Spatial patterns and niche differences in stochastic communities

Modeling diversity and distributions in tree communities based on individual biology: birth, death, dispersal

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Large Plot Symposium
ESA meeting, Albuquerque
August 2009

A stochastic community theory

Biology of individuals:

Mortality
Reproduction
Growth
Dispersal
Speciation

Community patterns:

Competition
Diversity
Abundance
Spatial patterns
Species-area relationship
Extinction

A stochastic community theory

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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.)

Importance of the neutral theory is not neutrality

Stochastic & individual-based community theory:

• stochastic individual demography
• species input (an open community)

I) Observed community patterns in diverse forests

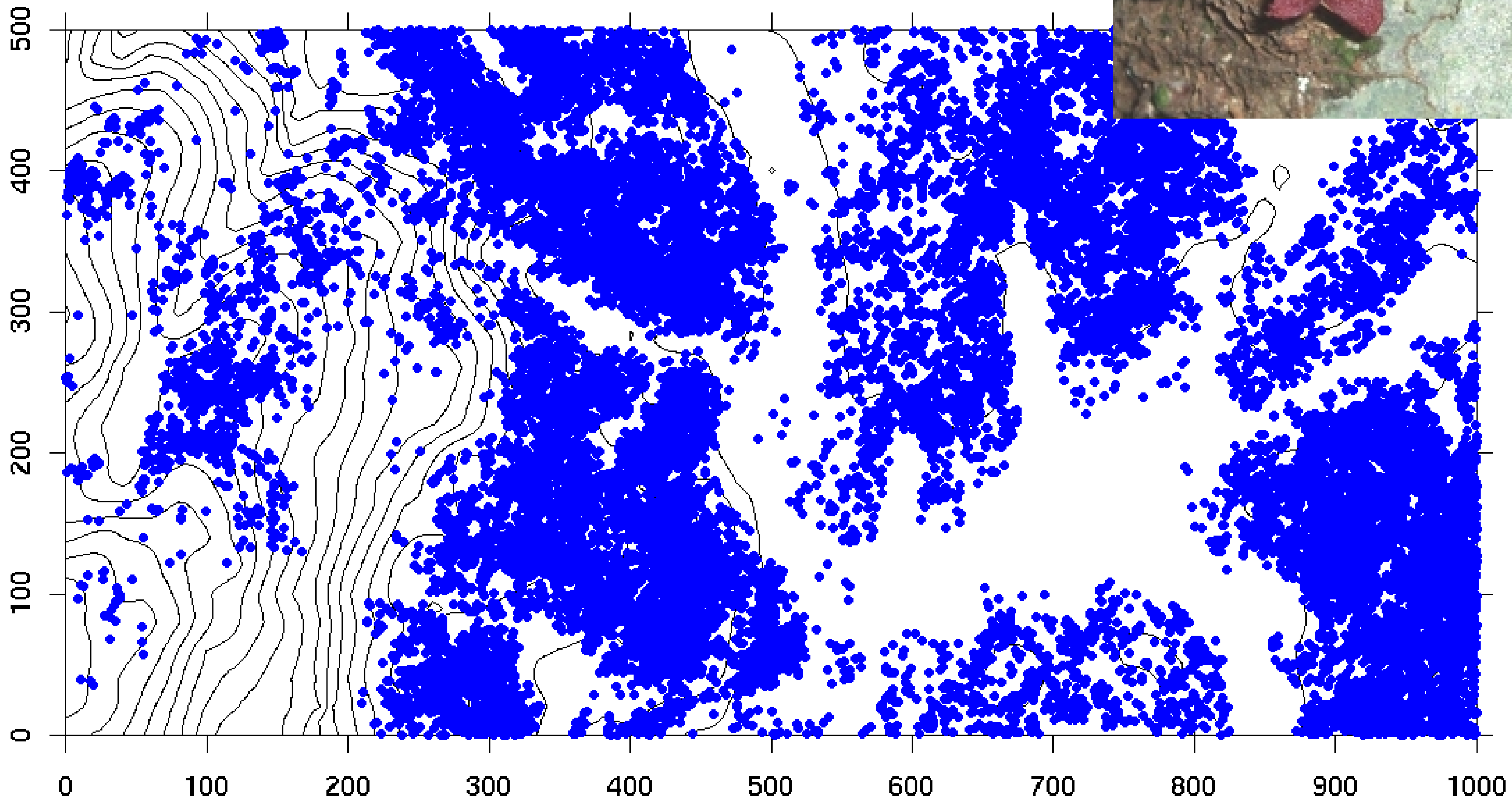
II) Theory aimed at understanding the patterns

1. Spatial distribution
2. Niche segregation

Turnera panamensis

Korup 50 ha plot (Cameroon)

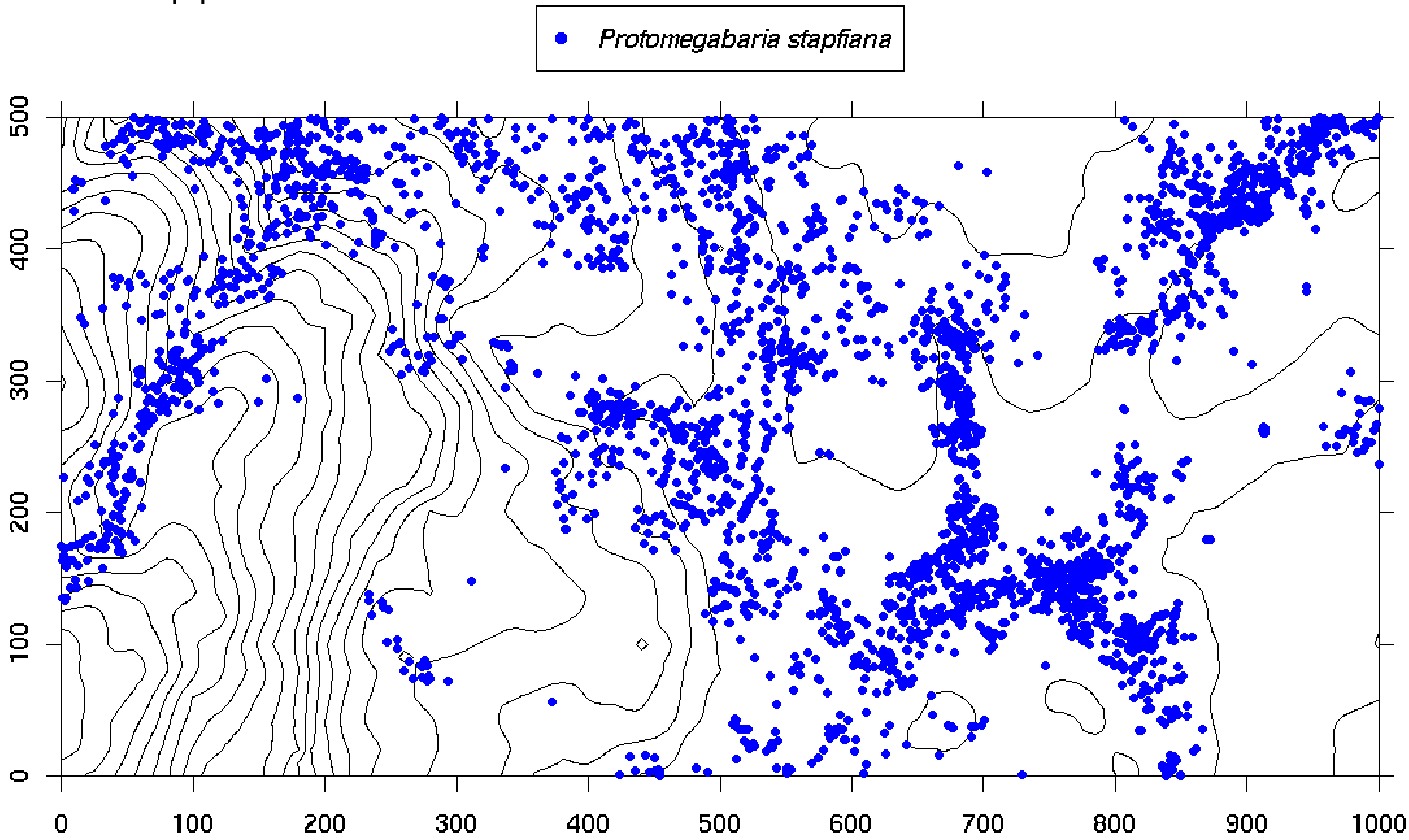
494 species,329000 individuals in full census ≥1 cm dbh



D. Kenfack

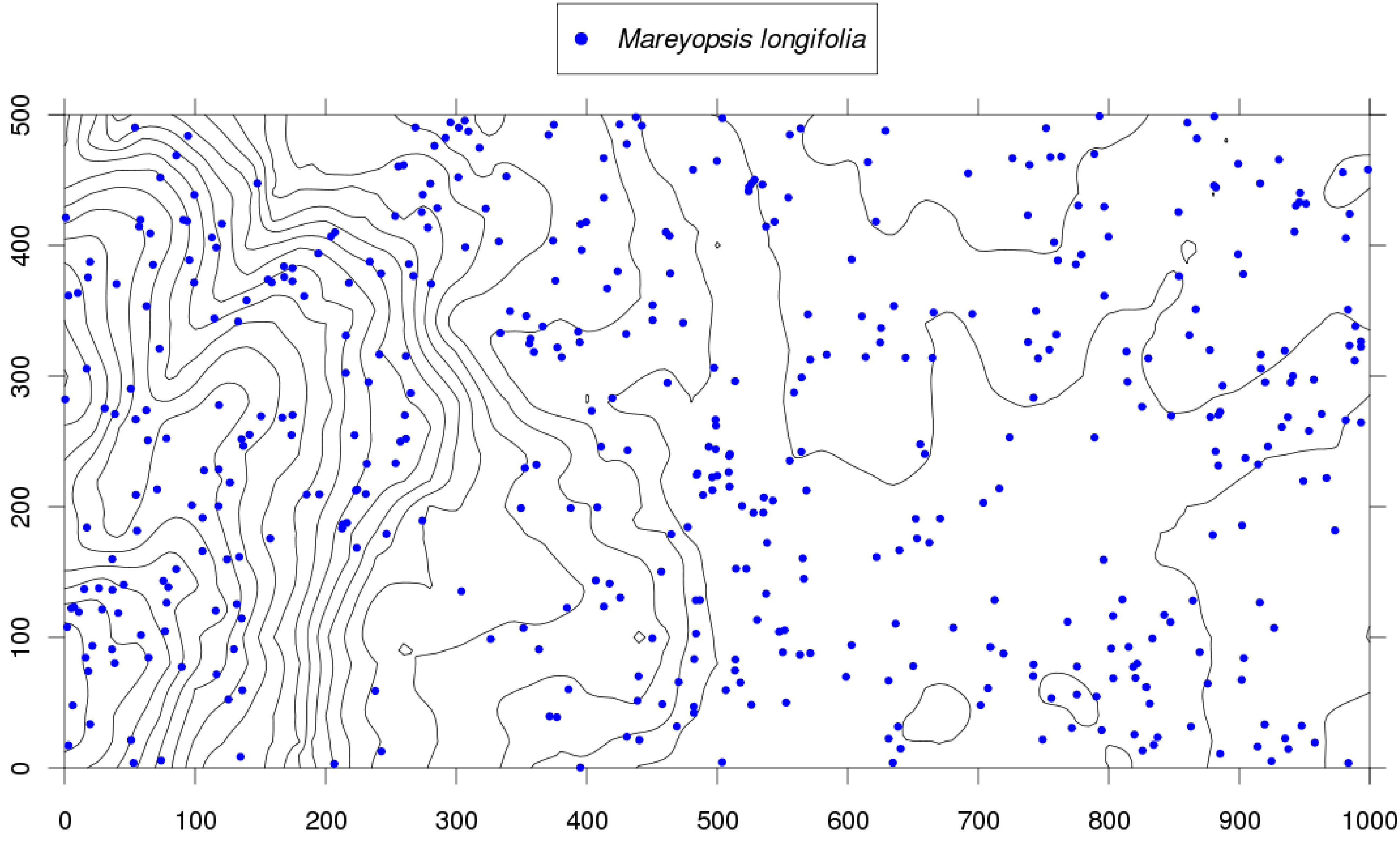
D. Kenfack, G. Chuyong, D. Thomas, R. Condit

Korup plot



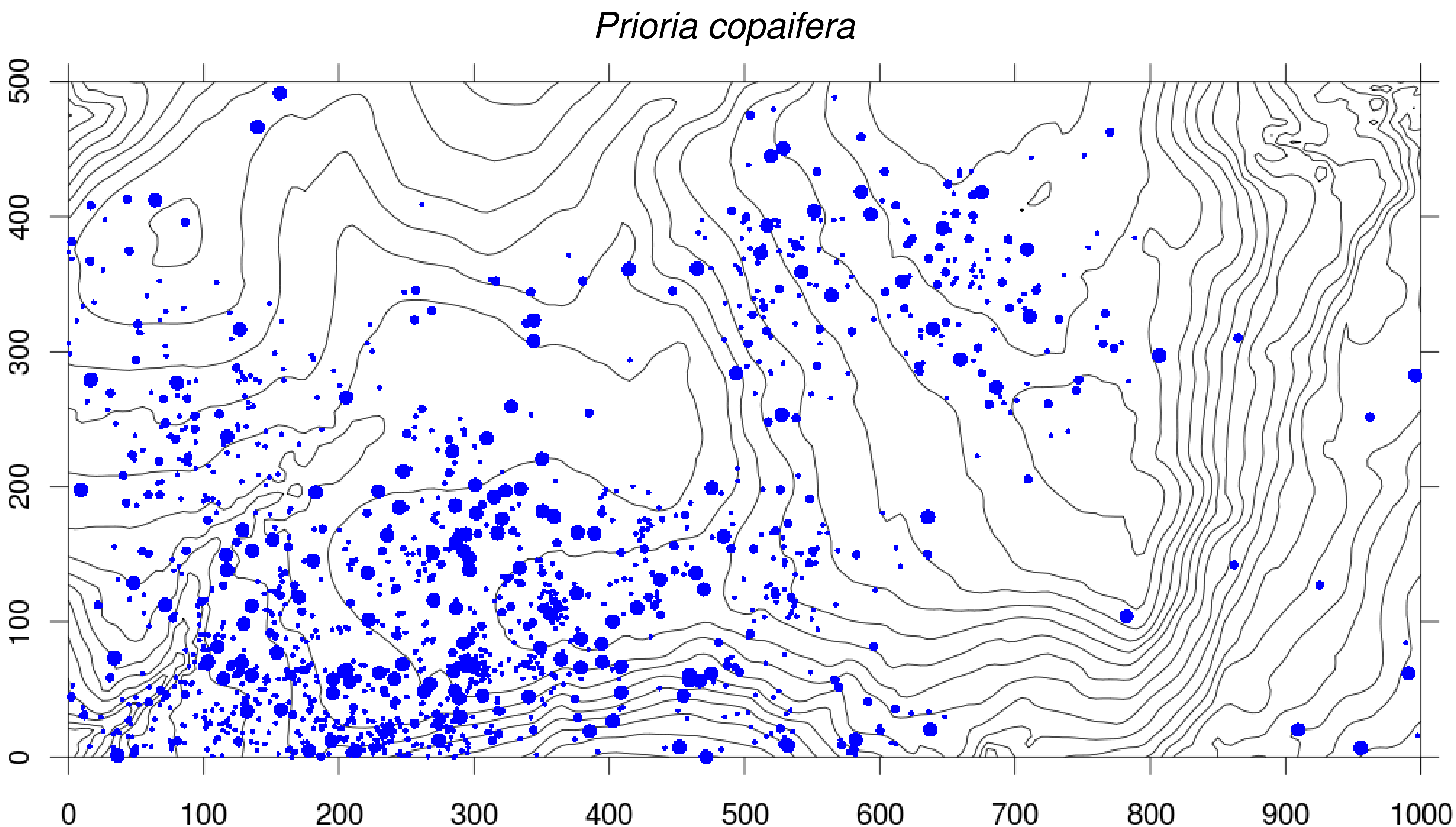
Protomegabaria stapfiana
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000

Korup plot



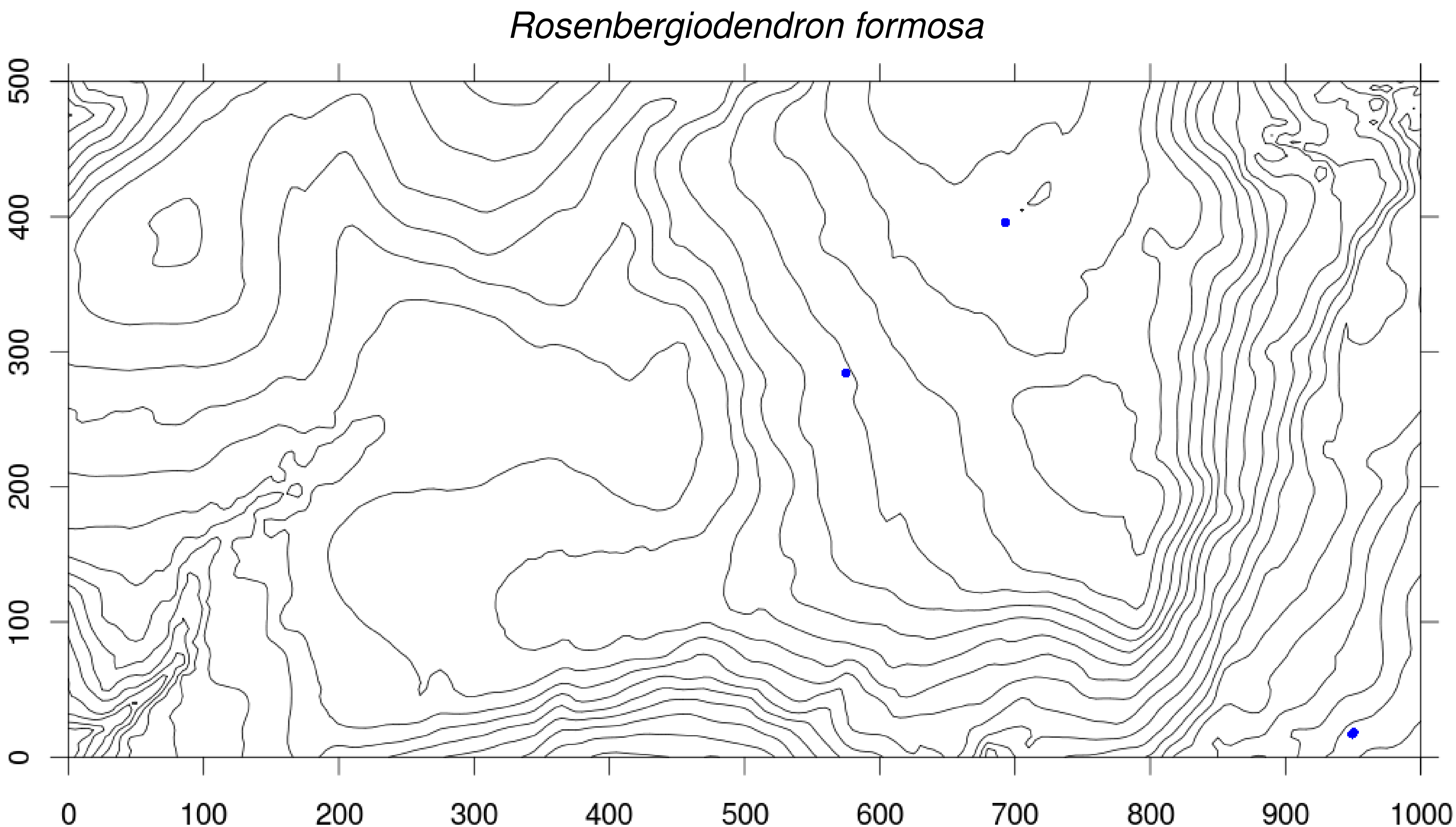
Mareyopsis longifolia
0
100
200
300
400
500
0
100
200
300
400
500
600
700
800
900
1000

BCI plot, Panama
301 species



S. Hubbell, R. Foster, R. Condit

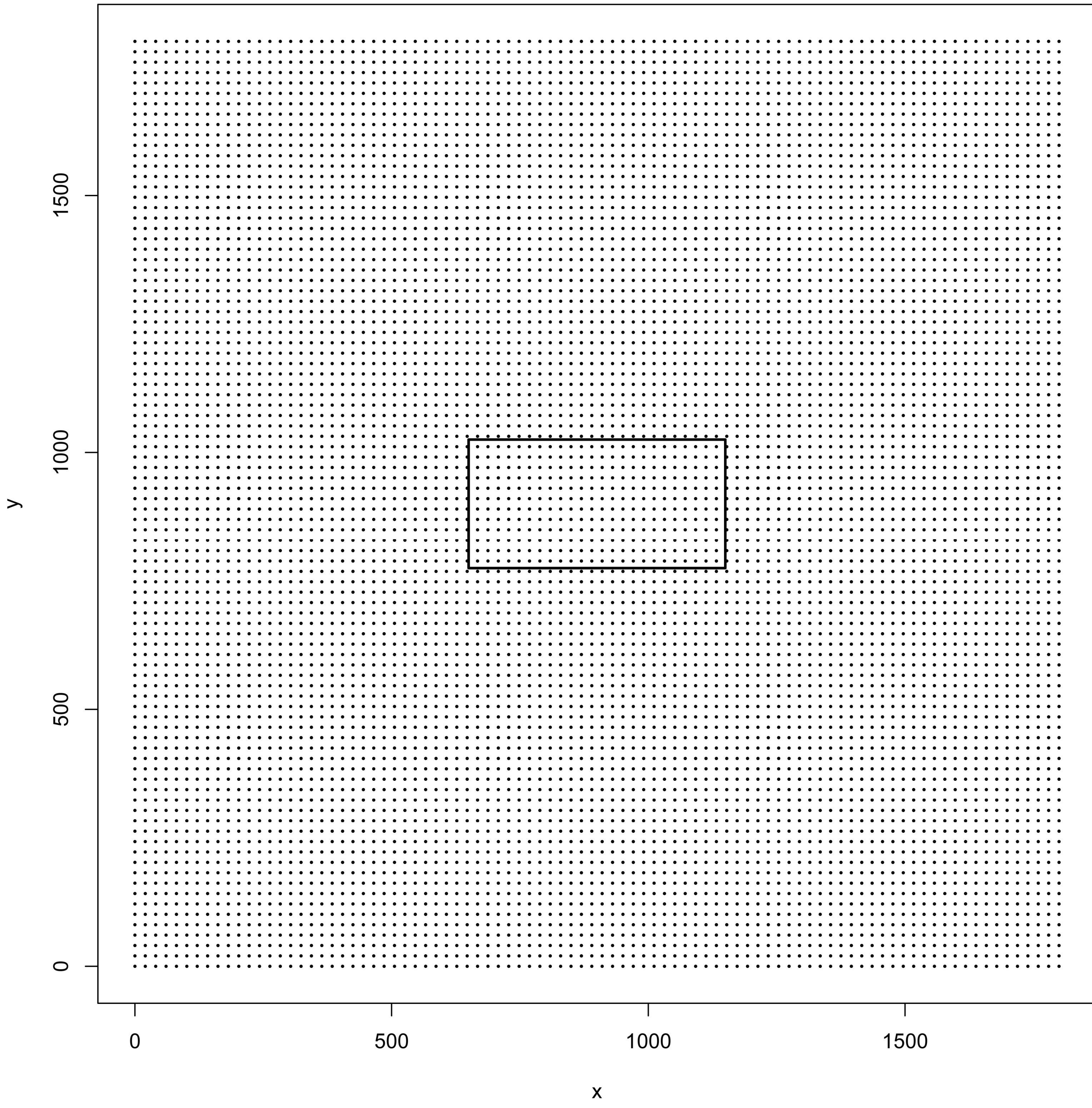
BCI plot, Panama



The Hubbell (voter) model

1800x1800 grid of trees
a '50-hectare' core

Fig. 6.1



Forestry models

- Individual trees
- Map positions
- Growth & resources
- Neighborhood competition
- Mortality
- Dispersal
- Distinct species
- Thousands of species
- Millions of years
- Speciation

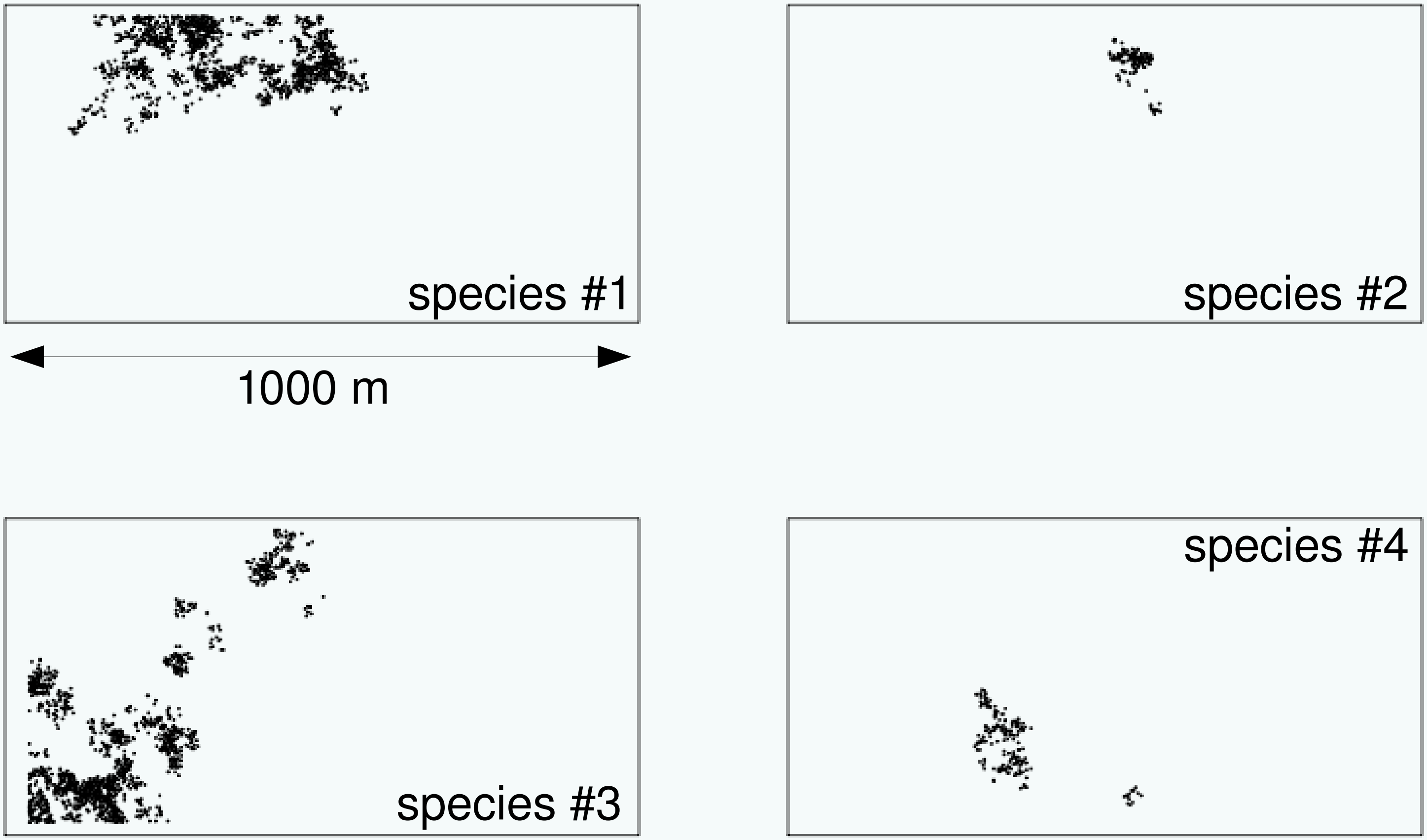
Diversity models

- Individual trees
- Map positions
- Growth & resources
- Neighborhood competition
- Mortality
- Dispersal
- Distinct species
- Thousands of species
- Millions of years
- Speciation

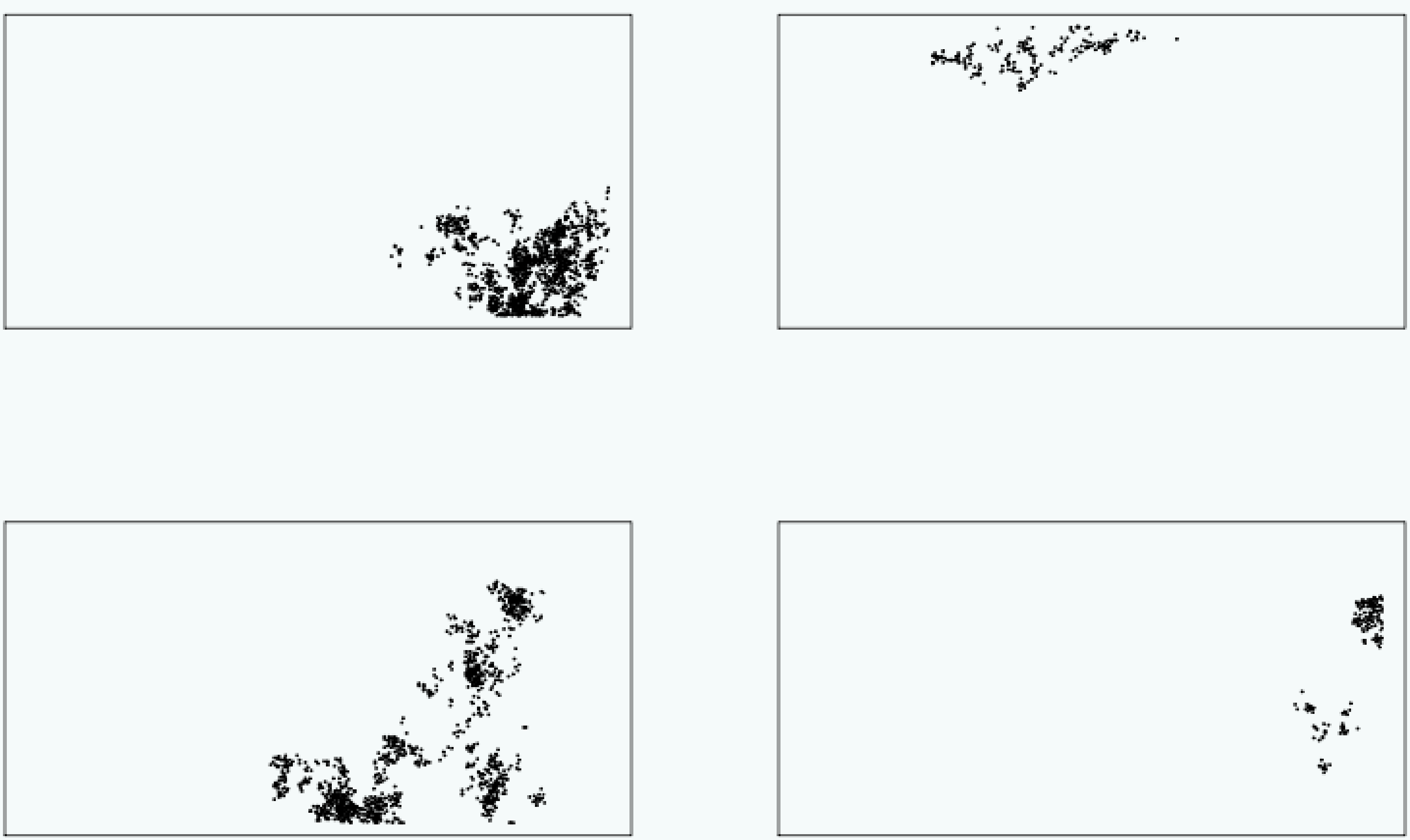
Theory on dispersal and range size

- Patchiness predicted from dispersal
- Conditions under which range size can be dispersal-limited

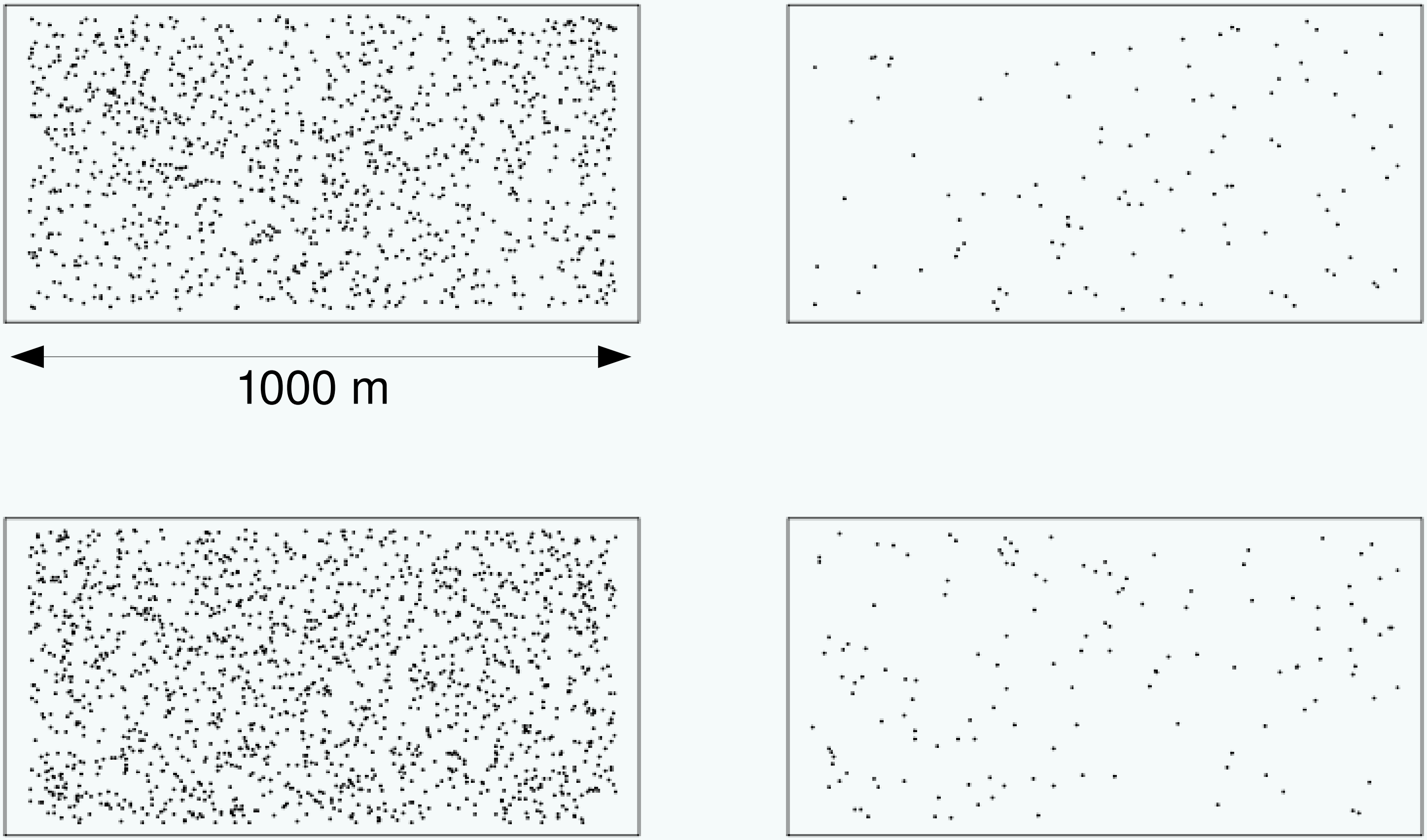
10-meter dispersal in 50-ha plot



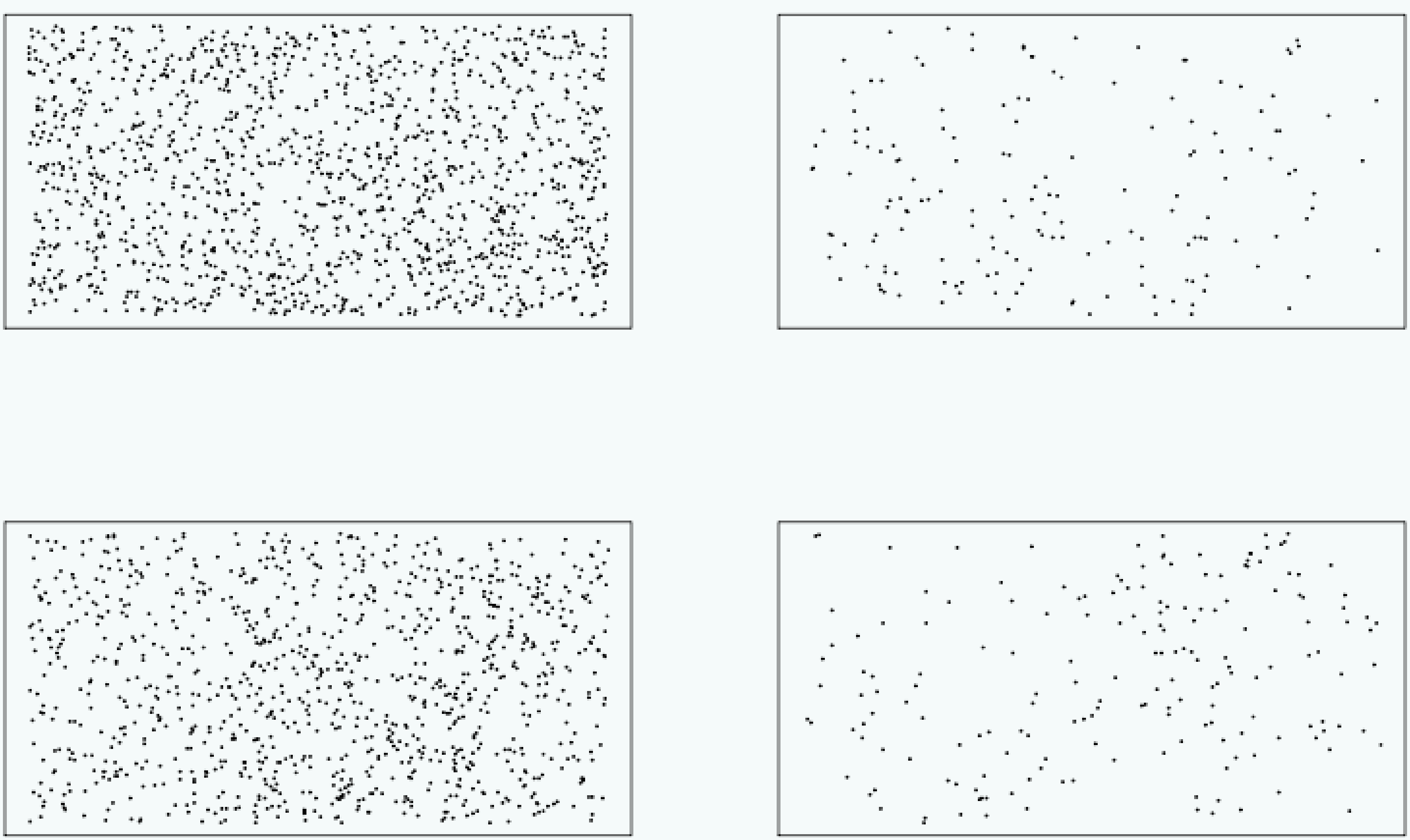
equilibrium patch sizes...



200-meter dispersal in 50-ha plot



equilibrium patch sizes...



A theory of dispersal limiting range size

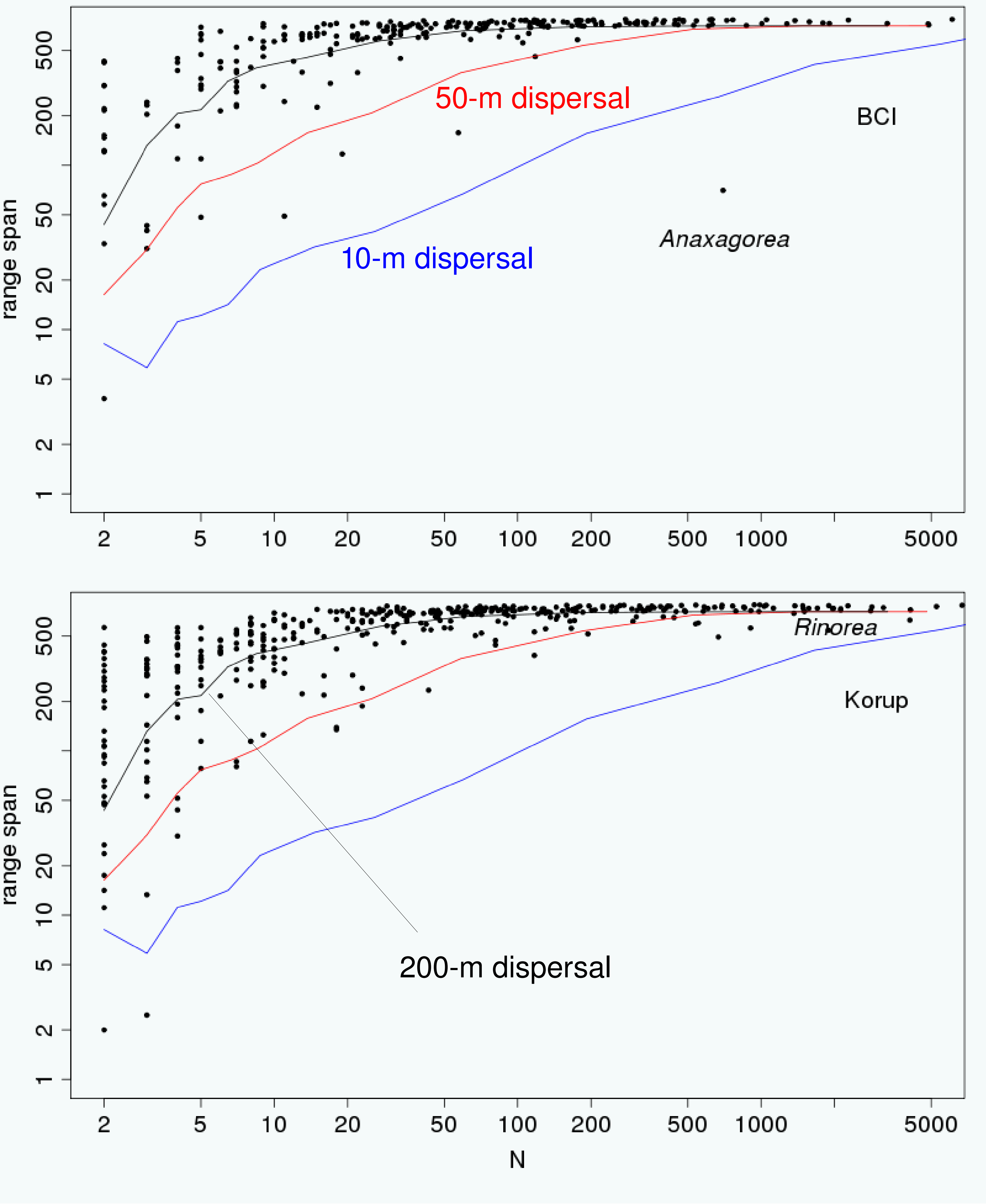
$$R \approx 2D\sqrt{(N)}$$

N = population size

R = linear span of range

D = maximum dispersal distance

Dispersal and range: observed and predicted



Summary
Spatial patterns in a neutral stochastic community

Poor dispersal creates very patchy distribution ...
... the degree of patchiness is simply related to dispersal distance

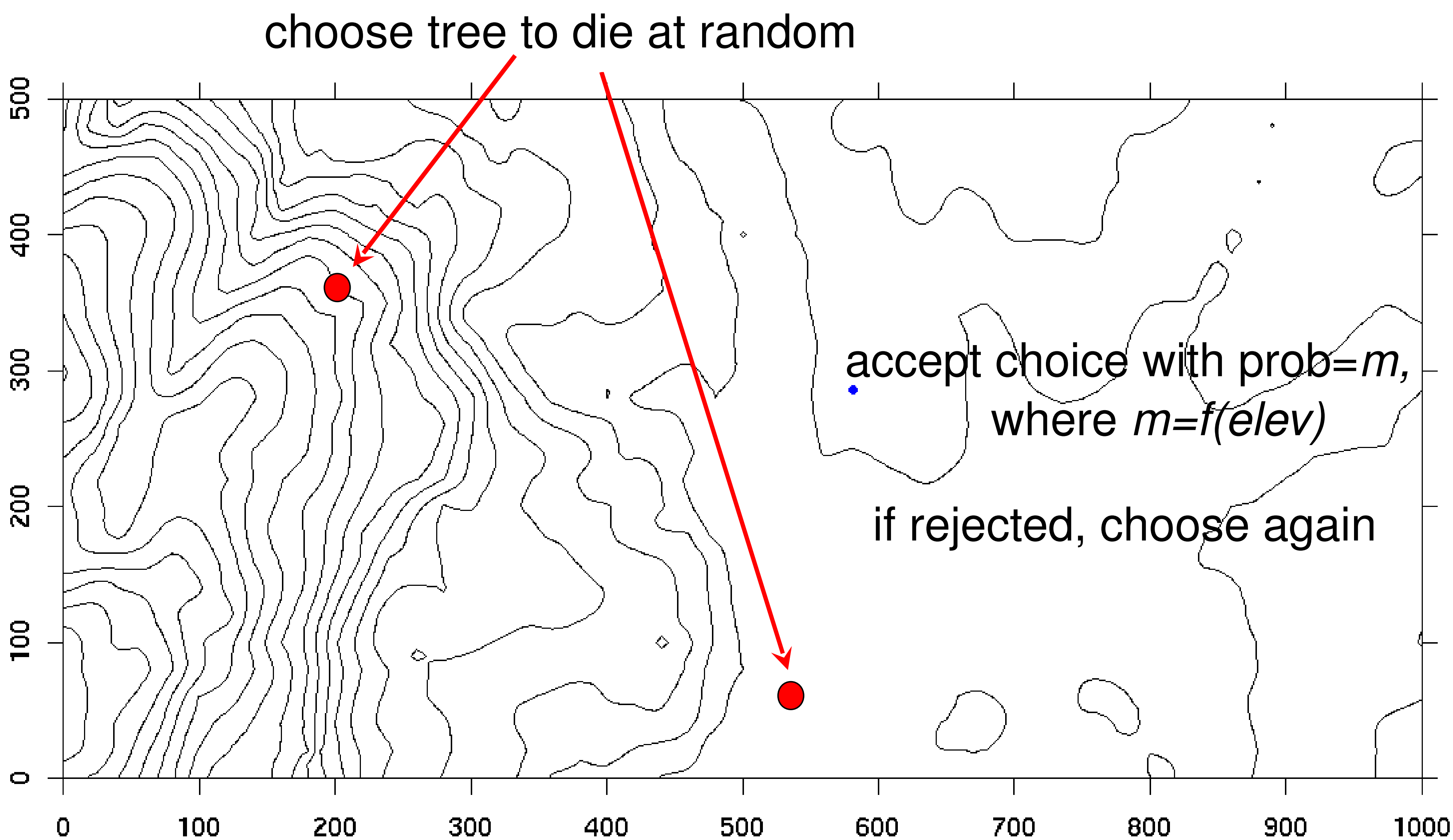
Most real tree species are widely distributed across 50 hectares ...
... matching simulations with ~ 200 m or better dispersal distances

Dispersal has minor impact on abundances and diversity

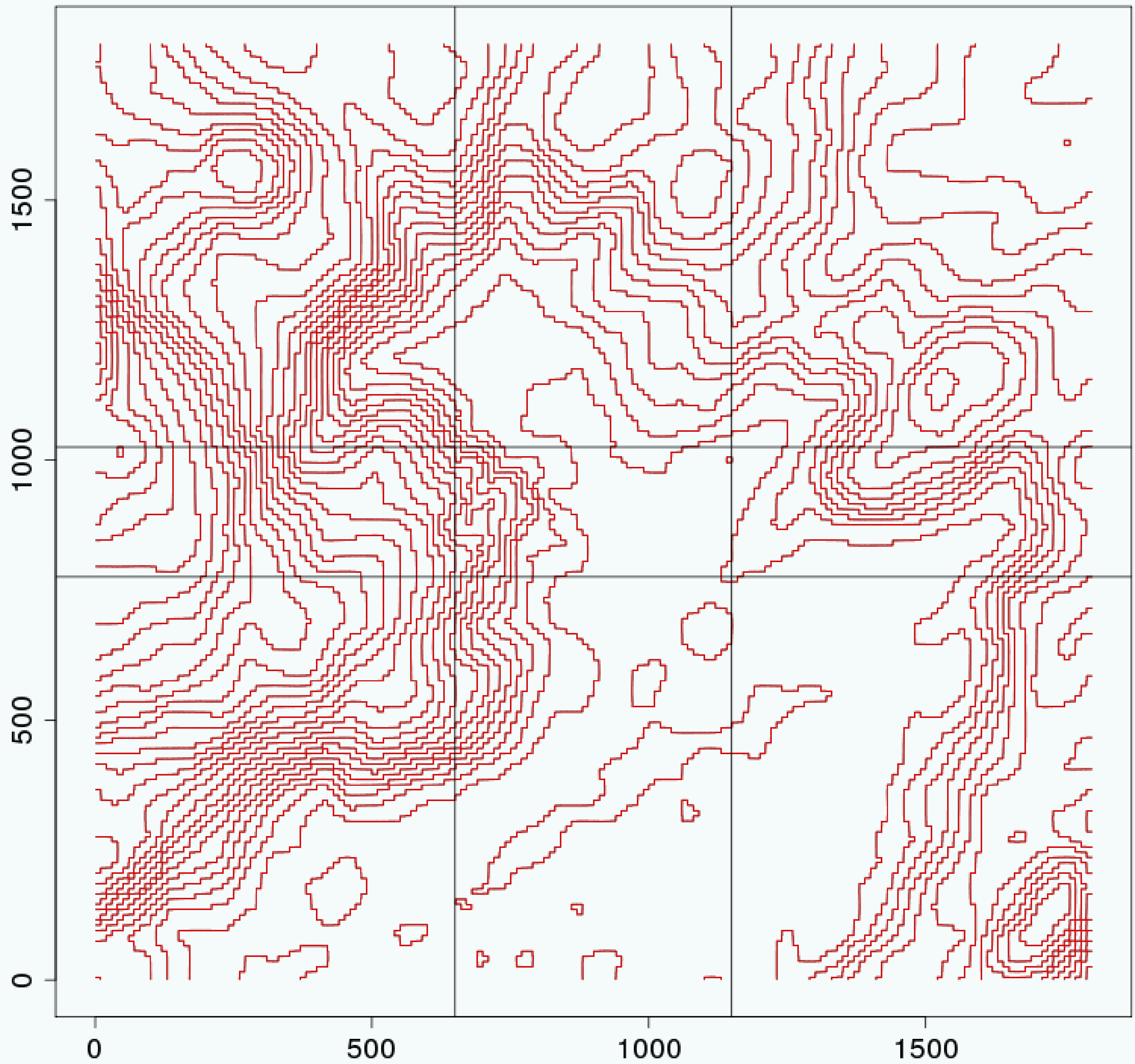
Niche segregation in a stochastic community

Coexistence where species input and dispersal are important

Incorporating niche differences into the stochastic model

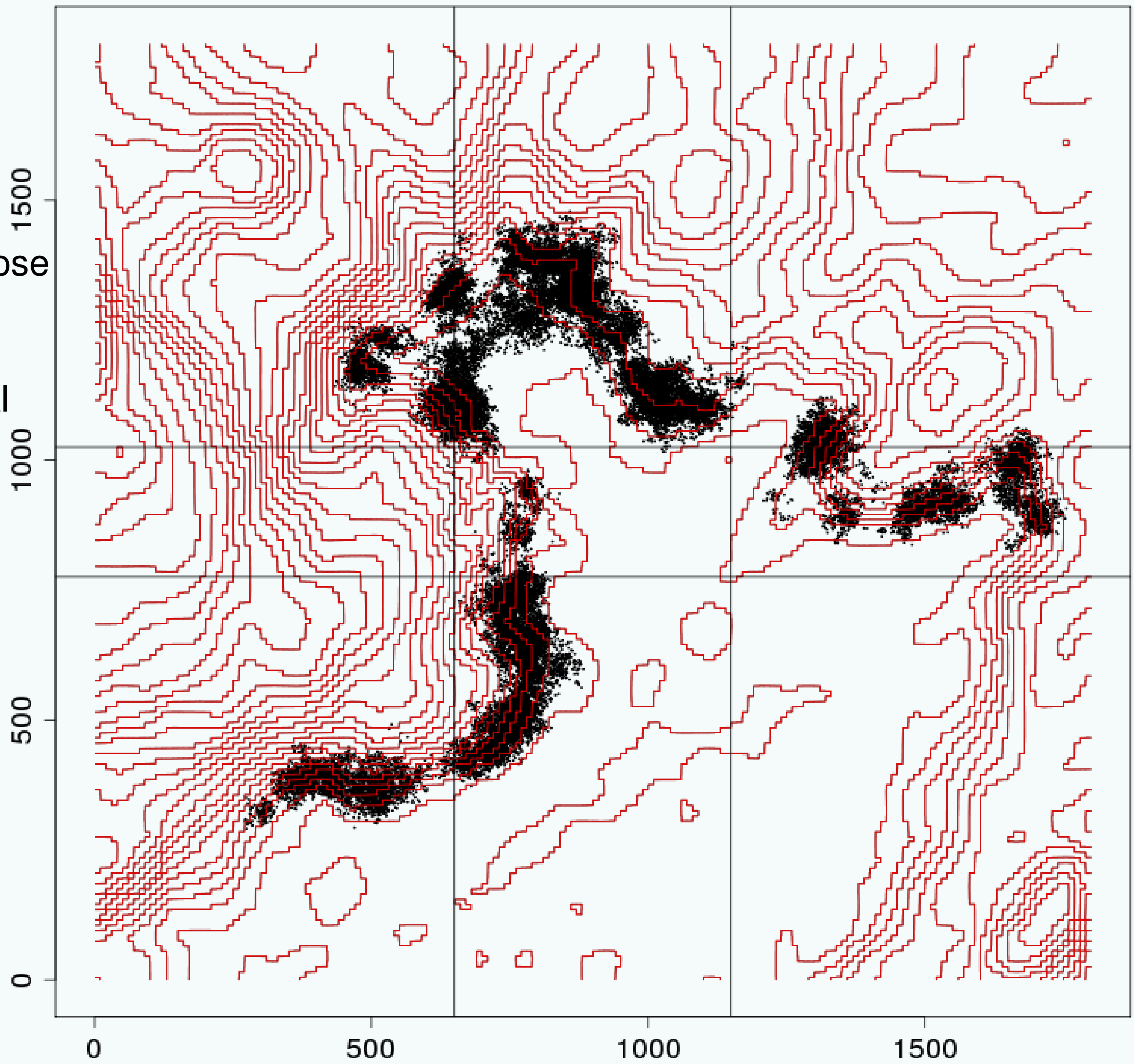


Real topography around Korup plot (10-m contours)



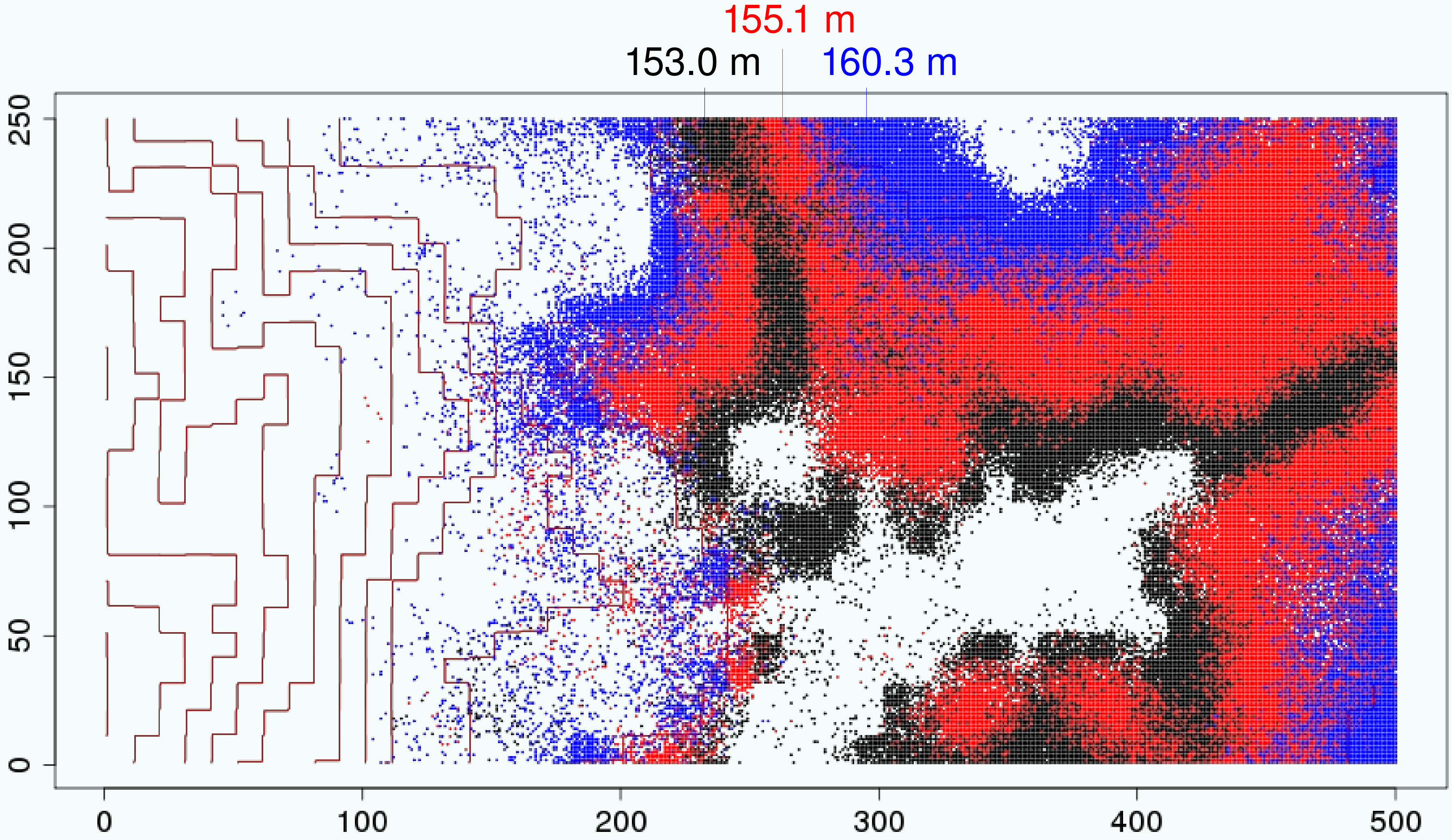
simulation with Gaussian niches: 4 m elevation bands

a species whose
niche is at
170±2 m
poor dispersal



Elevation of simulated 50 ha plot
(real contours of the Korup plot)

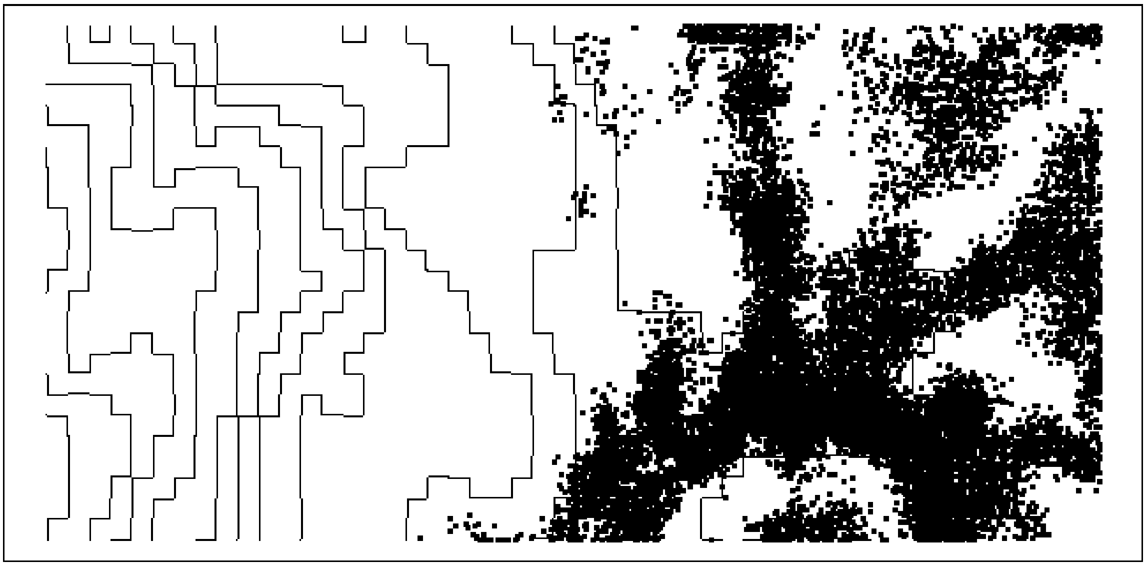
simulated species #18, #13, #3



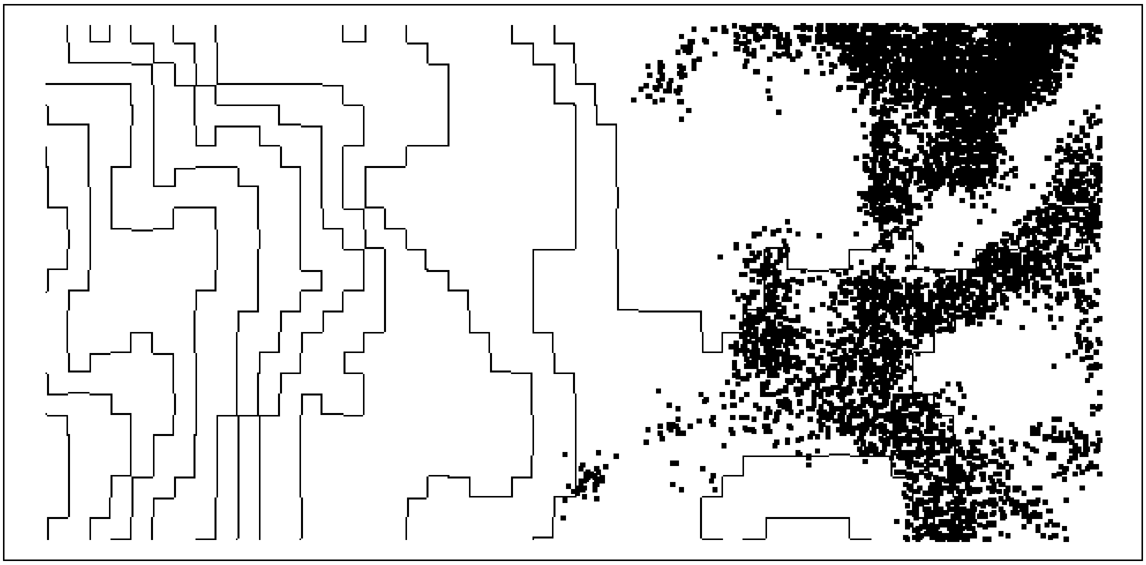
narrow Gaussian niches
precise tradeoffs in performance

poor dispersal (10 m limit)

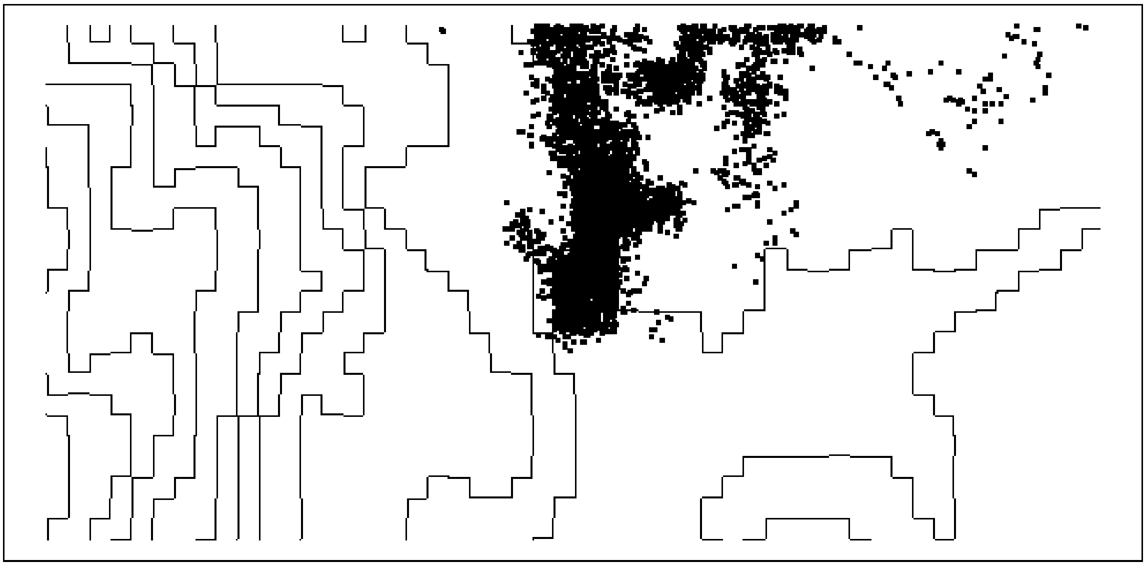
Coexistence with performance tradeoffs and species input



20-m dispersal, strong mortality effect of environment



3 coexisting species with identical environmental response



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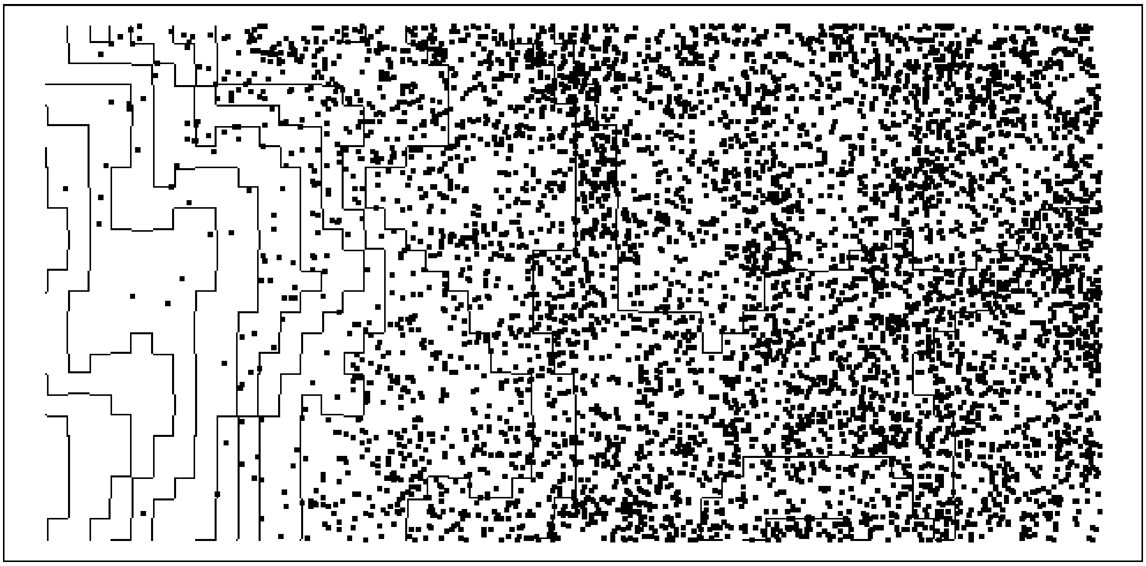
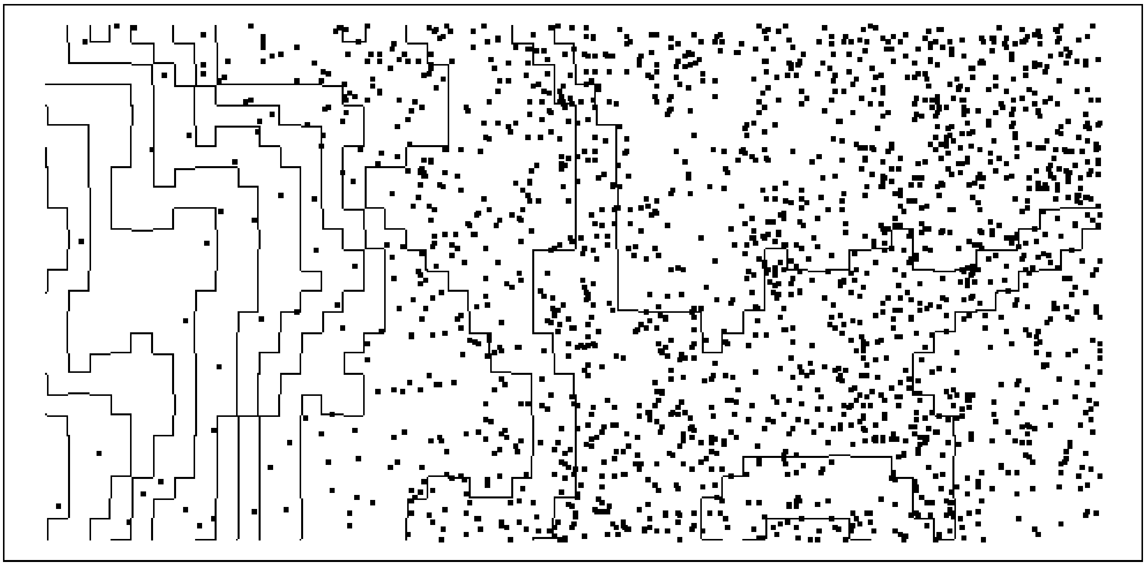


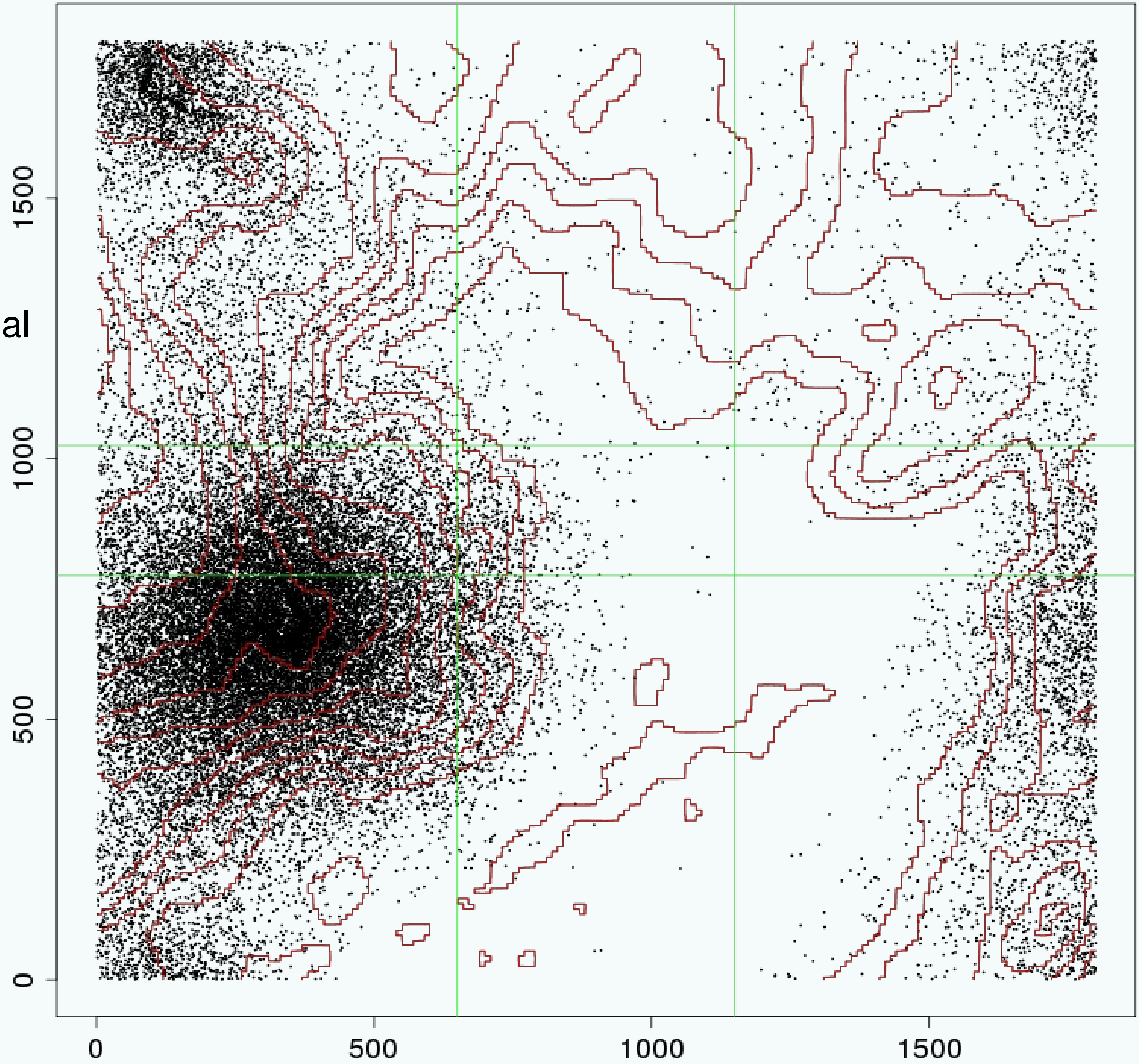
200-m dispersal, strong mortality effect of environment

3 coexisting species with identical environmental response

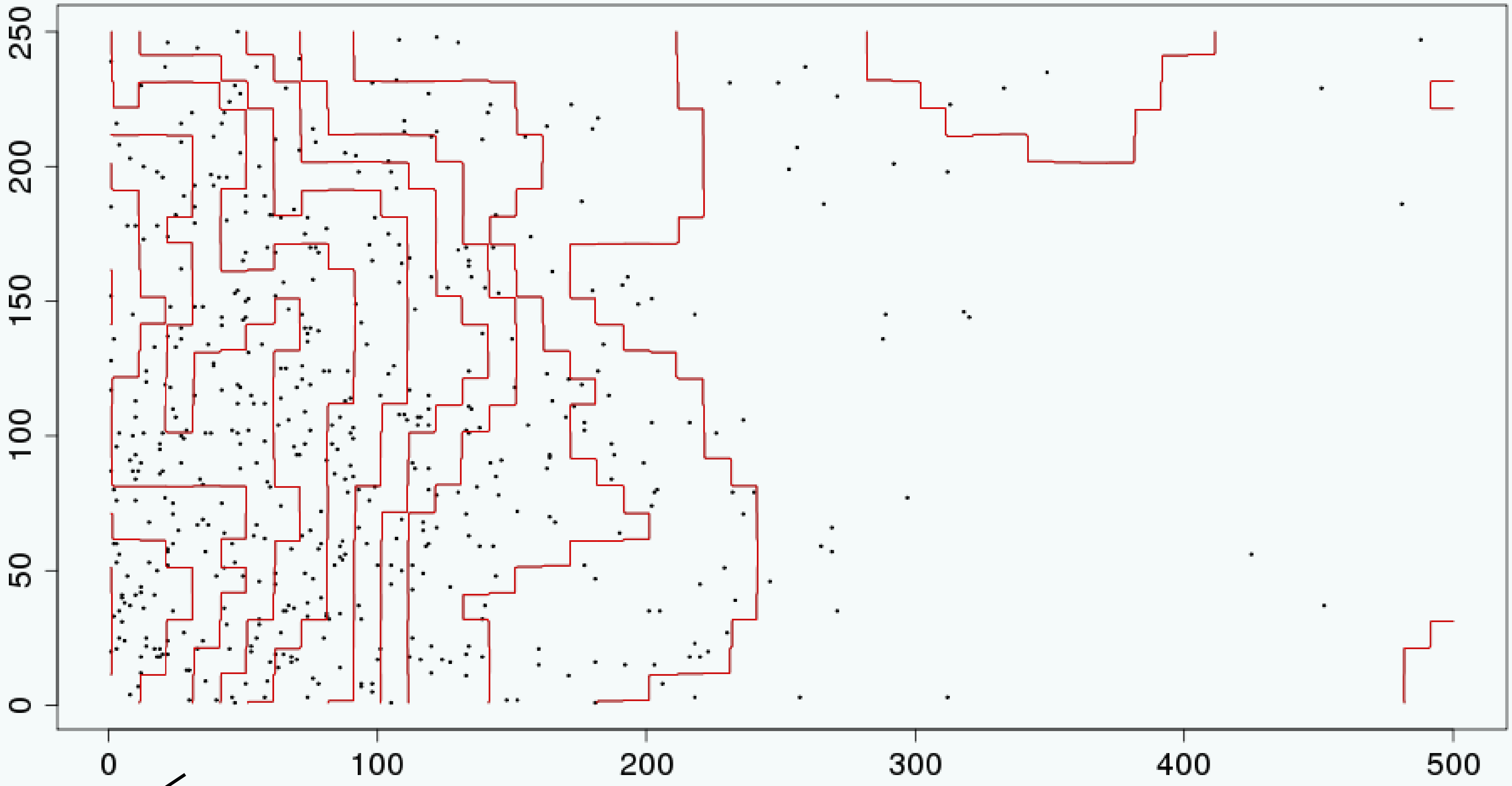


Species 29 has its niche optimum outside the 50 ha plot

good dispersal
(100 m limit)



Species 29



Optimum is 500 m
outside the plot

Comparing observed patterns with models

Nearly all species have distributions spanning most of 50 ha
==> *only matched by simulations with dispersal > 100 m*

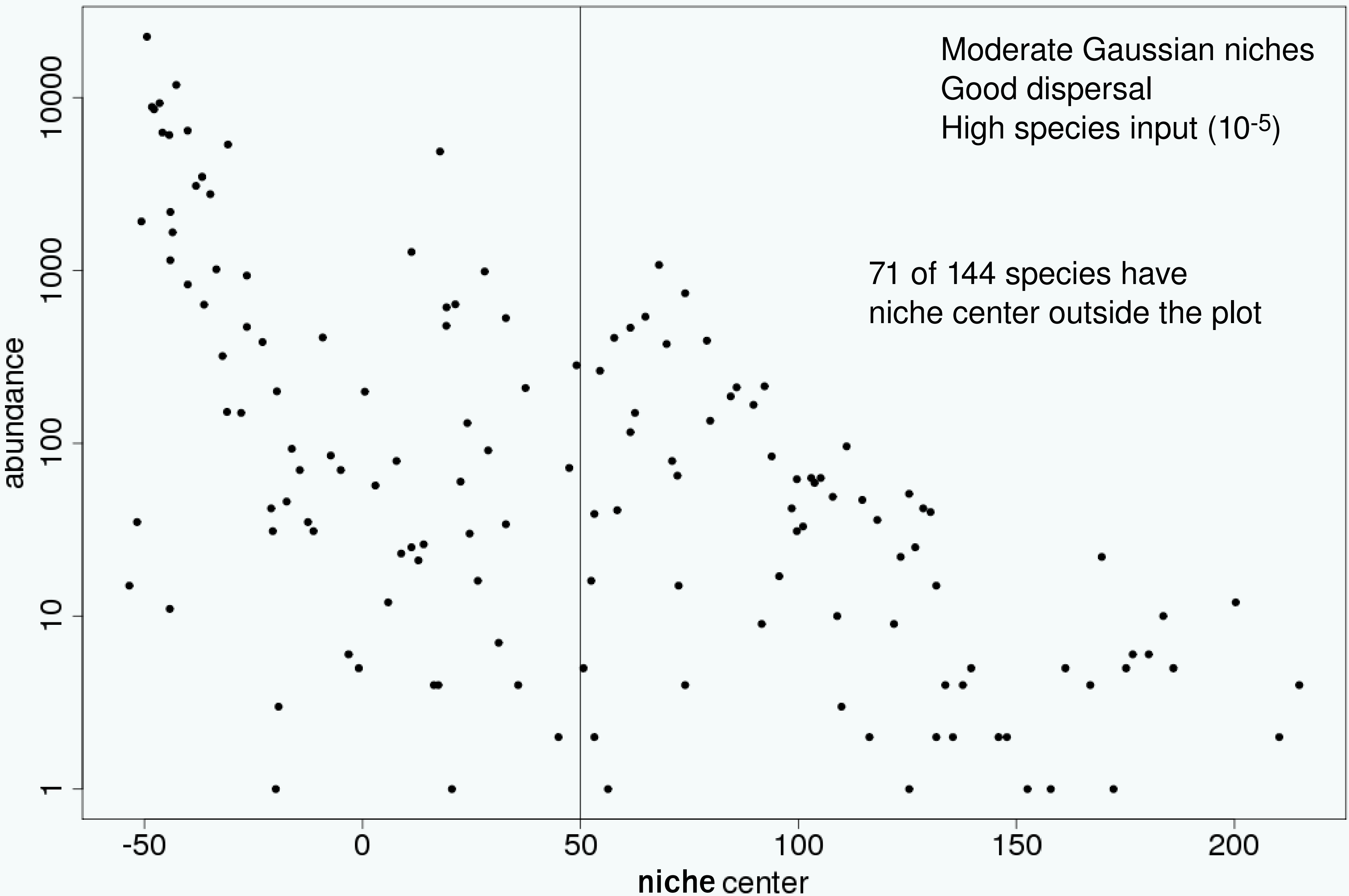
Many species show niche preferences around topography

with abrupt boundaries (little spillover)
==> *consistent with ~~poor dispersal~~, or very high mortality difference*

with fuzzy boundaries (much spillover)
==> *consistent with good dispersal and moderate mortality difference*

But some species are generalists
==> *mixture of specialists and generalists is hard to explain*

Abundance vs. species traits - simulated



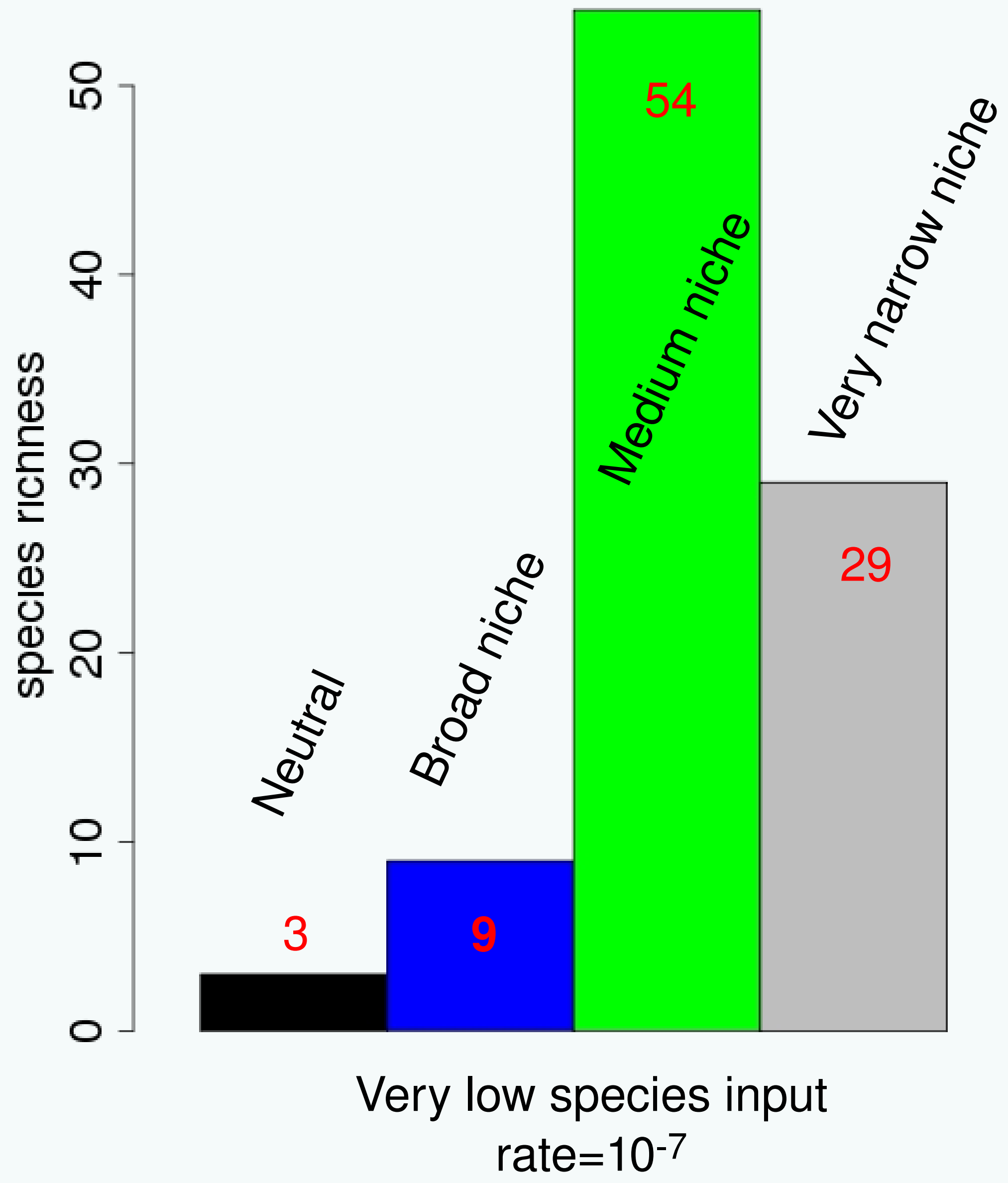
Species richness: species input vs. niche segregation

Diversity maintained by species input

Diversity maintained by niche segregation

Species richness
in a simulated 50-ha plot

--4 separate simulations
--niche breadth differs in each

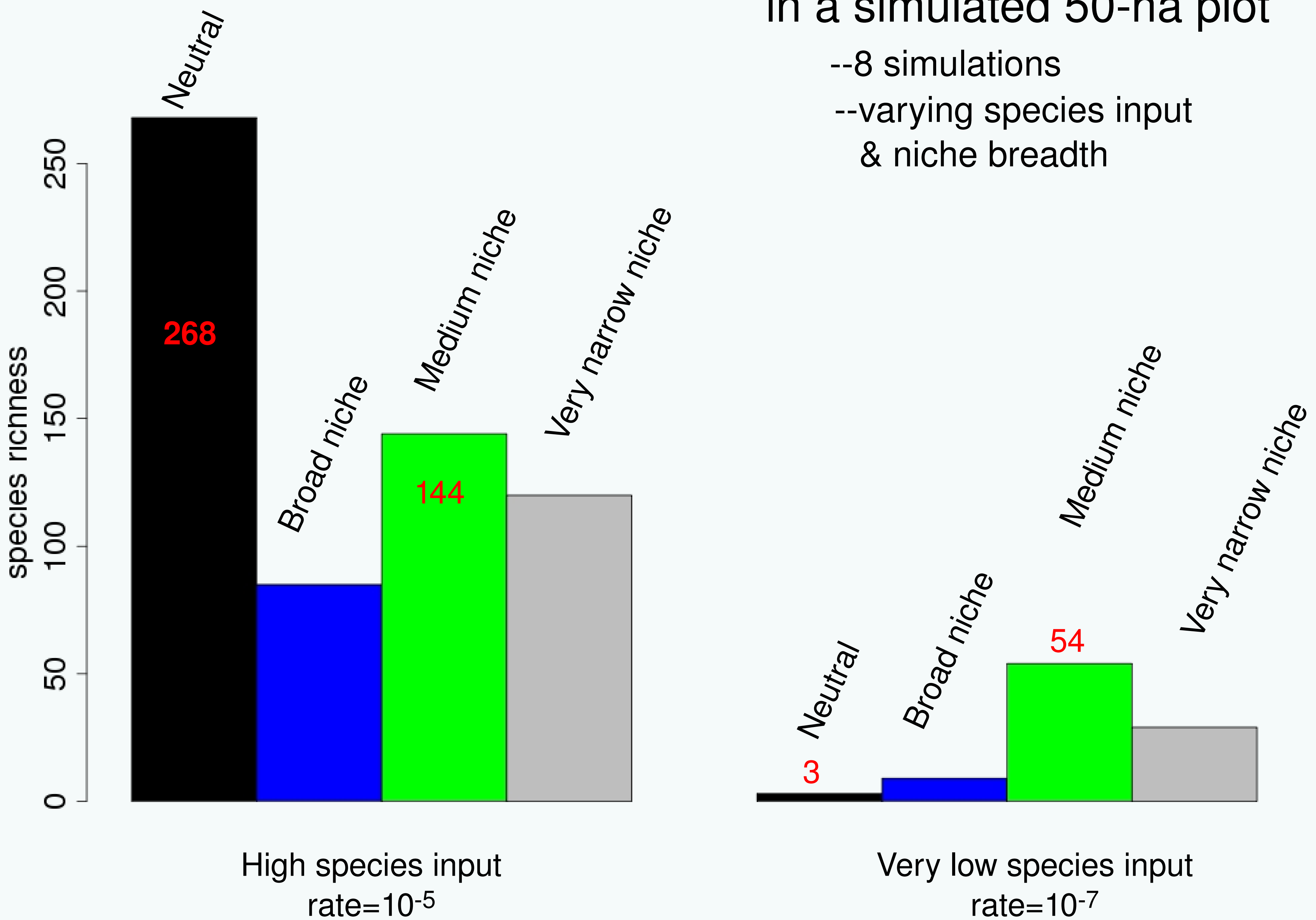


Observed after 20,000 generations
Not equilibria?

Species richness
in a simulated 50-ha plot

--8 simulations

--varying species input
& niche breadth



Dispersal and coexistence

- Immigrants compete with locally well-adapted species
- Substantial proportion of community may be sink (satellite) populations
- Provides a mechanism by which neutral (or sub-neutral) species can persist

Parmentiera cereifera

Species input vs. niche segregation

Diversity maintained by species input

- Diversity can be very high
- Many rare species
- Species traits weakly related to abundance
- Species differences are unimportant
  to diversity
- Community appears neutral

Diversity maintained by niche segregation

- At local scale, diversity is at best moderate
- Few rare species
- Species traits strongly related to abundance
- Coexistence theories matter and should predict diversity

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