Distance-dependent recruitment for tree species at Barro Colorado Island (Panama)

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Outline

- Background and theory
- Research objectives
- Barro Colorado Island (BCI) survey data
- Fitting empirical dispersal kernels
- Results and discussion

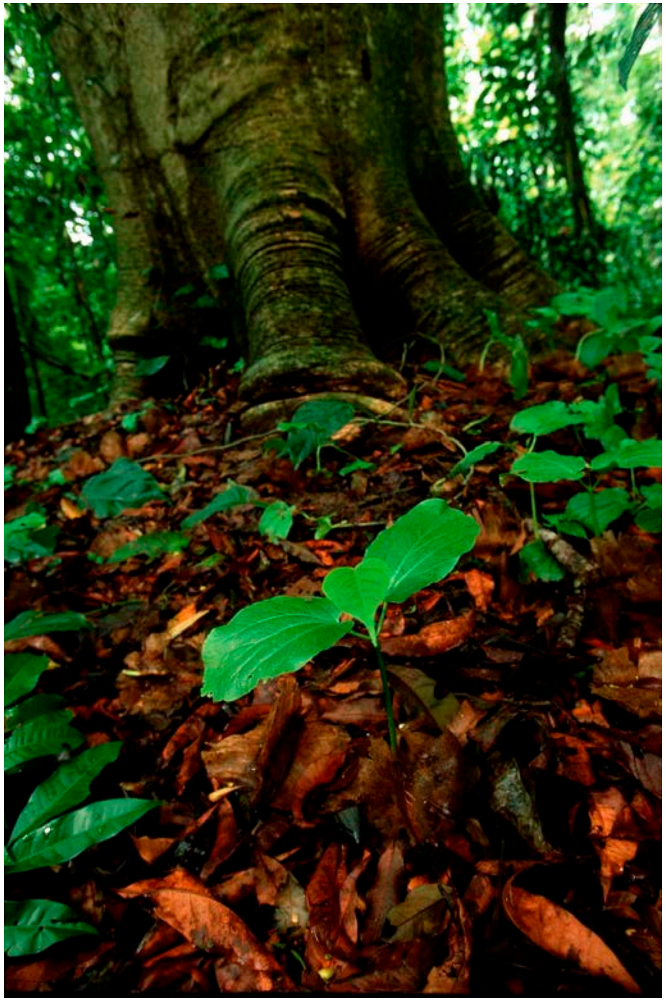


Photo: Christian Ziegler

Background and theory

Spatial distribution and coexistence of plant species shaped during early life history stages: seed dispersal and germination, seedling survival.

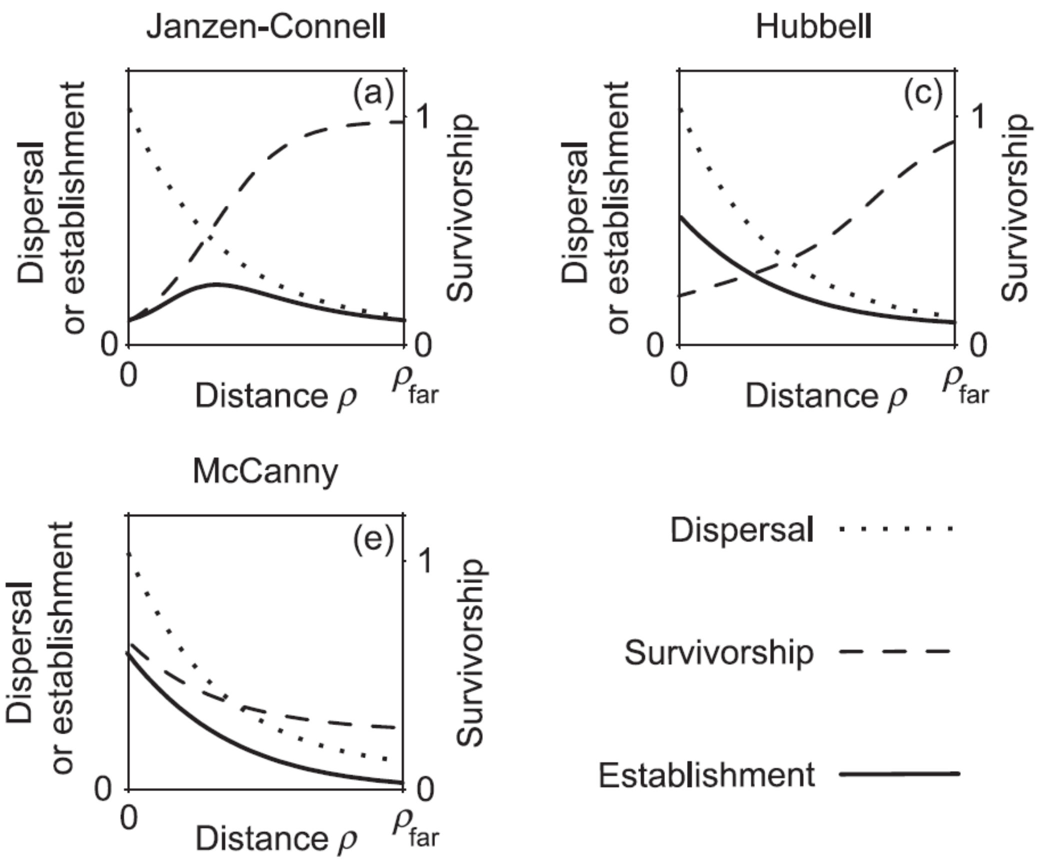
Janzen-Connell hypothesis

- Seed density greatest near parent,
- but so is mortality, due to concentration of specialist herbivores;
- therefore, seedling establishment peaks at distance from parent.

Other mechanisms (root mutualisms, satiation of herbivores) posited to increase survival near parent tree.

Background and theory

Distance-dependent seed dispersal and survivorship determine the seedlings' ***effective dispersal kernel***.



Nathan and Casagrandi (2004), based on McCanny (1985)

Background and theory

- Comita et al. (2014) meta-analysis of experimental studies shows evidence of distance- and density-dependent mortality for a wide range of plant communities, though the effects are stronger at the seedling, rather than seed, stage.

- Distance-dependent mortality may or may not lead to a seedling density peak away from parent.

- Few attempts to directly estimate the shape of the seedling effective dispersal kernel from field data.

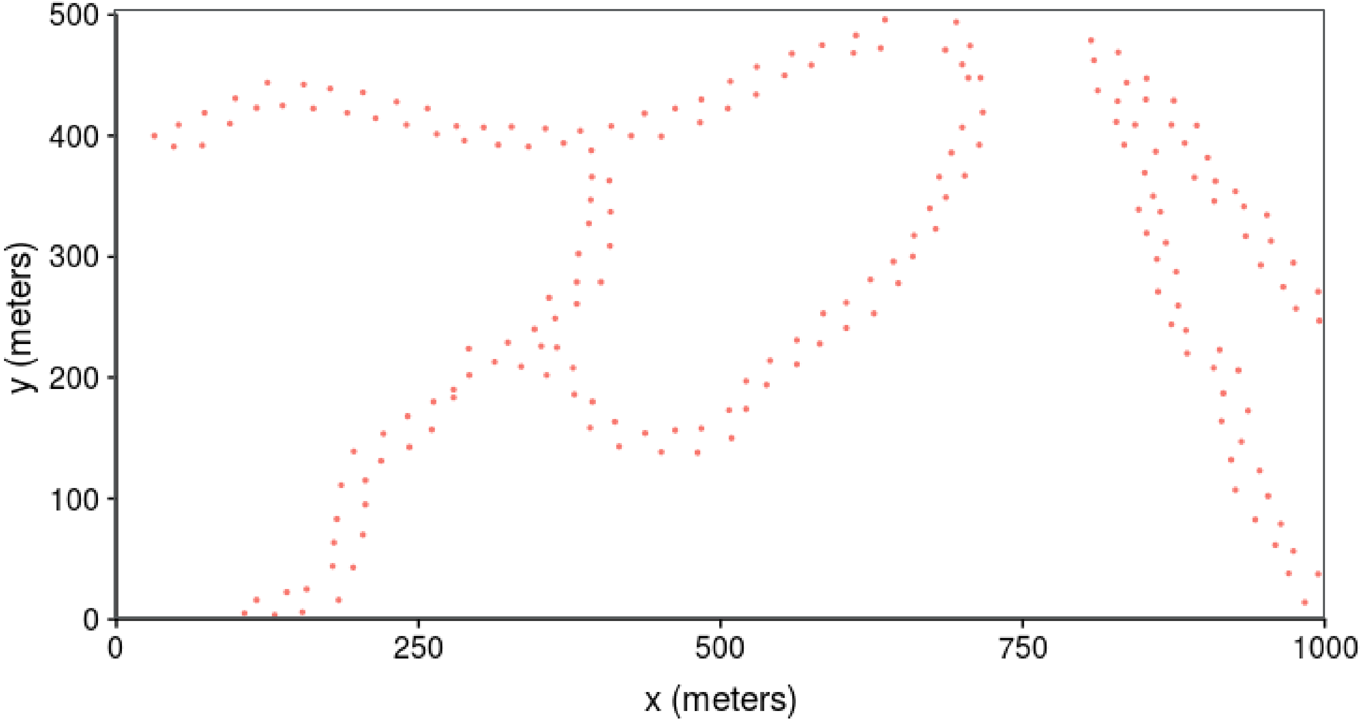
Objective of this study

Compare the empirical seed dispersal kernel and effective dispersal kernel for common tree species in the 50-ha forest census plot of Barro Colorado Island (BCI) in Panama.

- 27 species included
  (minimum of 100 seeds
  and 50 seedlings in data)

Photo: Christian Ziegler

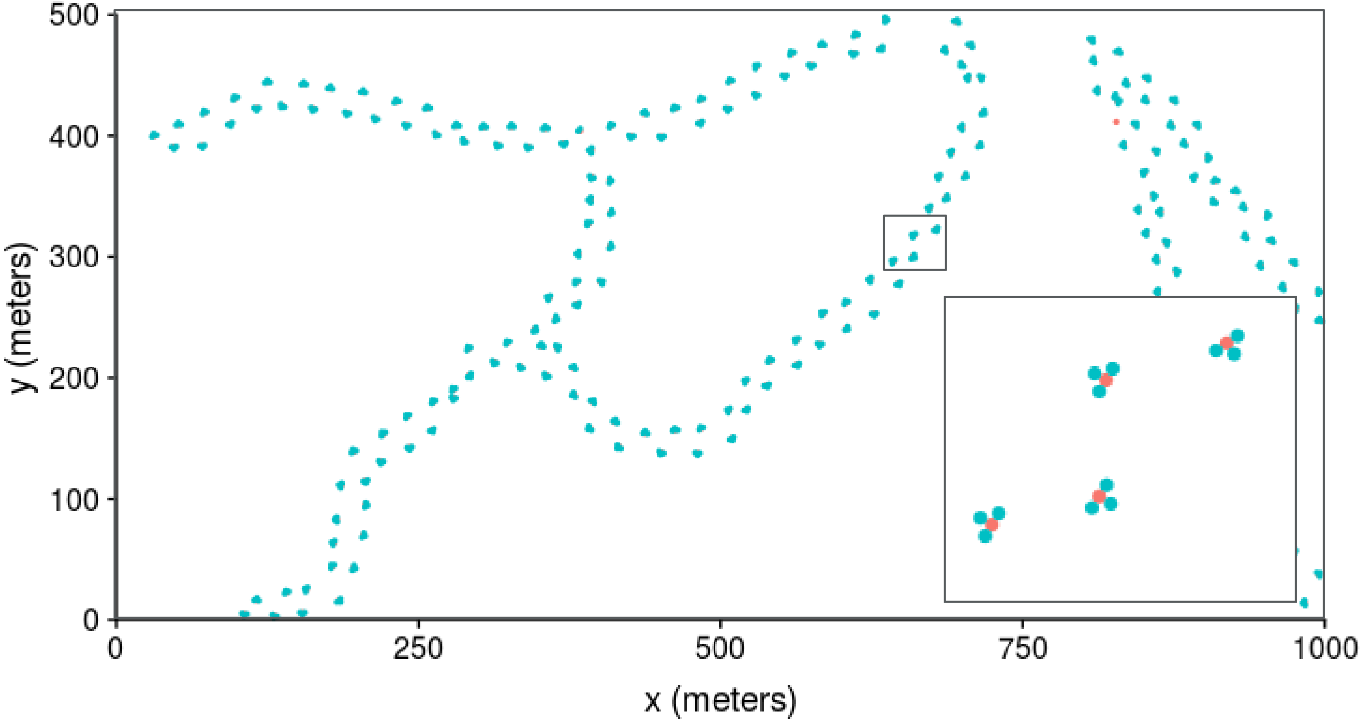
Seed and seedling surveys at BCI



0.5 m^2 traps for annual seedfall surveys (since 1987)

50-ha plot: All trees >1cm DBH censused every 5 years

Seed and seedling surveys at BCI



0.5 m² traps for annual seedfall surveys (since 1987)

1 m² quadrats for new recruits surveys (since 1995)

50-ha plot: All trees >1cm DBH censused every 5 years

Model for observed seed(ling) counts

Based on Muller-Landau et al. (2008) “Interspecific variation in primary seed dispersal in a tropical forest”

$$\widehat{S_{jy}} = a \sum_{i} Q(b_{iy}) F(r_{ij})$$

Expected seeds by trap (*j*) and year (*y*)

Model fit independently for each species

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Dispersal kernel as function of tree-trap distance

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Trap area

$$\widehat{S_{jy}} = a \sum_i Q(b_{iy}) F(r_{ij})$$

Expected seeds by trap (*j*) and year (*y*)

Seed production as function of basal area by tree (*i*) and year

Dispersal kernel as function of tree-trap distance

Model fit independently for each species

Model for observed seed(ling) counts

$$\widehat{S_{jy}} = a \sum_{i} Q\left(b_{iy}\right) F\left(r_{ij}\right)$$

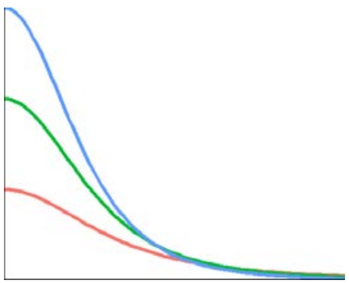
Seed production is proportional to basal area, variation of proportionality constant across years (random effect) modelled by lognormal distribution.

$$Q\left(b_{iy}\right) = e^{\beta_y} b_{iy}$$

$$\beta_y \sim N(\mu_\beta, \sigma_\beta)$$

Model for observed seed(ling) counts

Five candidate dispersal kernel functions



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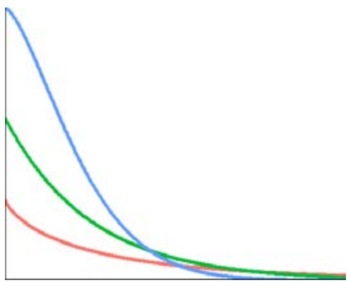
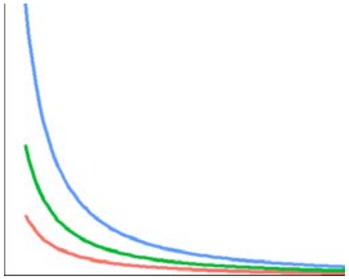
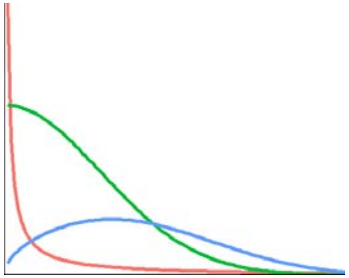


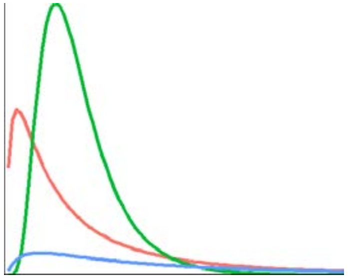
Exponential power



Inverse power

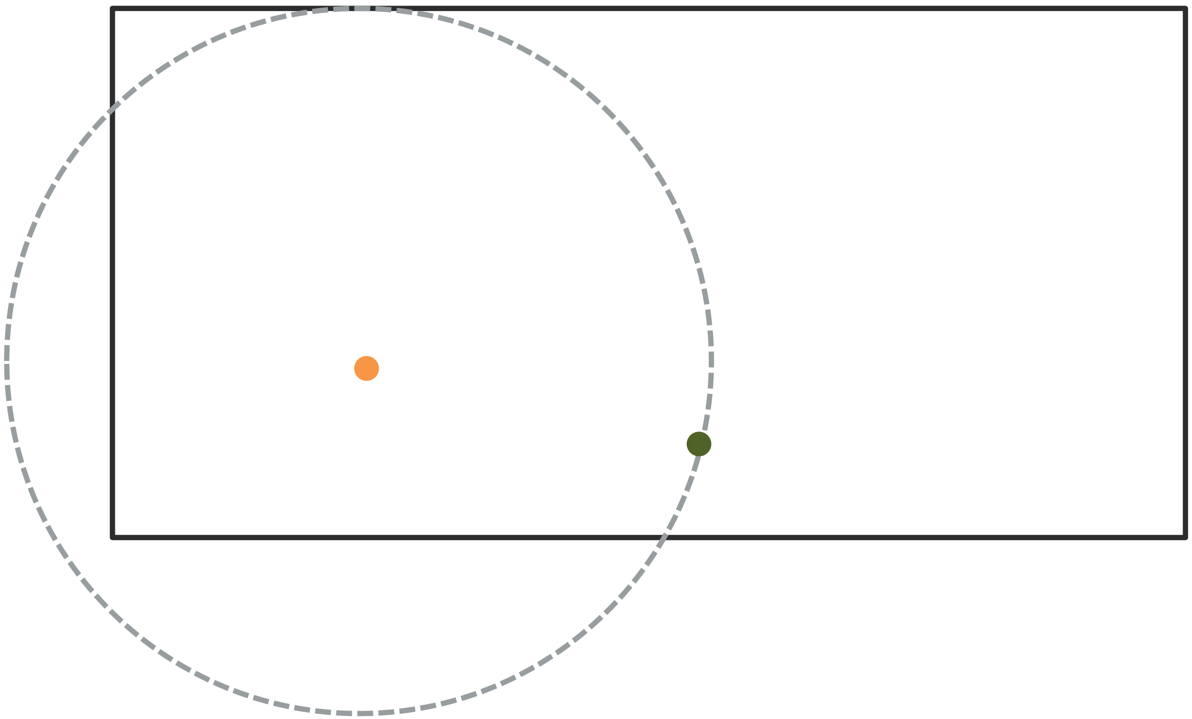


Weibull



Log-normal

Edge effects



Model for observed seed(ling) counts

Two candidate distributions for observed counts relative to expected:

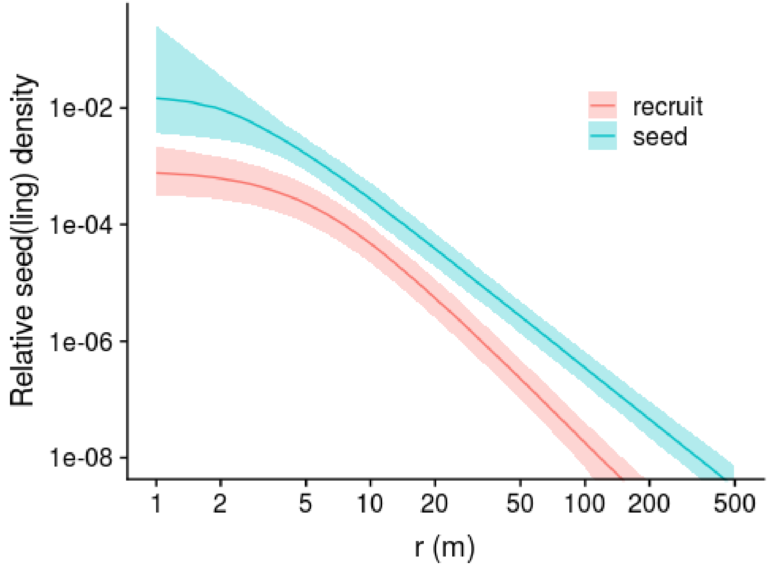
- Poisson: Variance = Mean
- Negative binomial: Variance = Mean + c Mean^2
  (c measures degree of overdispersion in counts i.e. seed clumping)

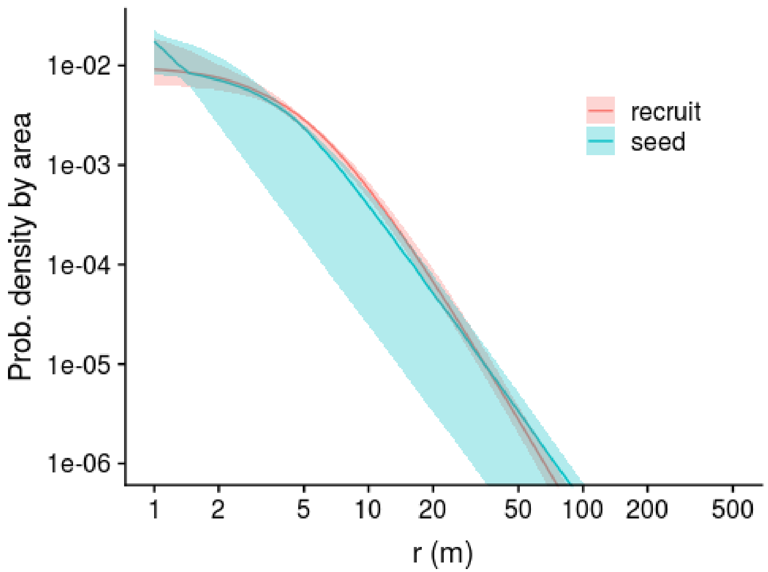
Estimation method

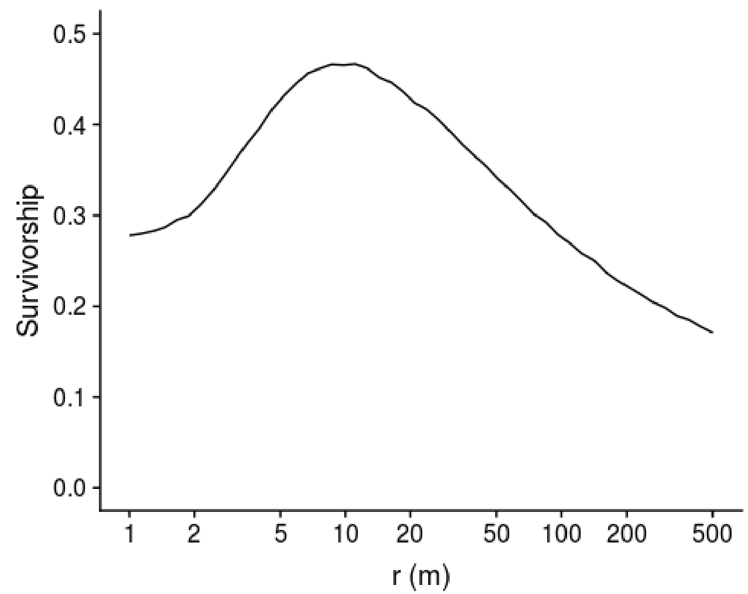
- Hierarchical Bayesian models: 3 to 5 parameters
    - Mean and standard deviation of annual seed production
    - Dispersal kernel parameters (1 to 2)
    - Clumping parameter (if negative binomial)
- Output: samples from joint posterior parameter distribution for each of the 9 candidate models by species.
- Use posterior parameter distributions to obtain predictive distributions for seed density at different distances (predicted kernel).
- Weighted multi-model predictive kernel obtained by model stacking (Yao et al. 2018).

Results

Similar kernels (6 species),
e.g. *Beilschmiedia tovarensis*



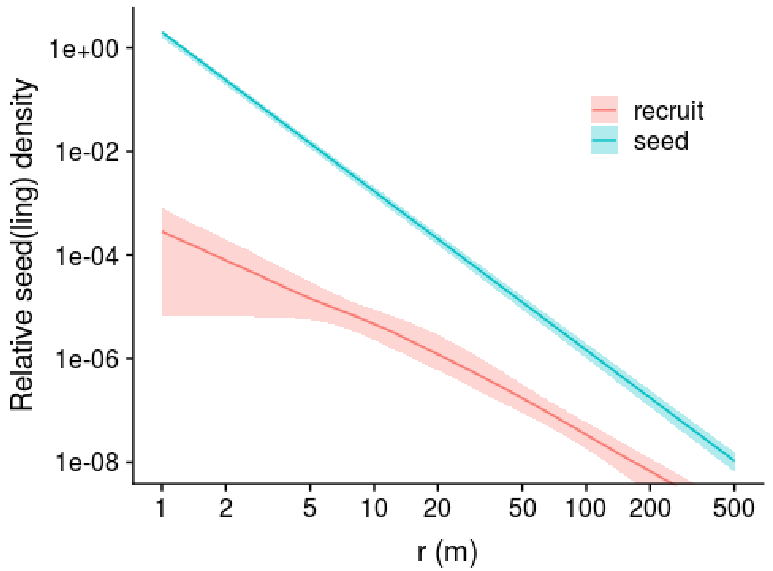


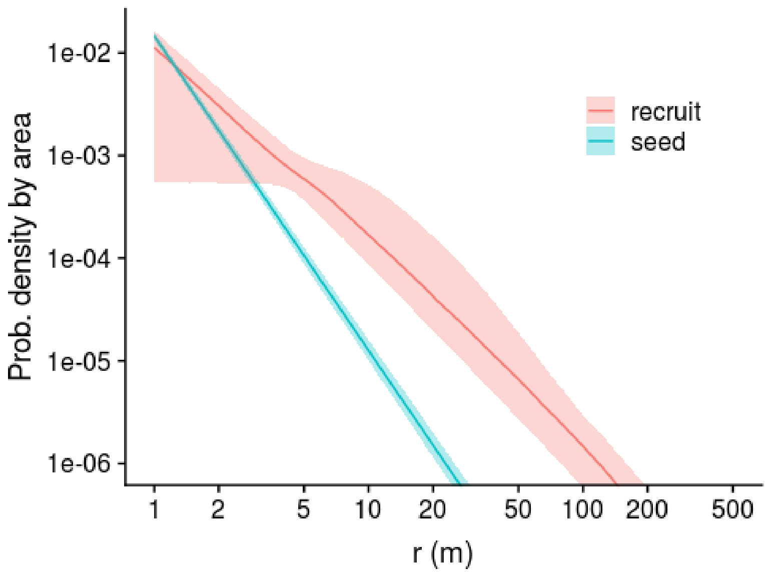


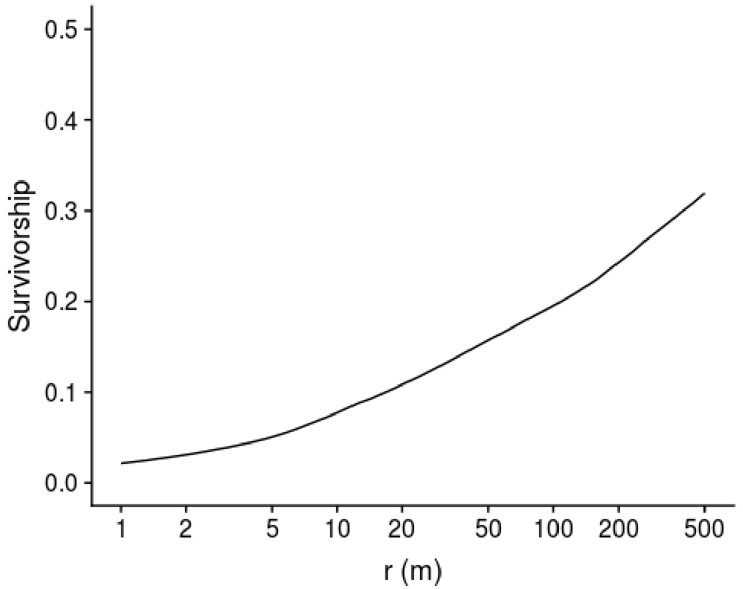
Results

Hubbell pattern (18 species),

e.g. *Brosimum alicastrum*



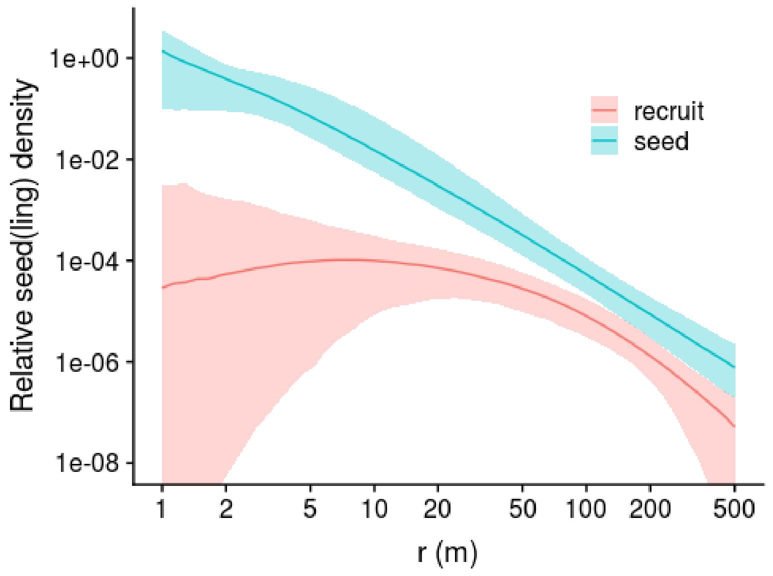


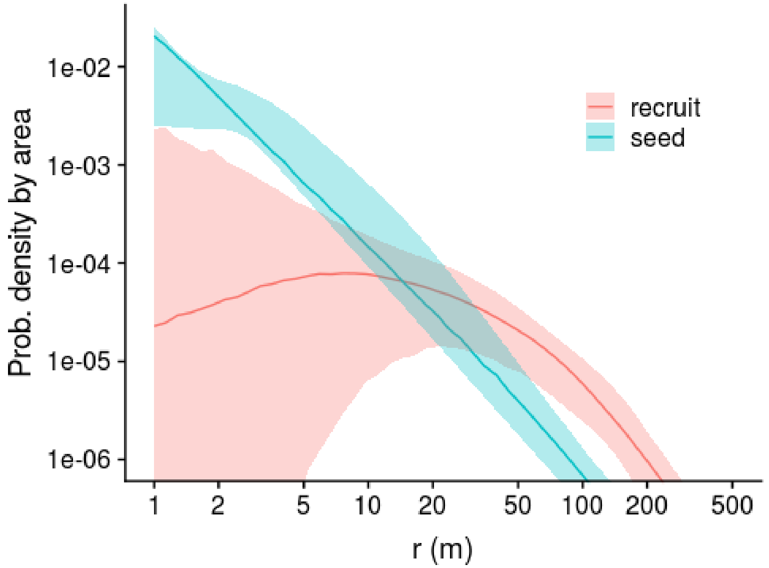


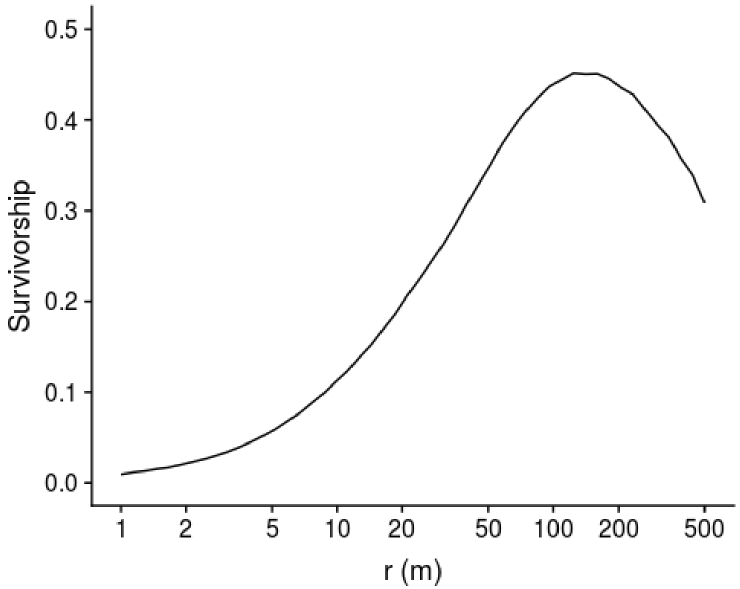
Results

Janzen-Connell pattern (3 species),

e.g. *Palicourea guianensis*







Discussion

- What explains interspecific variation in recruitment patterns?

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- How to include rare species in analysis?

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- What explains interspecific variation in recruitment patterns?
- How to include rare species in analysis?
- Timing of distance- and density-dependent mortality; compare these results to point process analysis of mortality during seedling stage (Murphy et al. 2017).

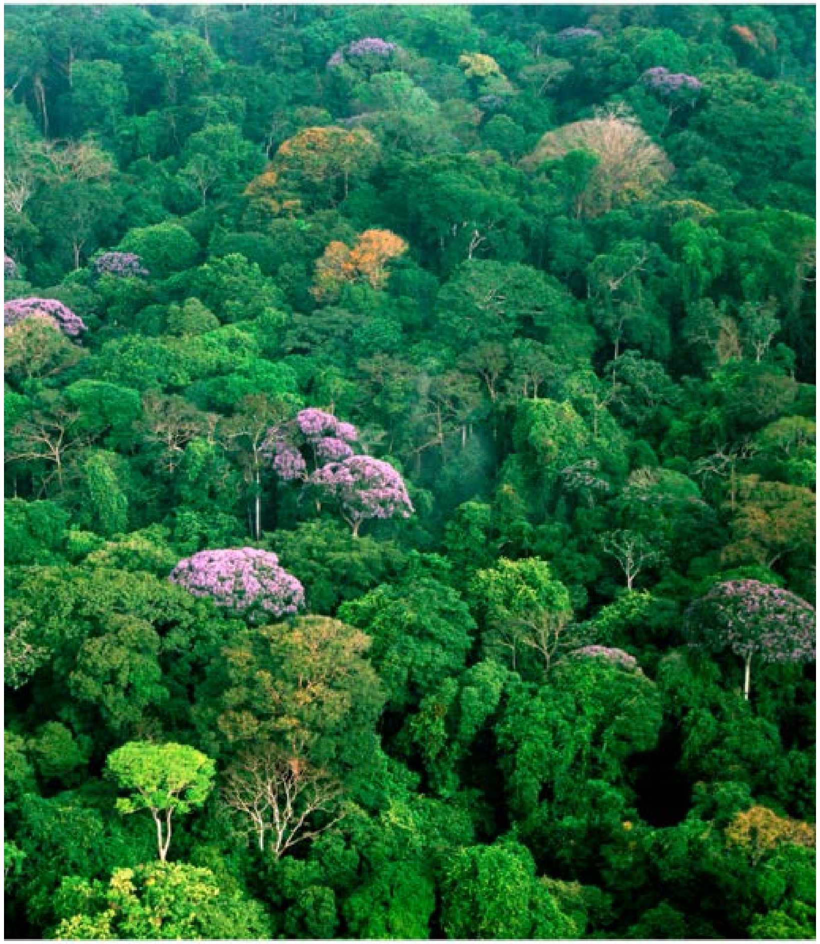
Photo: Christian Ziegler

Thank you for listening!

Questions?

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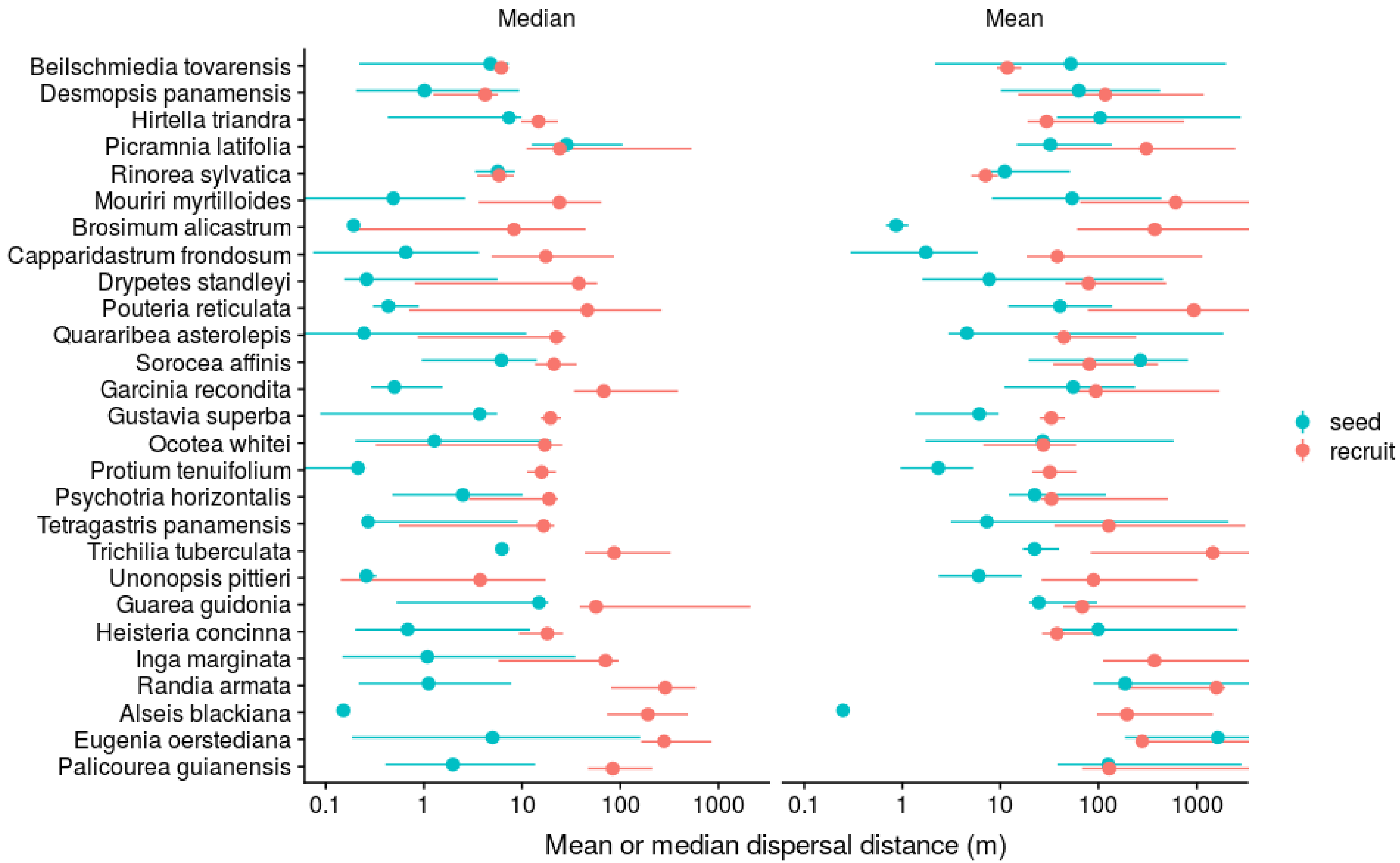
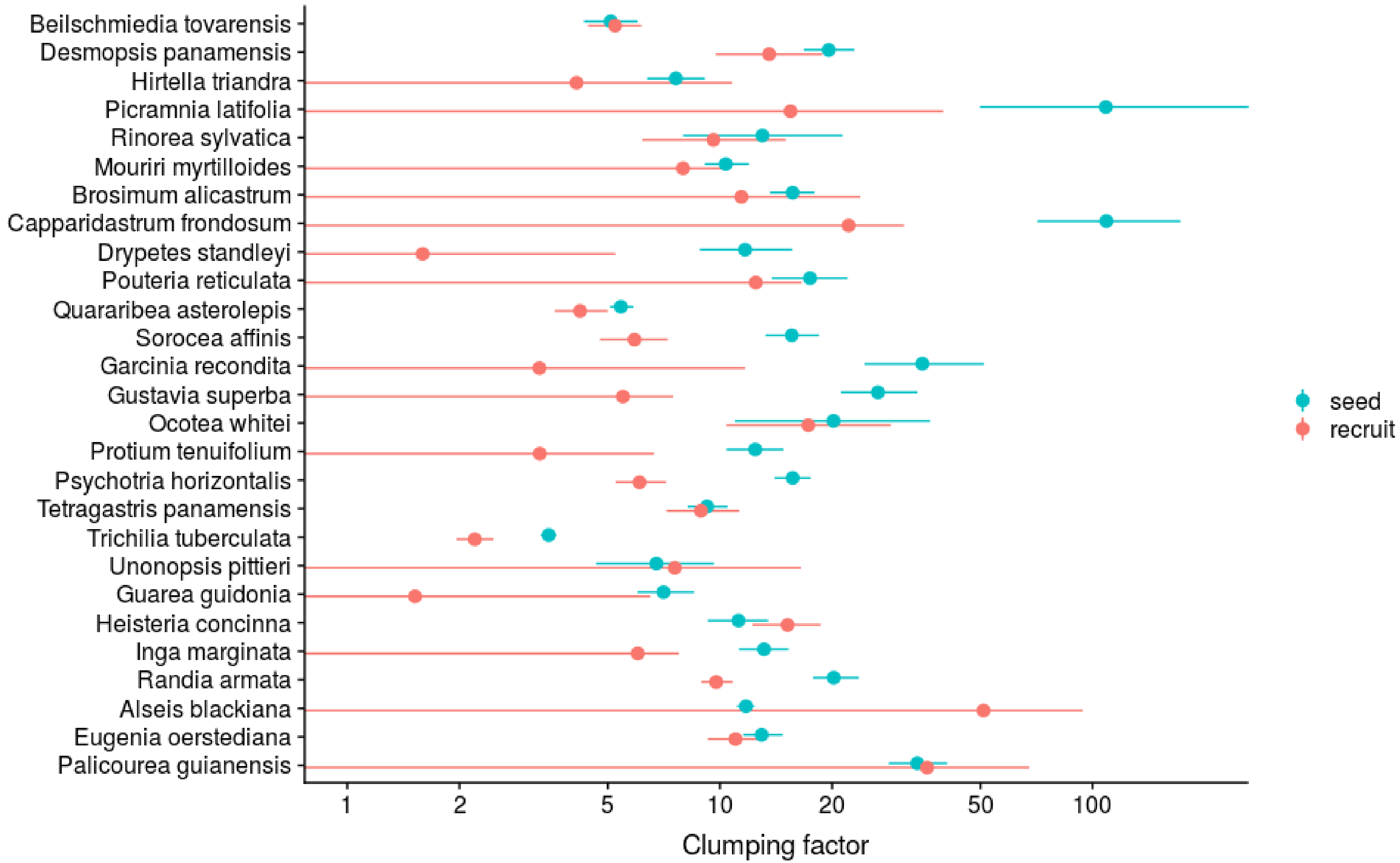
Results



Median
Mean
Beilschmiedia tovarensis
Desmopsis panamensis
Hirtella triandra
Picramnia latifolia
Rinorea sylvatica
Mouriri myrtilloides
Brosimum alicastrum
Capparidastrum frondosum
Drypetes standleyi
Pouteria reticulata
Quararibea asterolepis
Sorocea affinis
Garcinia recondita
Gustavia superba
Ocotea whitei
Protium tenuifolium
Psychotria horizontalis
Tetragastris panamensis
Trichilia tuberculata
Unonopsis pittieri
Guarea guidonia
Heisteria concinna
Inga marginata
Randia armata
Alseis blackiana
Eugenia oerstediana
Palicourea guianensis
0.1
1
10
100
1000
0.1
1
10
100
1000
Mean or median dispersal distance (m)
seed
recruit

Results



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Palicourea guianensis
1
2
5
10
20
50
100
Clumping factor
seed
recruit