The interacting effects of clumped seed dispersal and distance- and density-dependent mortality on seedling recruitment patterns

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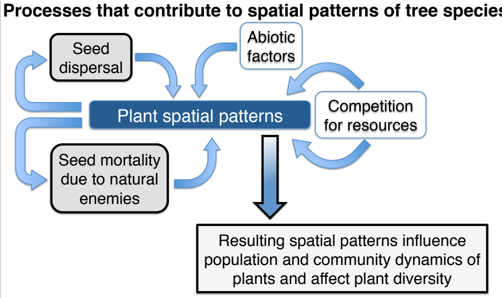
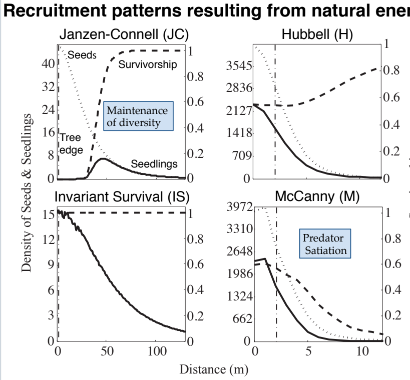
INTRODUCTION

Processes that contribute to spatial patterns of tree species



Question: How do patterns of seed dispersal and patterns of seed mortality by natural enemies influence spatial patterns of plants?

Recruitment patterns resulting from natural enemy attack

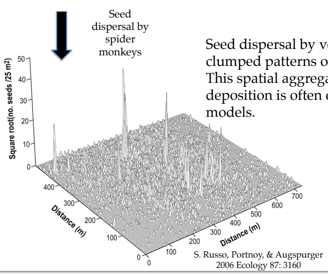


Seed dispersal is typically modeled as seed densities decreasing with distance from the nearest reproductive tree.

Theoretical studies to date have focused on vertebrate and invertebrate natural enemies.

Seed dispersal by vertebrates.

- ✧ 80-90% of tropical plants vertebrate-dispersed
- ✧ 60% of all angiosperms are dispersed by biotic means



Seed dispersal by spider monkeys

S. Russo, Portnoy, & Augspurger 2006 Ecology 87: 3160

Seed dispersal by vertebrates results in clumped patterns of seed deposition. This spatial aggregation in seed deposition is often overlooked in models.

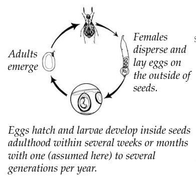
Differences in the life histories and movement of natural enemies determine their ability to track seeds and seedlings through space and time.

Specialized natural enemies are hypothesized to be critically important for shaping plant spatial patterns and maintaining plant diversity. Although soil-borne pathogens have been found to play a critical role in seedling survival, previous studies have not determined their influence on seedling recruitment patterns.

MODEL ORGANISMS

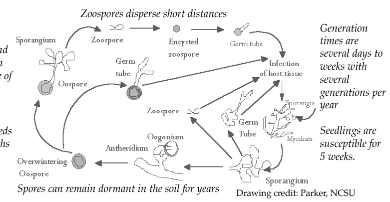
Both bruchid beetles and oomycetes are a major cause of plant mortality in agricultural and natural systems and tend to have a narrow range of hosts.

Insects: Bruchid beetles



Pathogens: Oomycetes

✧ soil-borne pathogens that cause damping-off disease

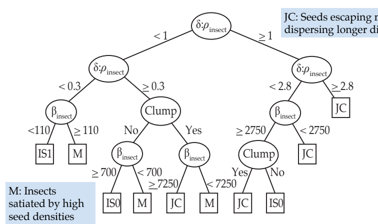


RESULTS

Insects | Pathogens

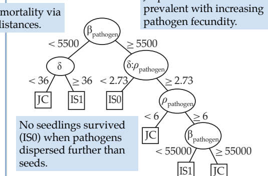
Factors important for recruitment patterns

Identified using decision trees. IS0 indicates no seedlings survived. IS1 indicates 99% of seeds survived. δ is the mean dispersal distance of seeds.



JC: Seeds escaping mortality via dispersing longer distances.

M: Insects satiated by high seed densities under tree

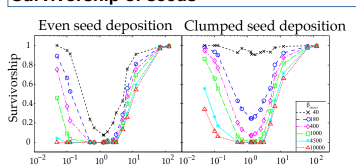


JC patterns more prevalent with increasing pathogen fecundity.

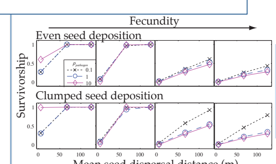
No seedlings survived (IS0) when pathogens dispersed further than seeds.

Under low pathogen fecundity & high seed dispersal, most seeds survived (IS1).

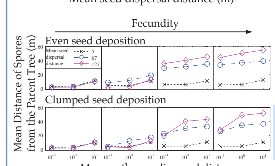
Survivorship of seeds



- ✧ Clumping allowed more seeds to escape through local satiate of insect seed predators.
- ✧ When seed and insect dispersal distances were similar, seed survivorship was low.
- ✧ Under even seed deposition, few seeds escaped when insect seed predation was effectively global.

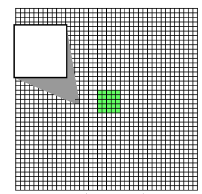


Survivorship of seeds increased with mean seed dispersal and pathogen dispersal distance and decreased with pathogen fecundity.

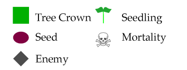


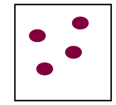
- ✧ Spores tracked seeds except at low pathogen fecundity.
- ✧ Mean distances at which spores are found increased with pathogen dispersal, seed dispersal, and fecundity
- ✧ Clumping reduced pathogen's ability to track spores.

MODEL PROCESSES: A spatially explicit simulation model



Events occur within cells of the landscape. The tree crown is located in the center of the landscape. Seeds and natural enemies disperse from the tree crown.

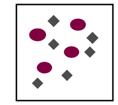




1. Seeds disperse to distance r according to a bivariate student's t :

$$f(r)=\frac{1}{\pi\exp(\alpha)\left(1+\frac{r^2}{\exp(\alpha)}\right)^2}$$

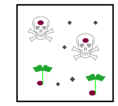
No. seeds per cell for
* even deposition:
$Poisson\left(\sum \eta f(r)\right)$
* clumped deposition:
$Negative\ binomial\left(\sum \eta f(r),\kappa\right)$



2. Natural enemies disperse to distance r according to a negative exponential:

$$g(r)=\frac{2}{\pi\rho^2}\exp\left(-\frac{2r}{\rho}\right)$$

No. enemies per cell:
$Poisson\left(\sum \beta g(r)\right)$

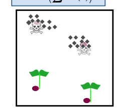


3. Seeds die or recruit into seedling

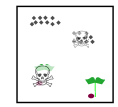
$$\Pr(Surv)=\exp\left(-v_{insect}\frac{I}{N}\right)$$

$$\Pr(Surv)=\exp\left(-\gamma v_{pathogen}P\right)$$

Pathogen dormancy
$P_{t+1}=P_t(1-\gamma)^N$



4. Natural enemies reproduce and survive until next year



5. A fraction of seedlings (> 1 yr. old) and dormant spores die each year

PARAMETER DESCRIPTIONS

Model Organism	Parameters	Values
Plant	Crown area	25 m²
	α, Seed dispersal distance parameter†	2.3 (5, 4.7), 7.5 (67, 49), 8.75 (125, 72) m
	κ, Dispersion parameter for seed deposition	0.1
	η, Tree fecundity	10,000 m $^{-2}$
	ω, Annual seedling mortality	0.5
Insect	ρ_{insect}, Mean dispersal distance‡	1 (1.1), 10 (9.7), 40 (39), 50 (48), (76) m
	β_{insect}, Fecundity	40, 180, 400, 1000, 4500, 10000 eggs
	v_{insect}, Infectivity	0.2
Pathogen	Dispersal events within a fruiting season	4
	$\rho_{pathogen}$, Mean dispersal distance‡	0.1 (0.14), 1 (1.1), 10 (9.7) m
	$\beta_{pathogen}$, Fecundity	1000, 10000,100000, 200000 spores
	$v_{pathogen}$, Infectivity	0.01
	γ, Probability of encountering one seed	0.0001
	μ, Annual mortality of dormant spores	0.9

CONCLUSIONS

✧ Our modeling study suggests that the relative dispersal distances of seeds and natural enemies are crucial to determining establishment rates and spatial patterns of seedlings.

✧ Better characterization of the movement and natural histories of natural enemies is critical to improving our understanding of seedling distributions and plant–enemy interactions.

ACKNOWLEDGEMENTS

National Science Foundation
University of Minnesota
Packard Fellowship in Science and Engineering
HSBC Climate Partnership

Published in *Journal of Ecology* **100** (4): 862-873

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