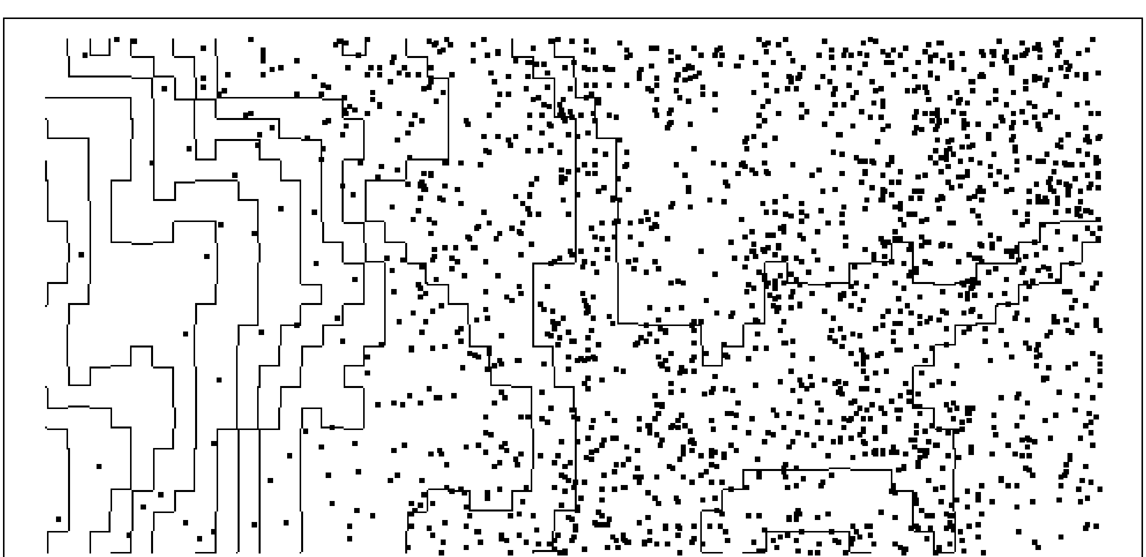


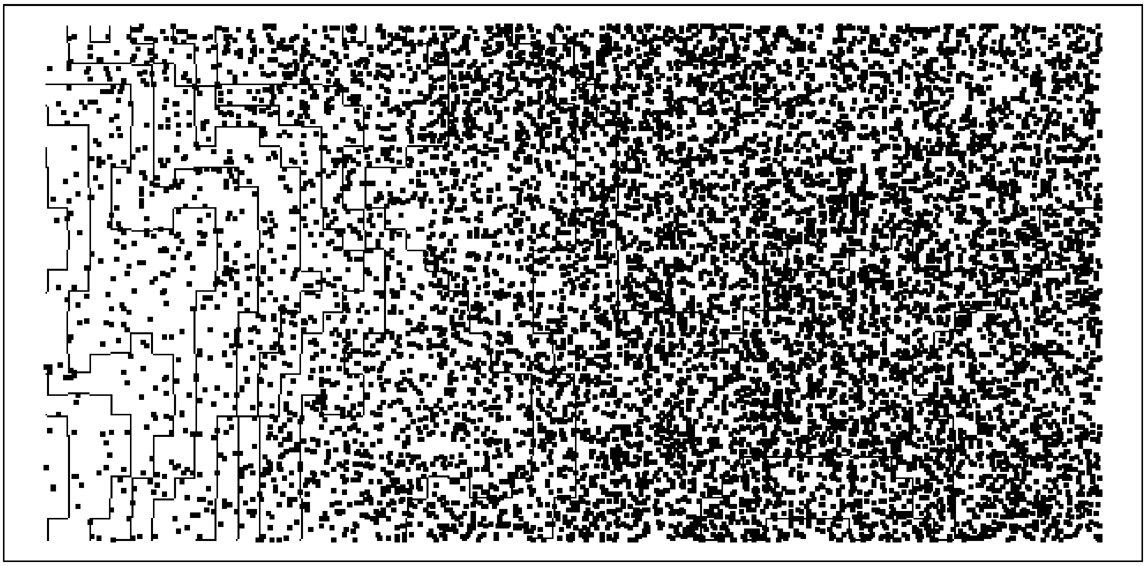


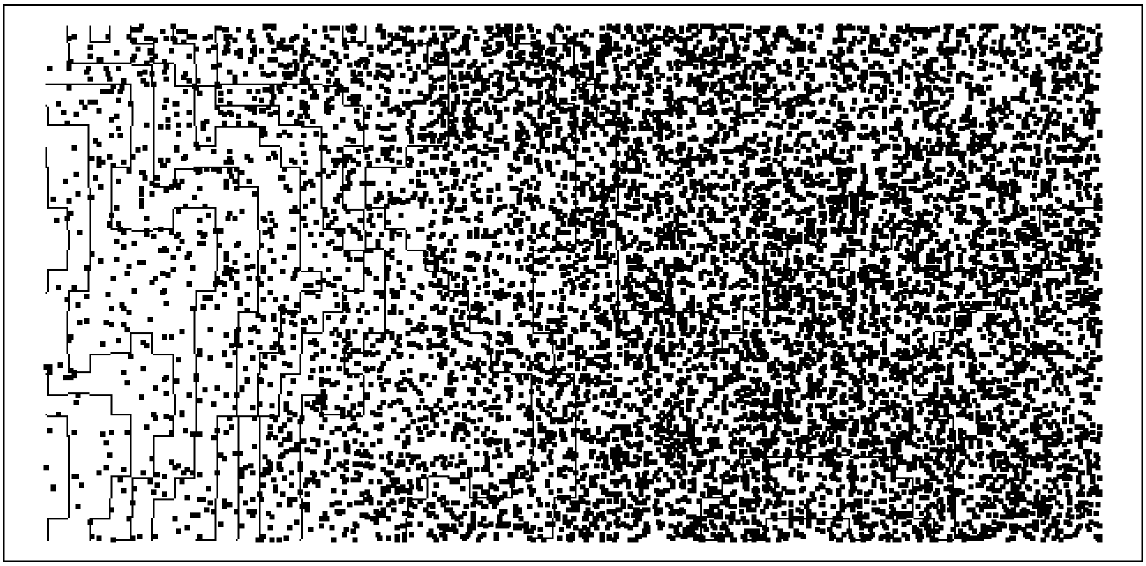
200-m dispersal, strong mortality effect of environment



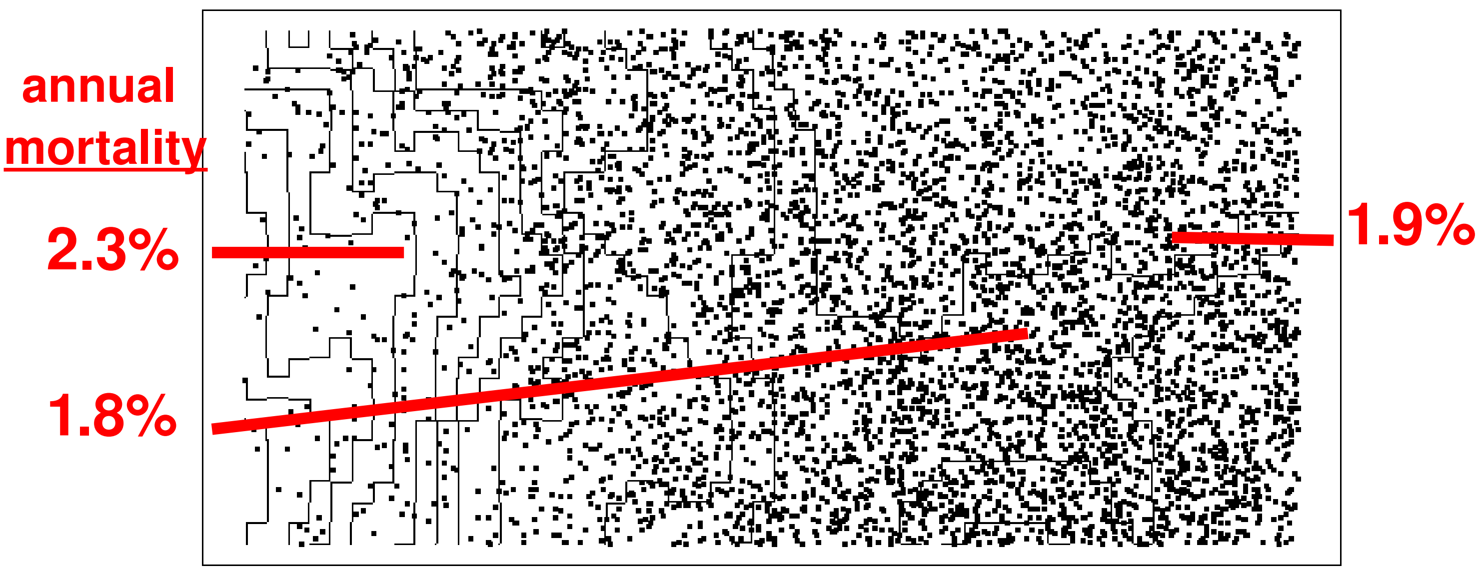
3 coexisting species with identical environmental response







200-m dispersal, weak mortality effect of environment



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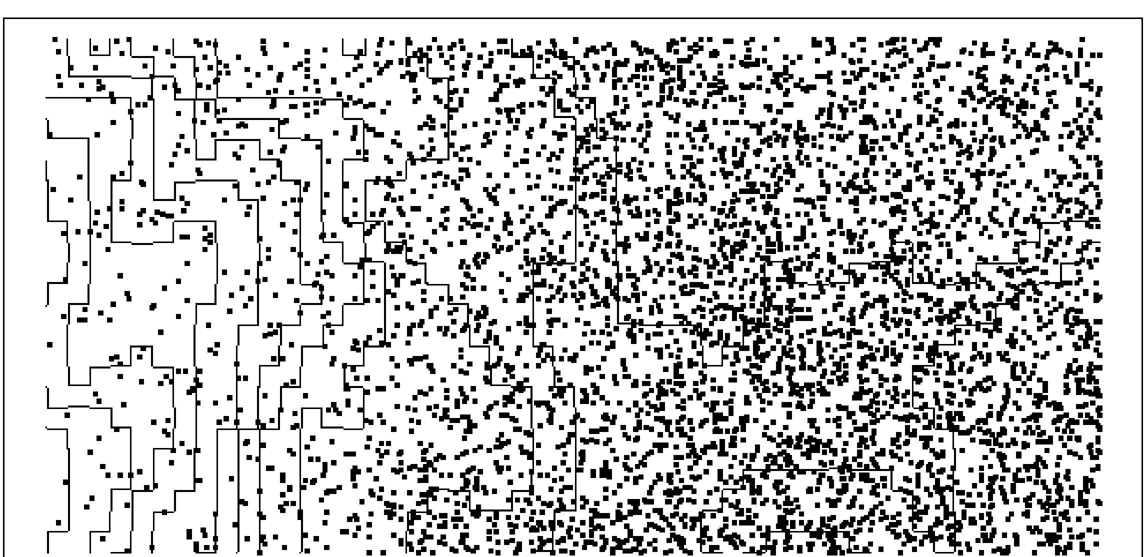
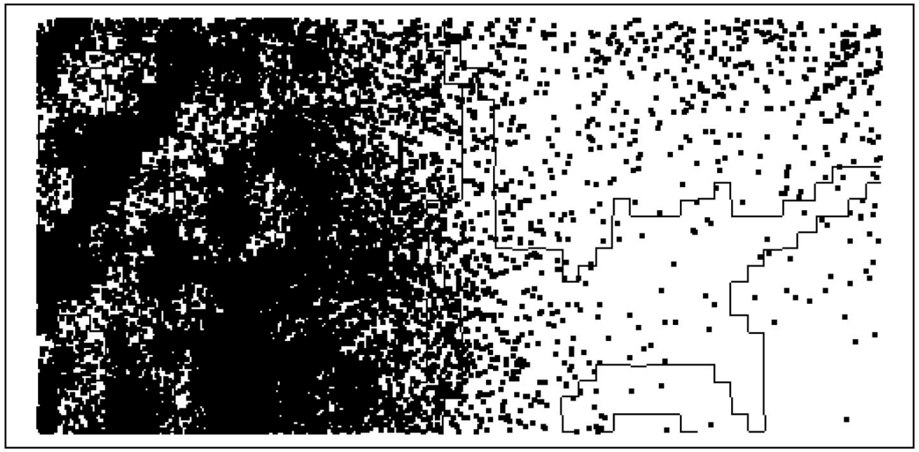
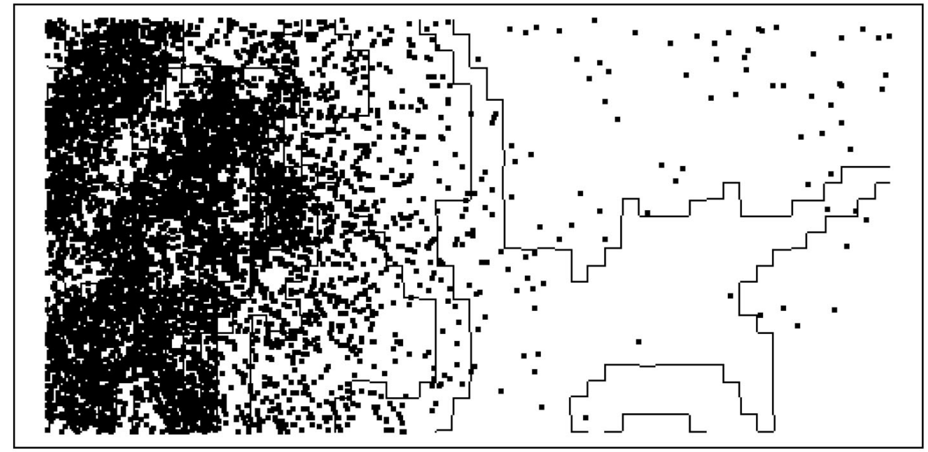


Simulated species distributions with niche differences

Community has 140 species, one with 17484 individuals ... 45 singletons

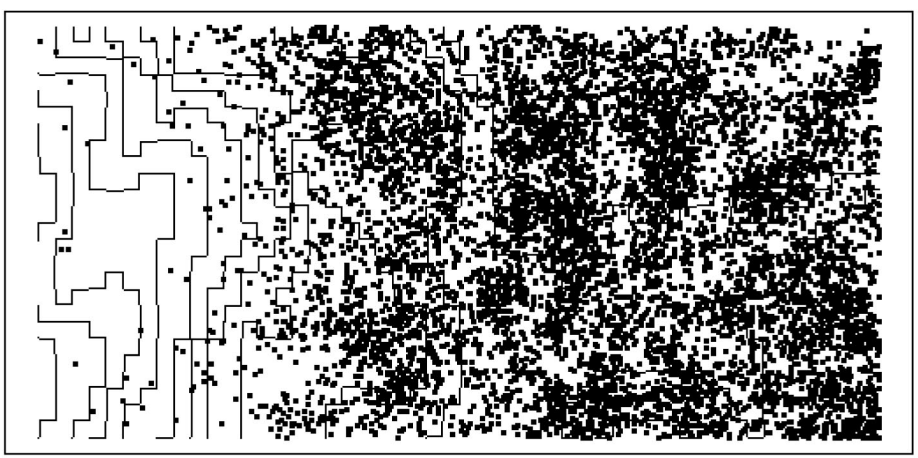


x1



x2

44 unique niche responses, 10 most abundant species all have one of these 4



x3

x4

more simulations....

Summary III: Spatial niches in a stochastic community

With species input, many species with the same habitat requirements co-occur

Poor dispersal can prevent species from reaching suitable habitat

Good dispersal sends species into unsuitable habitat

An unnamed *Cola* species

Modeling niche differences

Dispersal, fitness, species input

- Fitness responses to environment cause clear spatial associations

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- Species input leads to many species with identical fitness
- An identical subset behave like a neutral subcommunity

Conclusions and hypotheses for future work

- Demographic theory of diversity and abundance

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- Demographic theory of diversity and abundance
  - Predictions of community traits with few assumptions
  - Incorporates species input with demographic stochasticity
  - Analytical results for simplest models
  - Any level of complexity can be included

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  - Rare species always dominate
  - Abundance distribution follows power-law with slope $\sim -.7$
  - Species input must be dominant
  - Species differences are modest

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  - Dispersal distances
  - Rate of species input
  - Fitness differences
  - Strength of intraspecific competition (NDD)

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