Modeling the Spread of the Emerald Ash Borer

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Outline

Introduction

Emerald Ash Borer (EAB) problem

Project

Cedar Rapids Ash Inventory

Model

Agent-Based Modeling

Results

Comparison with some (available) observables

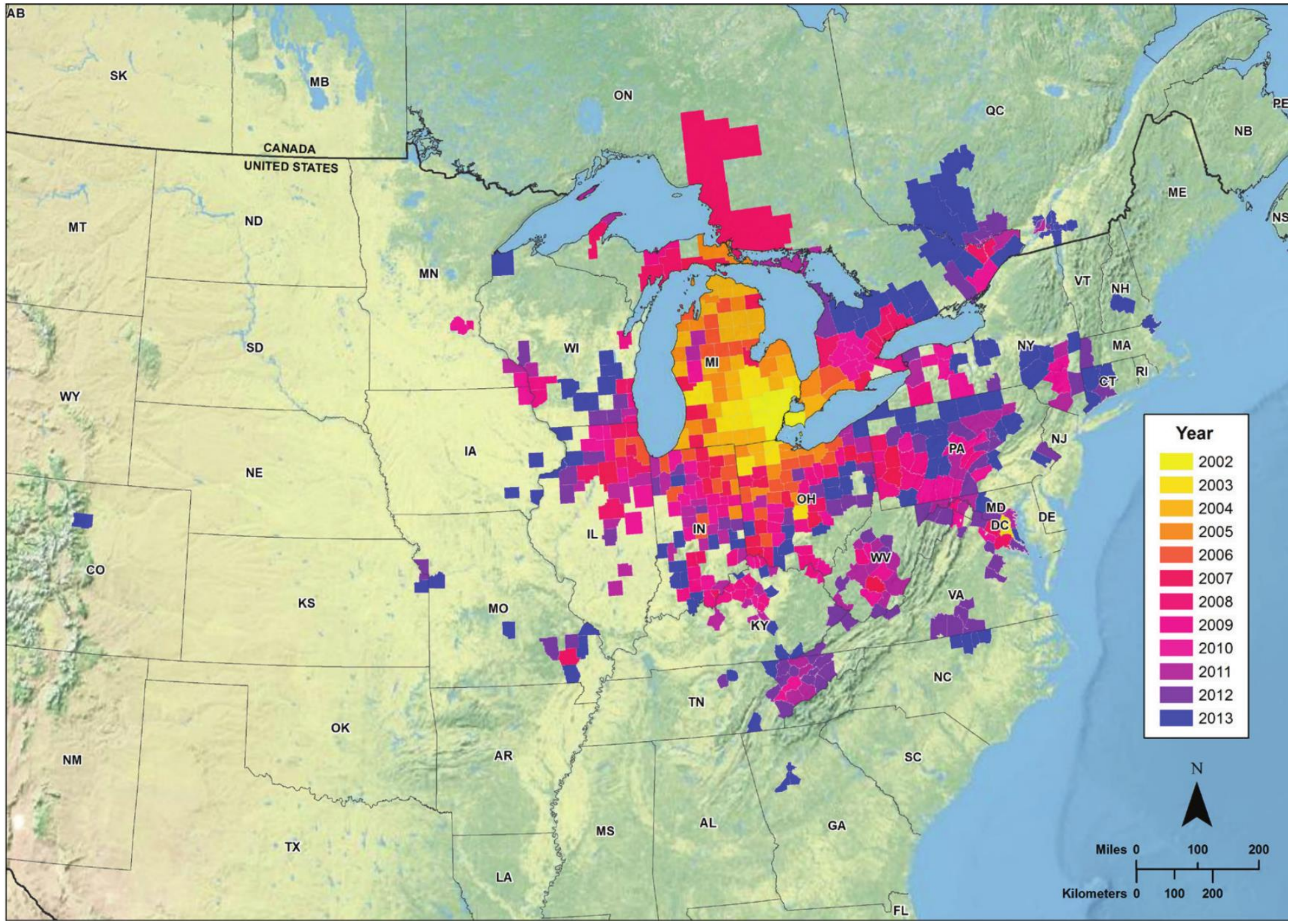
EAB in North America

Detroit 2002

- Investigating ash die-off
- EABs of Chinese origin
    - Infested crates, 1990s

EAB Spread

- Insect Flight (~2 km/year)
- Insect Ride (~20 km/year)
    - Infested firewood
    - Hitchhiking
    - Tree transplanting
- American + European Ash
    - Critically endangered



Initial detection of EAB in North America.
Figure from Haack et al. (2015)

Project

Model Spread of EAB

Computer simulation
Protected data

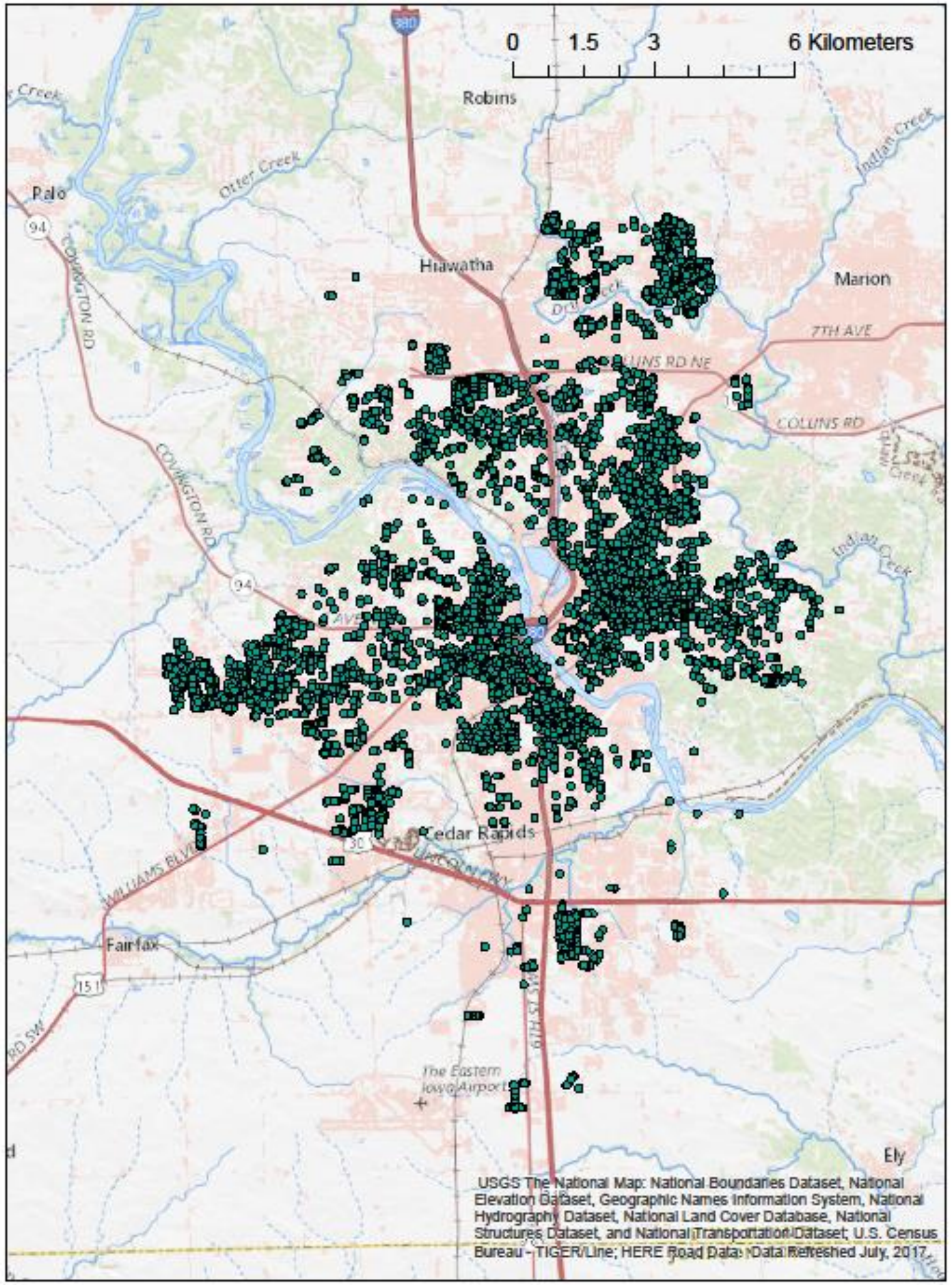
Cedar Rapids Street Tree Inventory

As of 03/29/2017 (~60,000 trees)
Type, Location, Condition, DBH, etc.

Filter for:
Type = Ash
Condition ≠ Dead
DBH > 5 cm

⇒ 7044 trees

Ash Trees in Cedar Rapids



LIFE CYCLE OF THE EMERALD ASH BORER

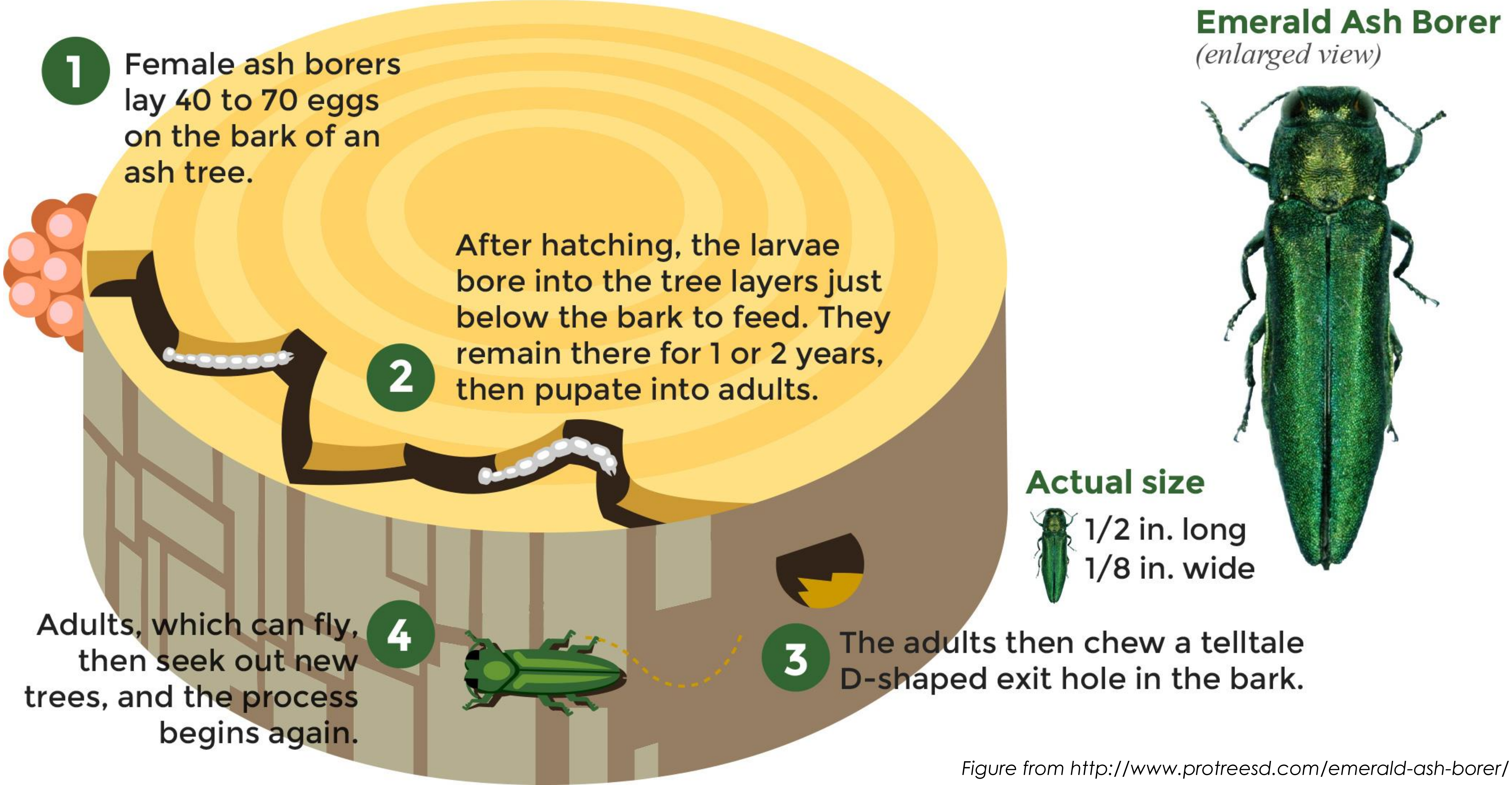
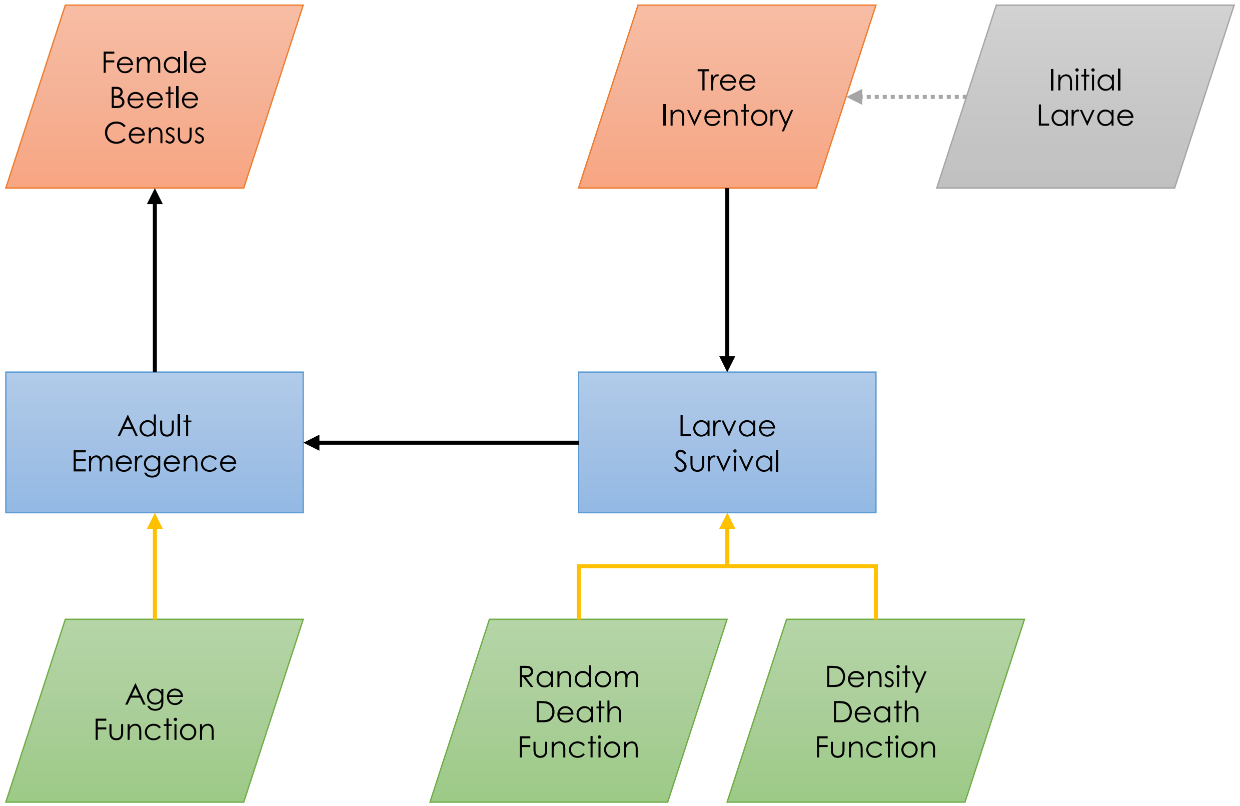
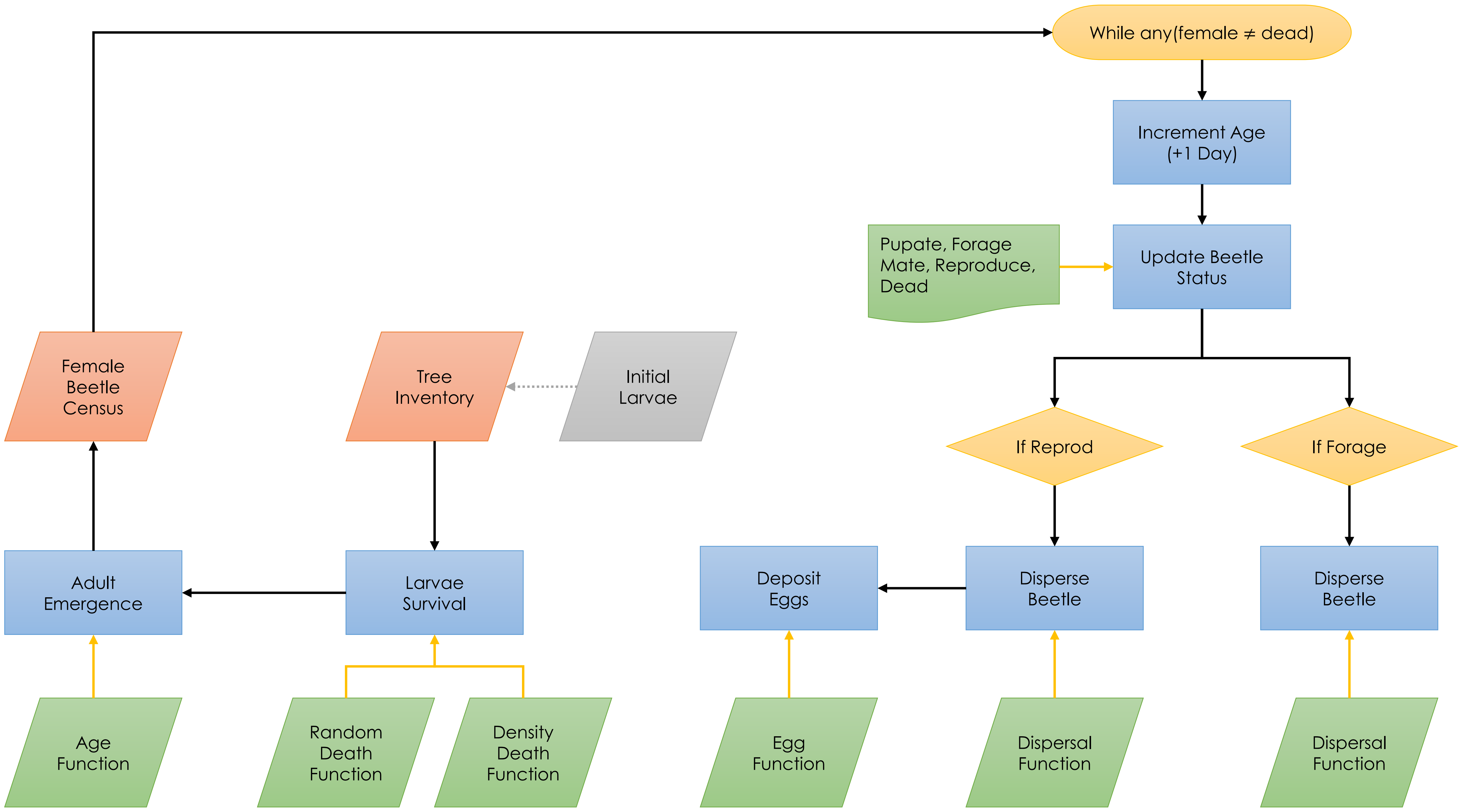


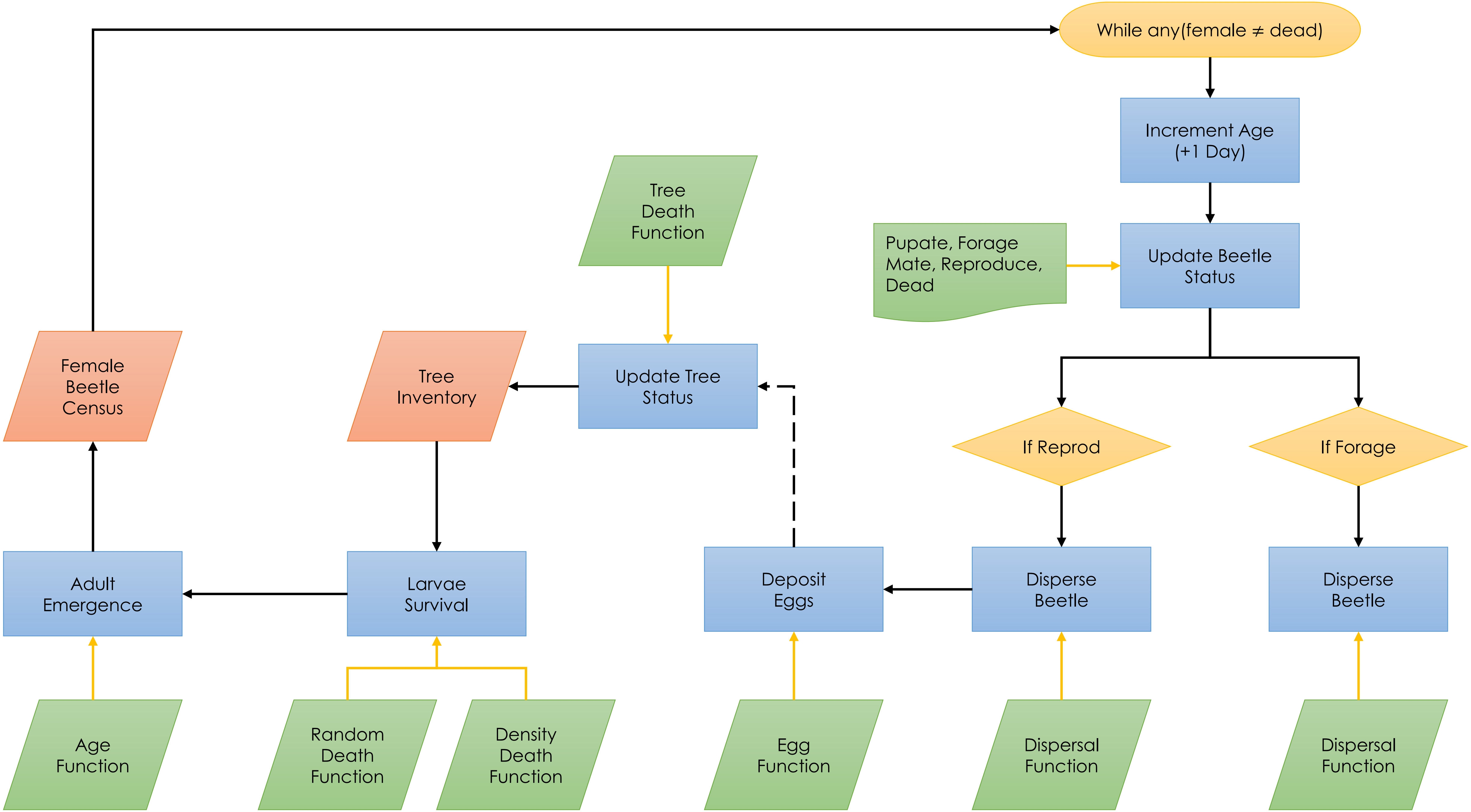
Figure from http://www.protreesd.com/emerald-ash-borer/

Model


Female Beetle Census
Tree Inventory
Initial Larvae
Adult Emergence
Larvae Survival
Age Function
Random Death Function
Density Death Function



While any(female ≠ dead)
Increment Age (+1 Day)
Pupate, Forage Mate, Reproduce, Dead
Update Beetle Status
Female Beetle Census
Tree Inventory
Initial Larvae
If Reprod
If Forage
Adult Emergence
Larvae Survival
Deposit Eggs
Disperse Beetle
Disperse Beetle
Age Function
Random Death Function
Density Death Function
Egg Function
Dispersal Function
Dispersal Function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Deposit Eggs
Egg Function
Tree Death Function
Update Tree Status
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Larvae Survival
Random Death Function
Density Death Function
Adult Emergence
Age Function
Female Beetle Census

Larval Death

Maximum densities

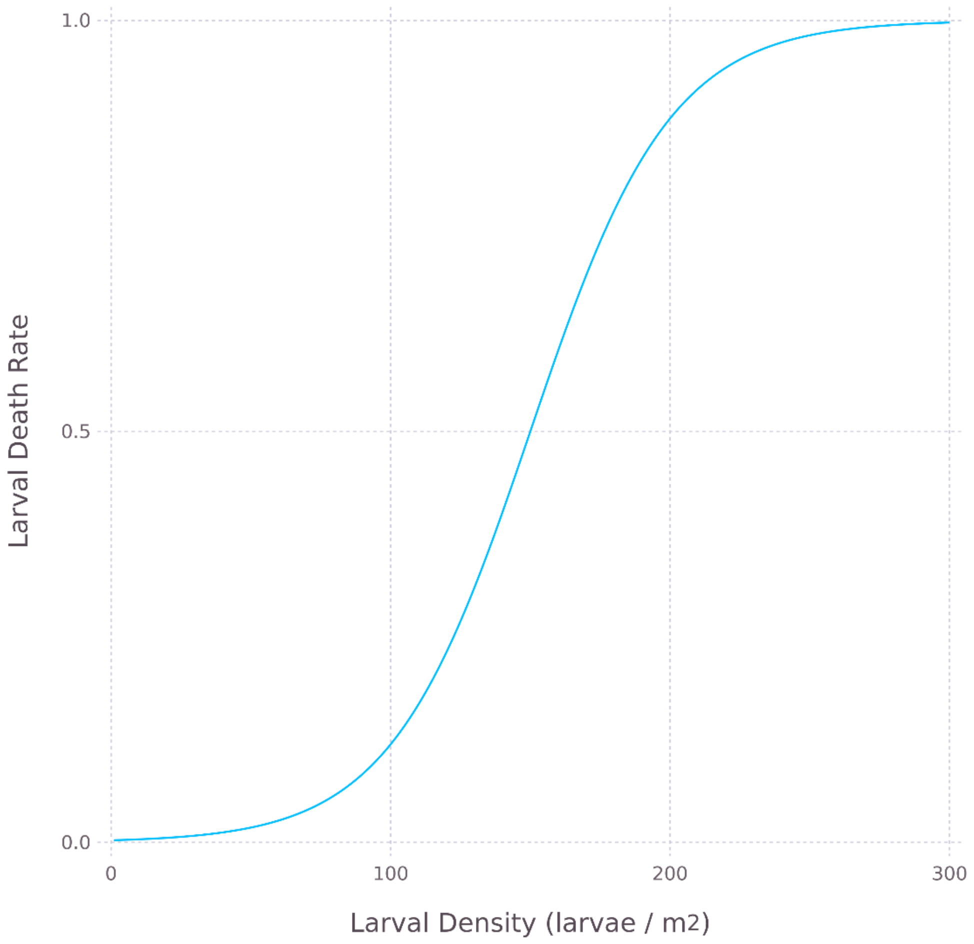
300 – 1000 larvae / m^2

Larvae don't survive

Logistic Death Rate†

$$r_{death}(x; x_0 = 150, \sigma = 25)$$

$$x \longmapsto \frac{x - x_0}{\sigma}$$



† Similar to BenDor et al. (2006)

Larval Death

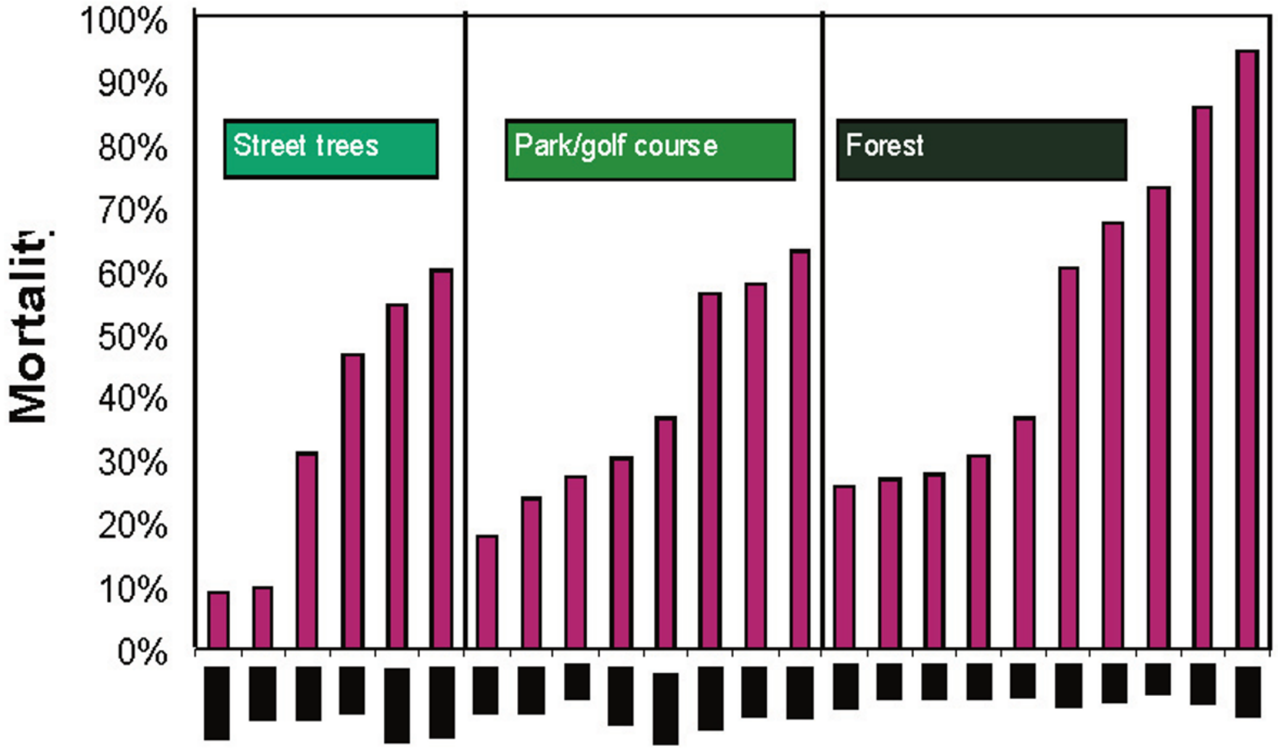
Woodpeckers

Density threshold

Highly variable

Uniformly Random

$r_{death} \sim U[0, 0.6]$



Mortality attributed to woodpeckers at 24 Michigan sites.
Figure from Cappaert et al. (2005)

Other Functions & Parameters

Age

Set to zero (Pupate)

Eggs

$n_{deposit} \sim U_{INT}[1,10]$

Tree Death

$T - T_{infest} = 3\ years$

Beetle Status (age in days)				
		Pupate	$\leq$	0
0	$<$	Forage	$\leq$	7
7	$<$	Mate	$\leq$	10
10	$<$	Reproduce	$\leq$	22
22	$<$	Dead		

Dispersal Function

Host Preferences

Ash Abundance, Type
Condition (e.g. stressed, infested)
Distance

Simple Model

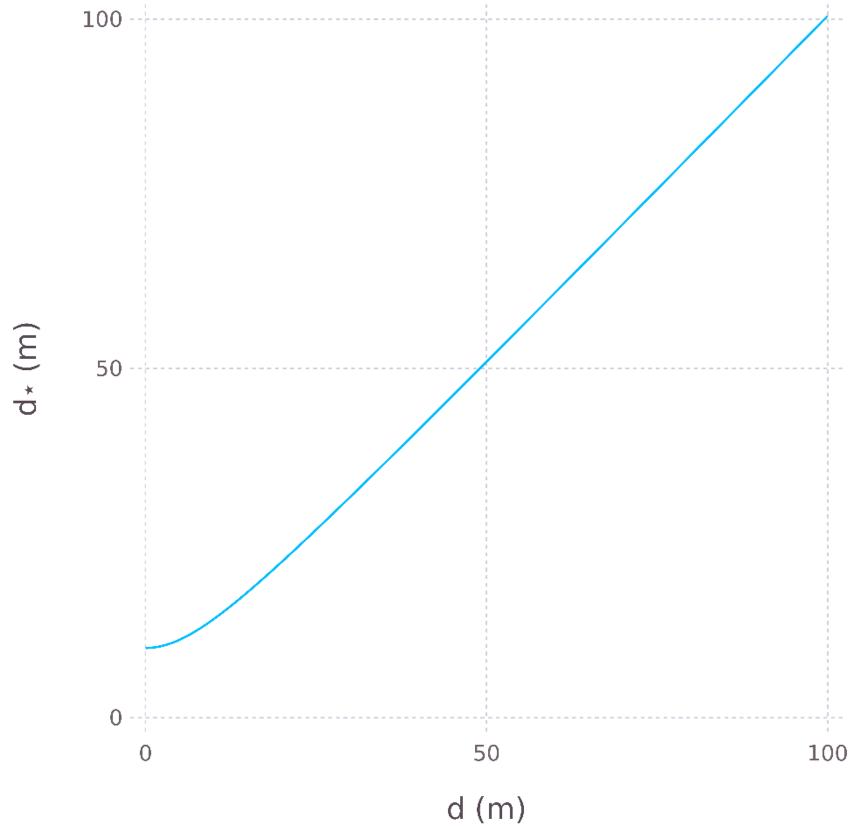
$$w_i \propto \frac{\sigma_i}{(d_\star)_i^\chi} \qquad\qquad p_i = \frac{w_i}{\sum_j w_j}$$

σ = Surface Area

$$d_\star = \begin{cases} \sqrt{d^2 + \epsilon^2} & d < 2.8\ km \\ \infty & d \geq 2.8\ km\ \ or\ dead \end{cases}$$

ϵ = buffering parameter (10 meters)

χ = power index (≥ 0)



Simulation

5-year Simulation

$\chi \in \{1, 2, 3\}$

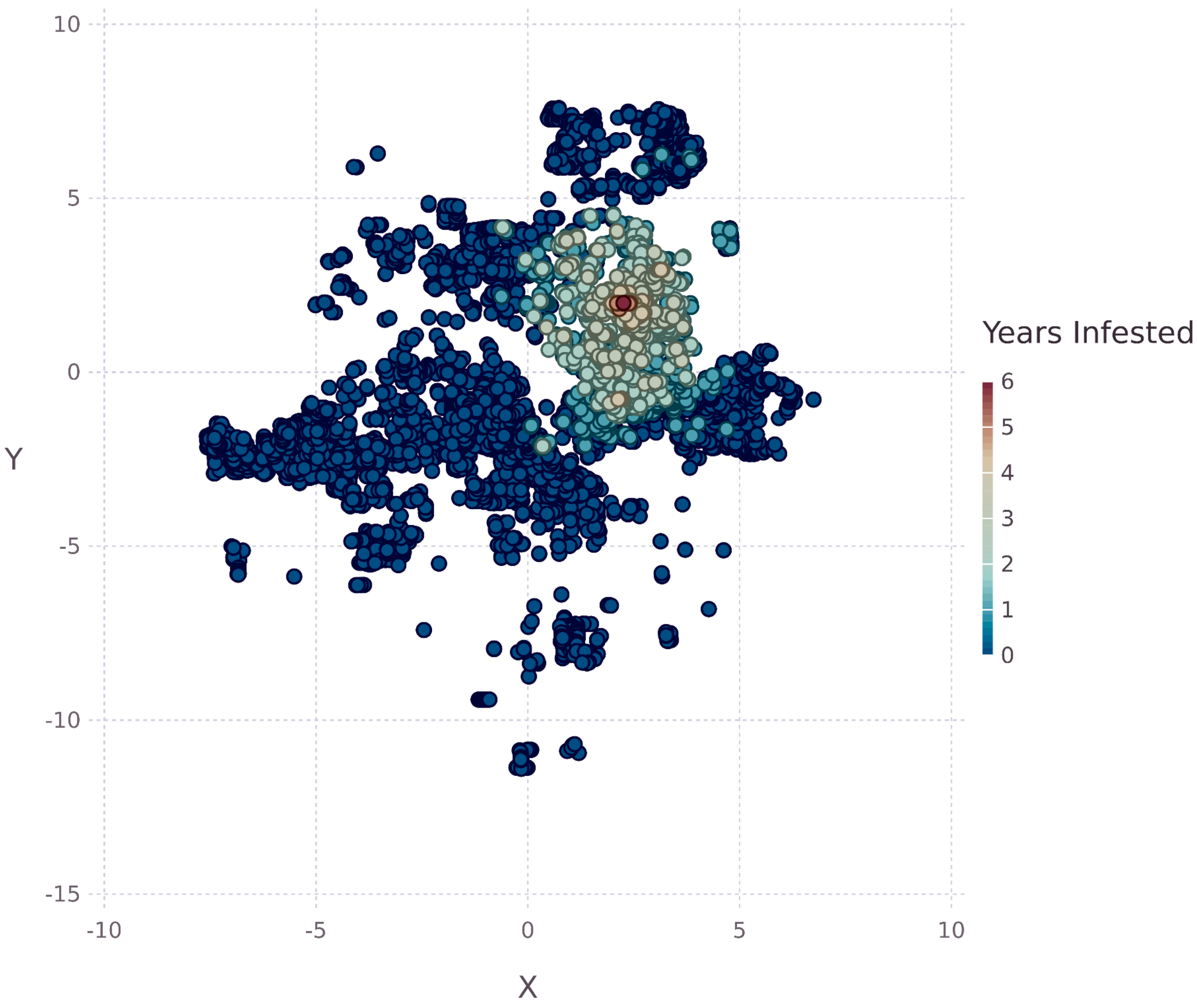
Starting Point

1 infested tree

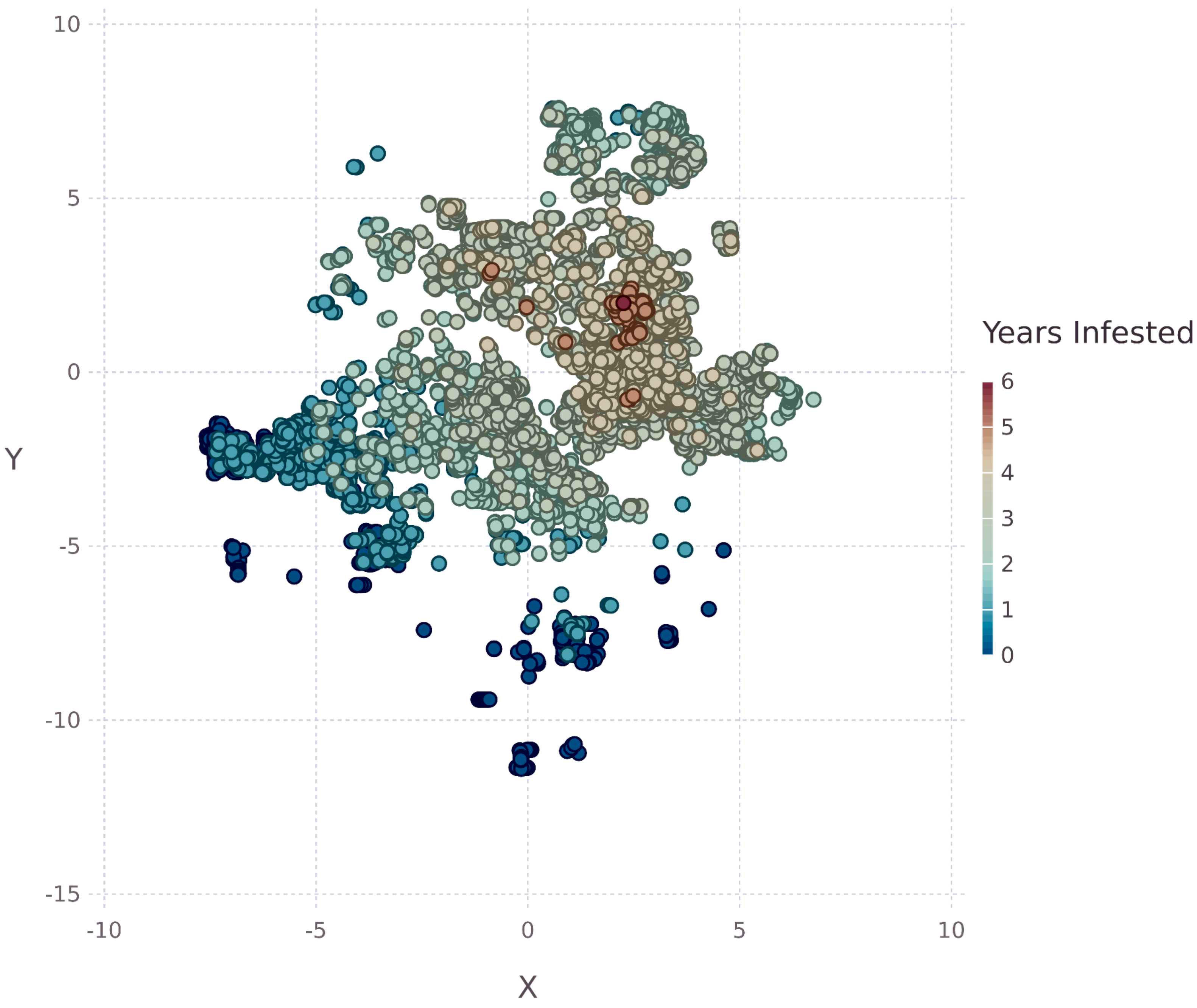
50 larvae

Compare dispersion, larval densities, and exit holes with observed values

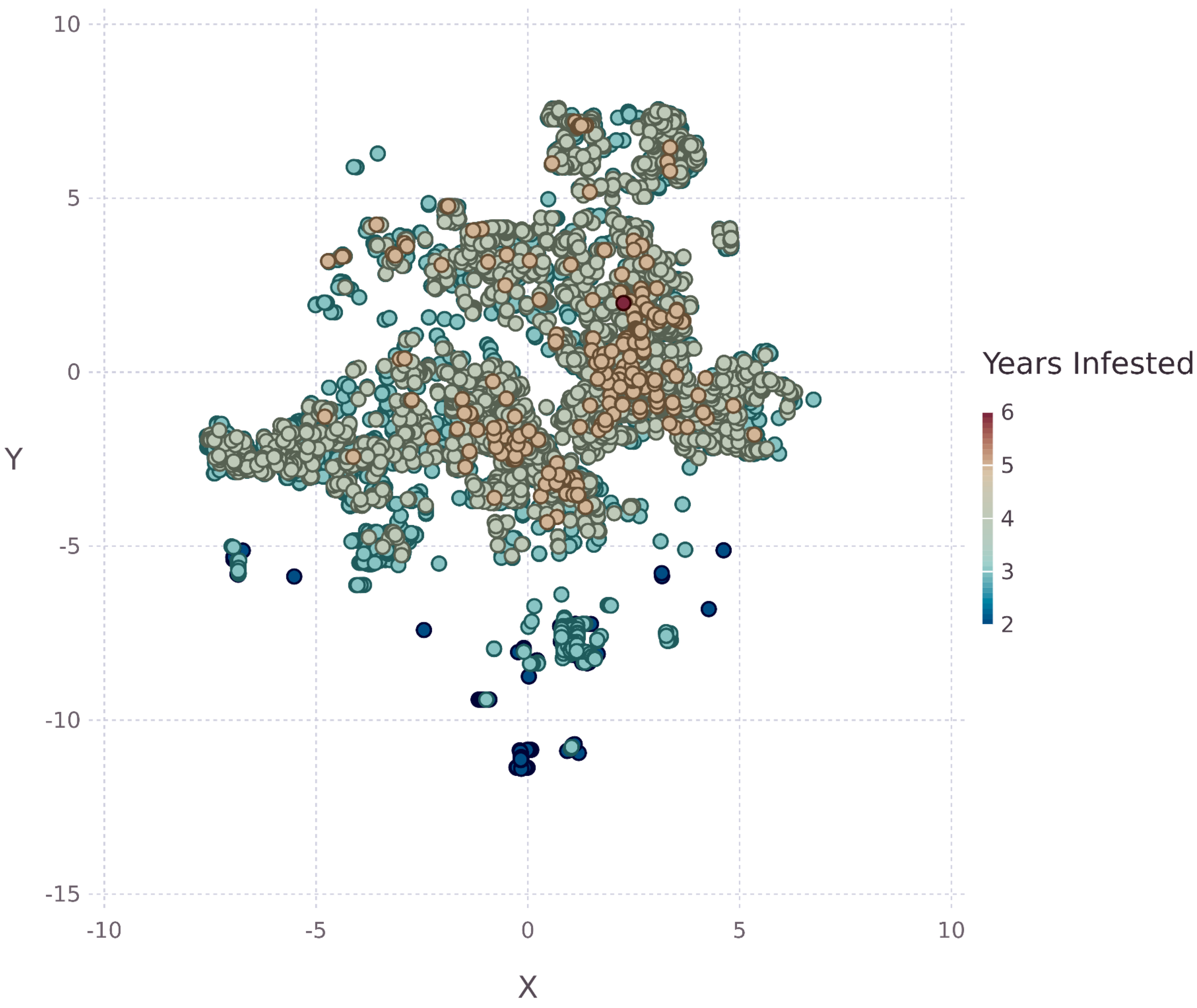
$\chi = 3$



$$\chi = 2$$



$$\chi = 1$$



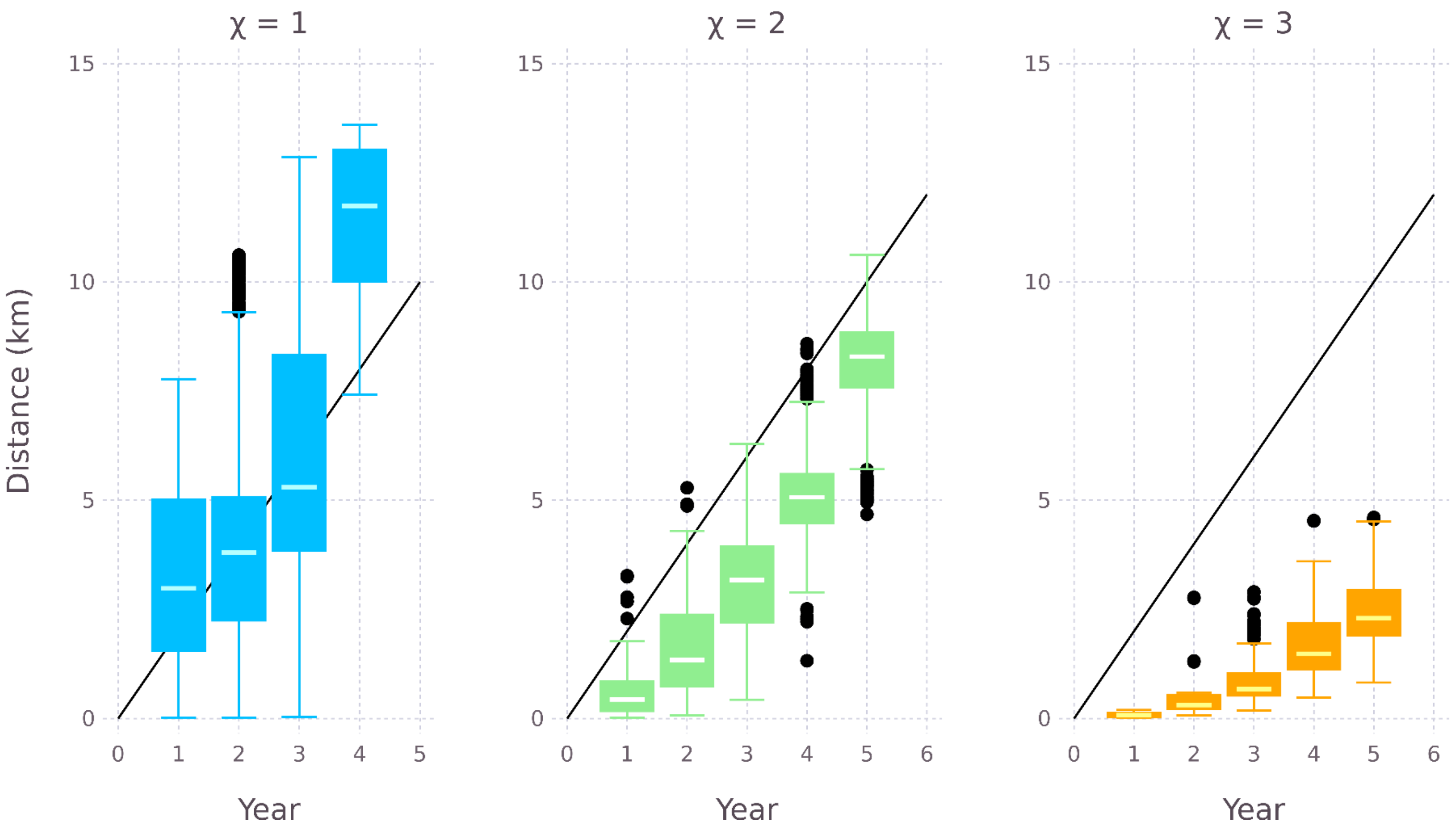
Dispersal

Observations

~2 km / year

Simulation Results

Closest: $\chi = 1$



Exit Holes

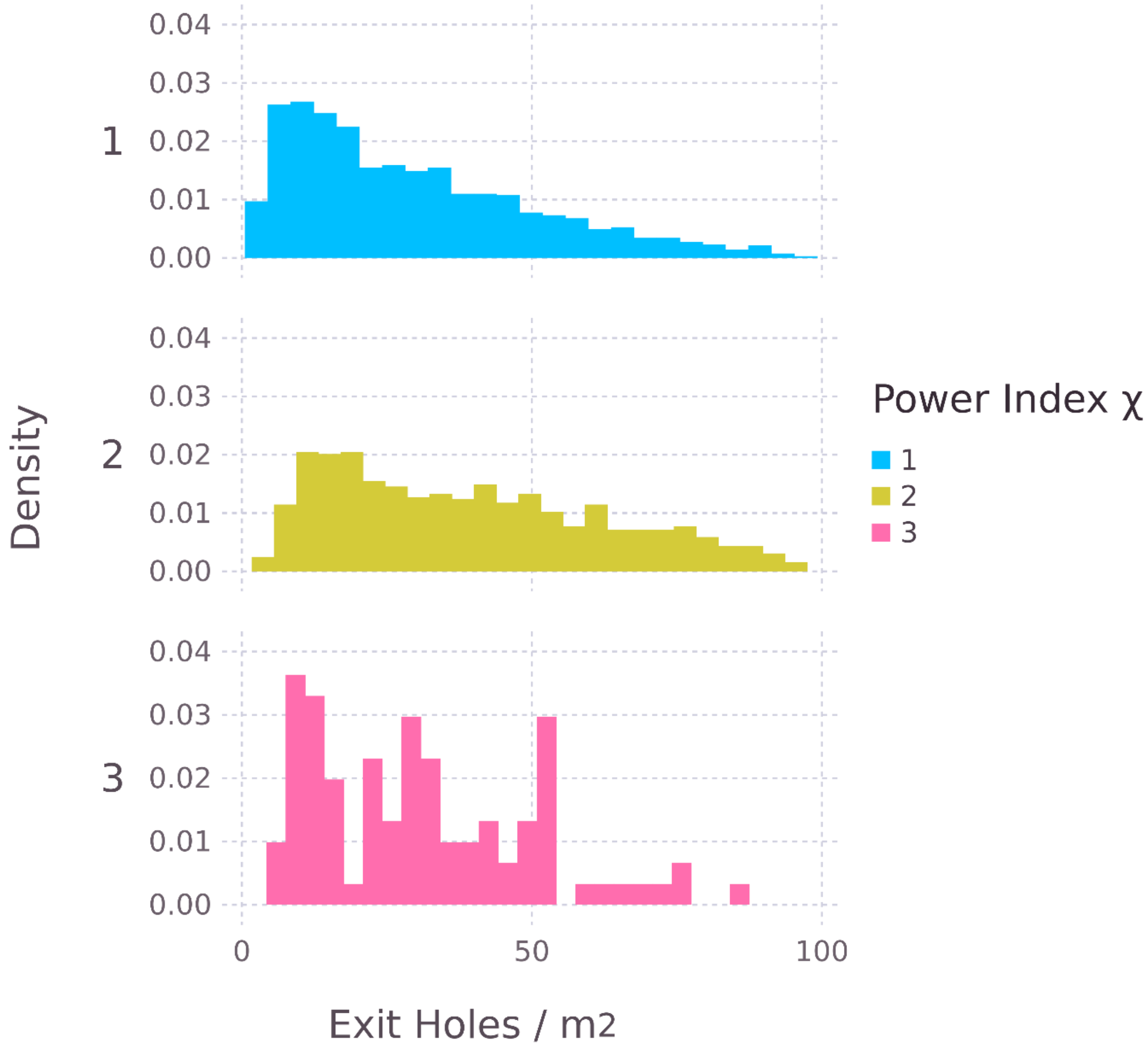
Observations

$$\approx 90\ \frac{exit\ holes}{m^2}$$ (McCullough 2007)

Simulation Results

Select dead trees after 5 years

Less exit holes than expected



Larval Densities

Observations

< 300 larvae / m^2

Simulation Results

Select dead trees after 5 years

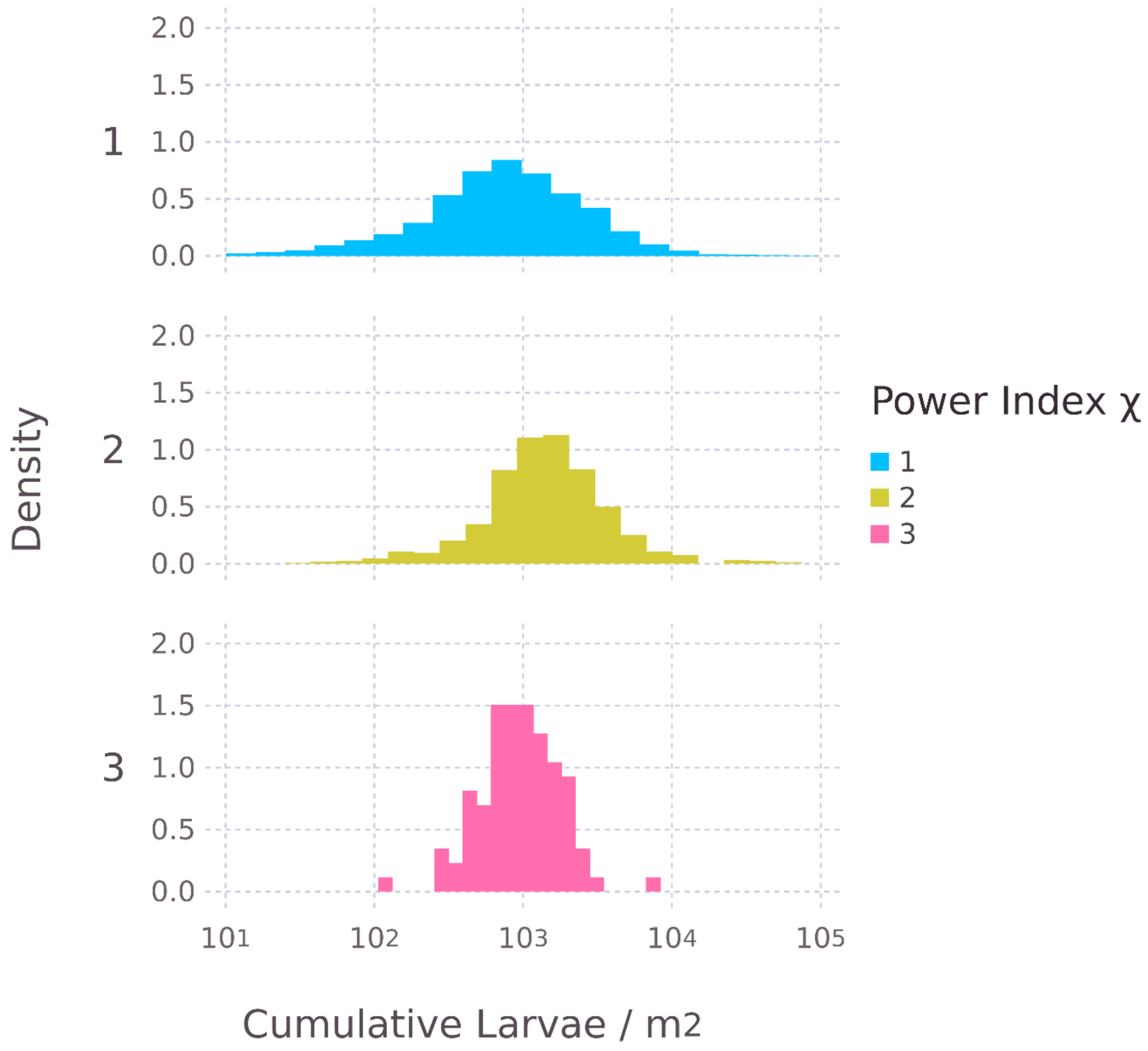
$\chi = 1$

small trees attacked too often

$\chi = 3$

range too concentrated

Area of study too small?



Conclusions

Model

Host selection algorithm

Too simple ⇒ decision theory

Need appropriate data

Cedar Rapids

EAB infestation underway, 2018

References

T. BenDor, S. Metcalf, L. Fontenot, B. Sangunett, and B. Hannon. Modeling the spread of the emerald ash borer. Ecological Modelling, 197(1-2):221–236,8 2006. ISSN 0304-3800.

D. Cappaert, D. G. McCullough, T. M. Poland, and N. W. Siegert. Emerald ash borer in north america: A research and regulatory challenge. American Entomologist, 51(3):152–165, 2005

R. A. Haack, Y. Baranchikov, L. S. Bauer, and T. M. Poland. Emerald ashborer biology and invasion history, 2015

D. McCullough and N. Siegert. Estimating potential emerald ash borer (coleoptera: Buprestidae) populations using ash inventory data. Journal of economic entomology, 100:1577–86, 10 2007.