Assessing the effectiveness of clear cutting in eradicating the pine wood nematode

Christelle Robinet[1], Philippe Castagnone-Sereno[2], Manuel Mota[3], Géraldine Roux[1,4], Corinne Sarniguet[5], Xavier Tassus[6], Hervé Jactel[7]

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[2] INRA, Institut Sophia Agrobiotech, Sophia Antipolis, France
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[5] ANSES, Nematology Unit, Le Rheu, France
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[7] INRA, BIOGECO, Cestas, France

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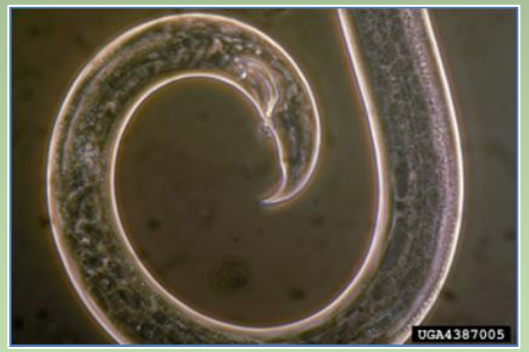
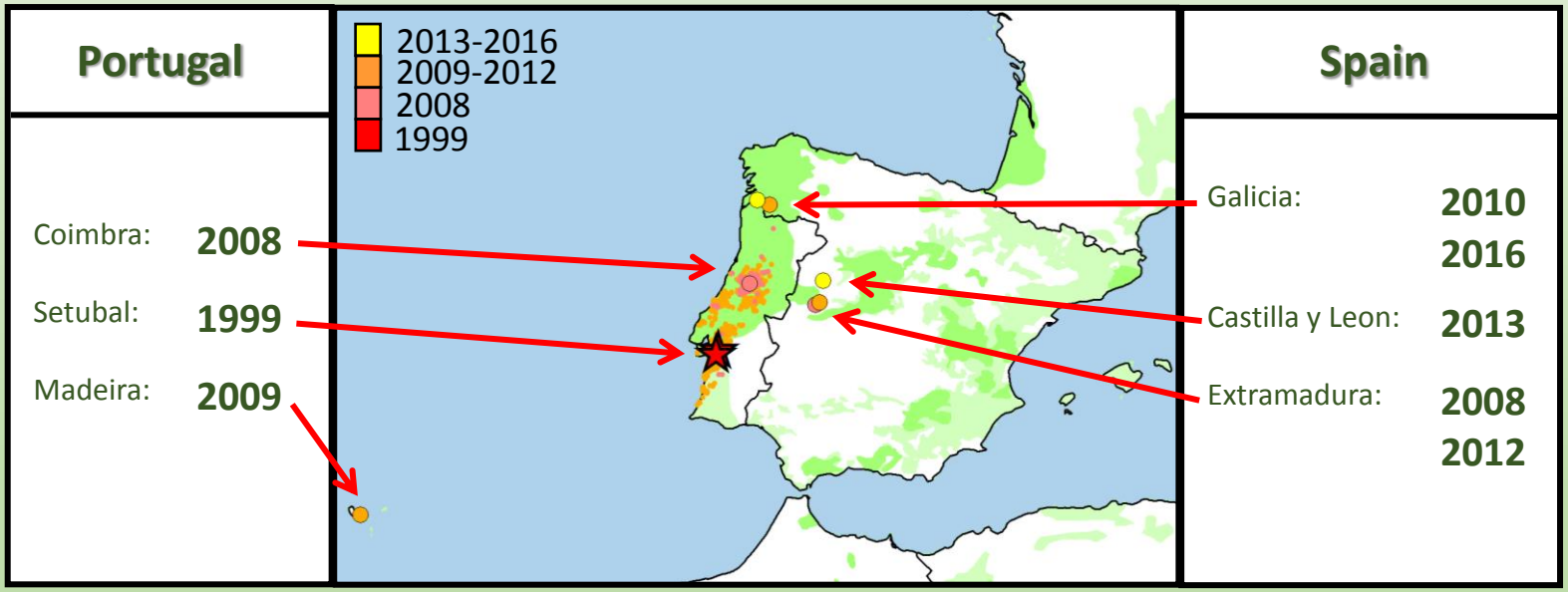


European situation

- The PWN was detected in Europe in 1999
- Despite emergency measures immediately applied, it has spread to Portugal and it was also detected at several locations in Spain near the Portuguese border



European situation

A great concern in France, a neighboring country

- The Pyrenean mountains which separate the Iberian Peninsula from France and the rest of Europe could be only a partial barrier to the PWN spread (Haran et al. 2015 *PLOSONE*)

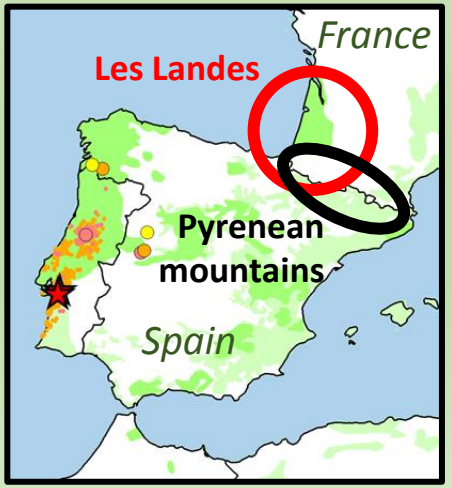

PLOS ONE

Haran et al. 2015

RESEARCH ARTICLE

Altitudinal Barrier to the Spread of an Invasive Species: Could the Pyrenean Chain Slow the Natural Spread of the Pinewood Nematode?

Julien Haran[1,2]*, Alain Roques[1], Alexis Bernard[1], Christelle Robinet[1], Géraldine Roux[1,2]



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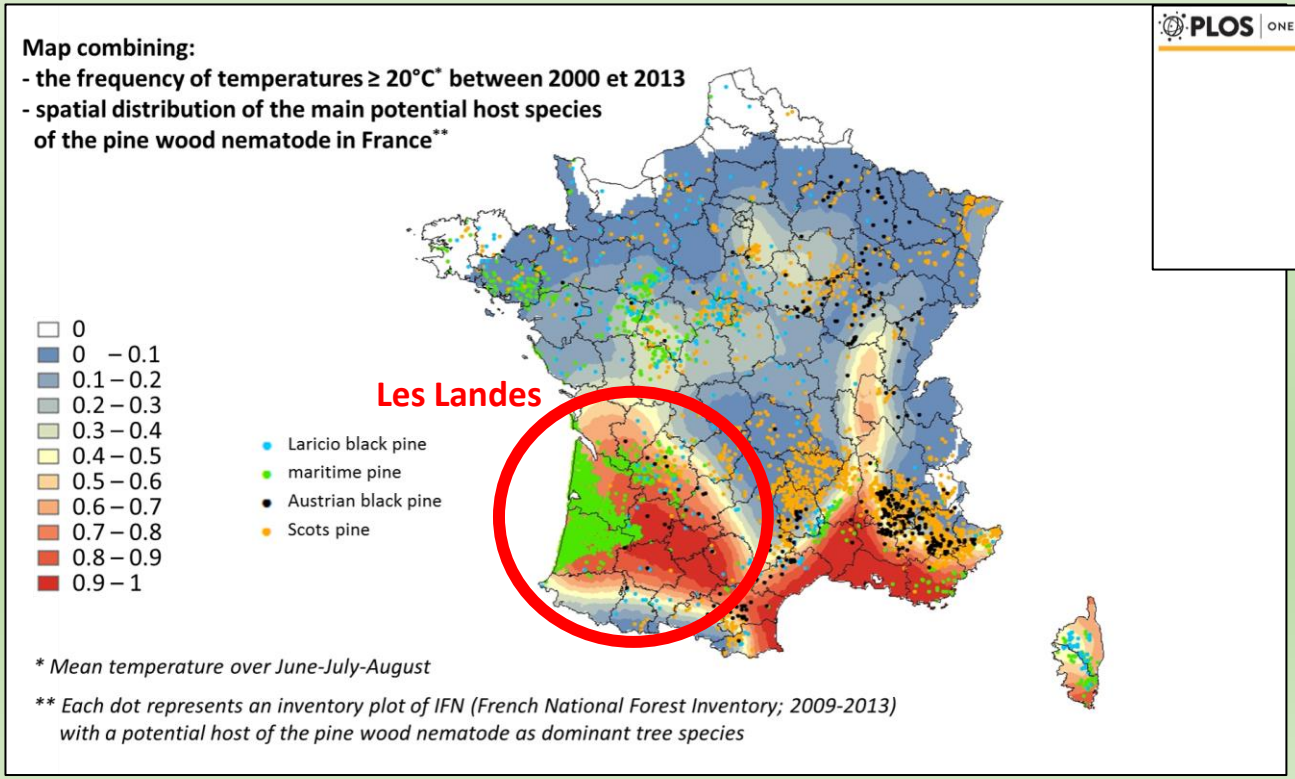
- The Pyrenean mountains which separate the Iberian Peninsula from France and the rest of Europe could be only a partial barrier to the PWN spread (Haran et al. 2015 *PLOSONE*)
- A large plantation forest of maritime pines (called « Les Landes »)

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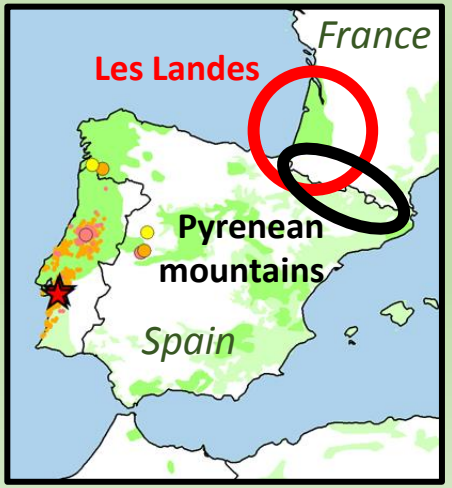

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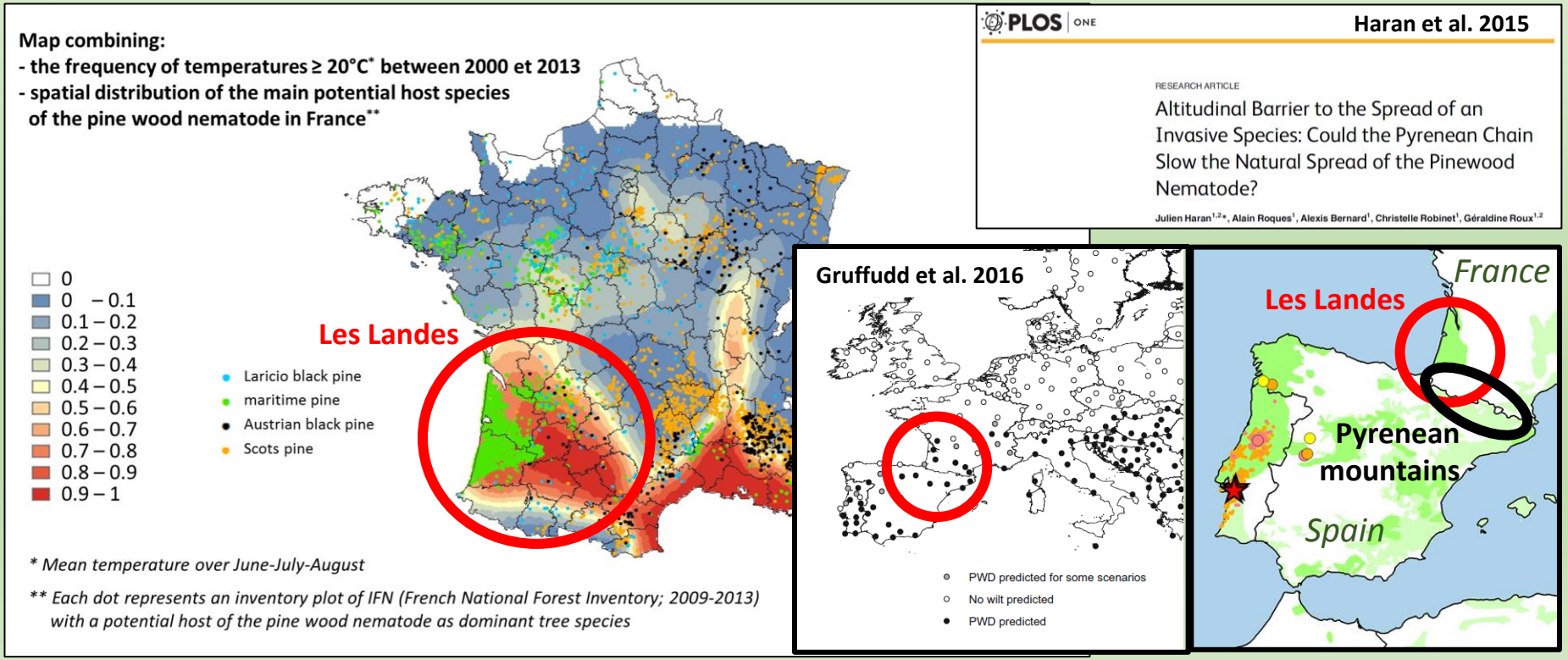
- Climate in southern France likely favorable to the development of the PWD (Gruffudd et al. 2016 *Biological Invasions*)



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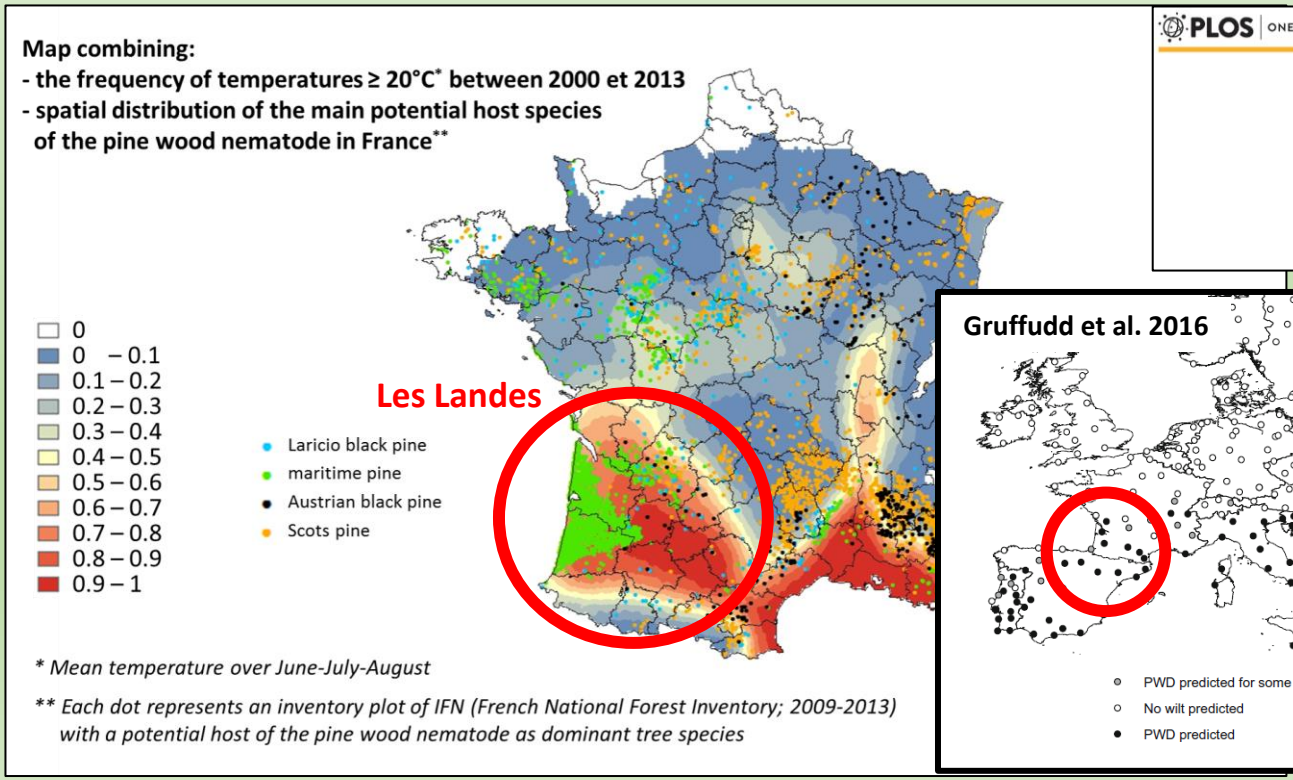
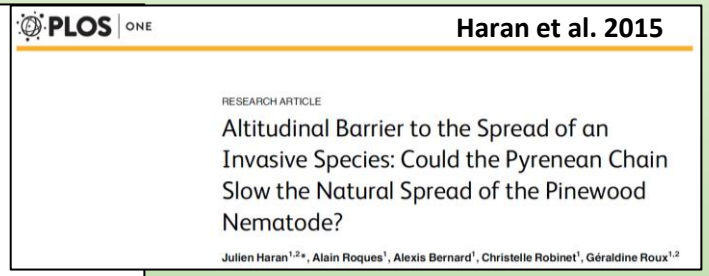
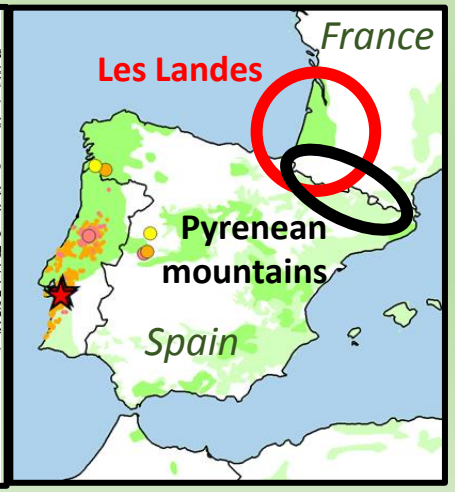
- The Pyrenean mountains which separate the Iberian Peninsula from France and the rest of Europe could be only a partial barrier to the PWN spread (Haran et al. 2015 *PLOSONE*)
- A large plantation forest of maritime pines (called « Les Landes »)
- Climate in southern France likely favorable to the development of the PWD (Gruffudd et al. 2016 *Biological Invasions*)
- The European vector, *Monochamus galloprovincialis*, is widely distributed







European regulation

L 266/42 EN Official Journal of the European Union 2.10.2012

COMMISSION IMPLEMENTING DECISION

of 26 September 2012

on emergency measures to prevent the spread within the Union of *Bursaphelenchus xylophilus* (Steiner et Buhrer) Nickle et al. (the pine wood nematode)

(notified under document C(2012) 6543)

(2012/535/EU)

2. When establishing a demarcated area, the Member State concerned shall immediately, in that area, create a zone with a minimum radius of 500 m around each susceptible plant in which PWN has been found to be present, hereinafter 'the clear-cut zone'. The actual radius of that zone shall be determined, for each susceptible plant in which PWN has been found to be present, based on the risk of transmission of PWN by the vector further than 500 m away from that susceptible plant.

In the clear-cut zone all susceptible plants shall be felled, removed and disposed of. The felling and destruction of those plants shall be carried out from the outside of the zone towards the centre. All necessary precautions shall be taken to avoid spreading PWN and its vector during felling.

3. Where a Member State concludes that creation of a 500 m-radius clear-cut zone, as referred to in point 2, has unacceptable social or environmental impacts, the minimum radius of the clear-cut zone may be reduced to 100 m around each susceptible plant in which PWN has been found to be present.

European regulation

Radius of 500 m
=
40,000 trees in continuous forest cover (e.g. Les Landes)

=> it could have significant environmental consequences
and it would require considerable human resources

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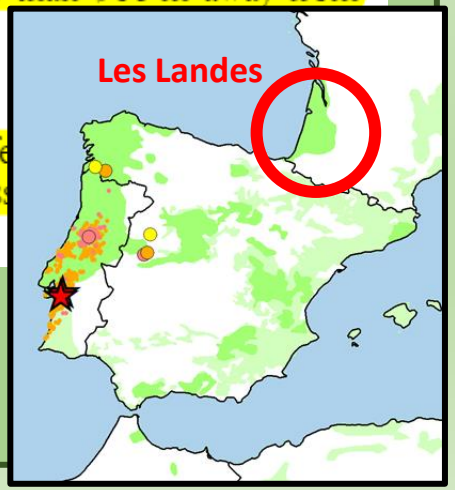

European regulation

To explore the relevance of this emergency measure, it was necessary:

- (1) to estimate the dispersal distance of the European vector, *Monochamus galloprovincialis*
  - Flight mill experiments
  - Mark, release and recapture experiments

European regulation

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- (1) to estimate the dispersal distance of the European vector, *Monochamus galloprovincialis*
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  - Mark, release and recapture experiments
- (2) to assess the effectiveness of the clear cutting
  - Calibration of a simulation modelling
    first, fitted to the flight mill dispersal distances
    then, refined to recapture rates and times
  - Simulations of the clear-cutting

Request for an opinion on "the control strategy imposed by Implementing Decision 2012/535/EU of 26 September 2012 on emergency measures to prevent the spread within the European Union of *Bursaphelenchus xylophilus*"
https://www.anses.fr/fr/system/files/SVEG2014SA0103RaEN.pdf

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FLIGHT MILL *(Monochamus galloprovincialis)*

Mature beetles

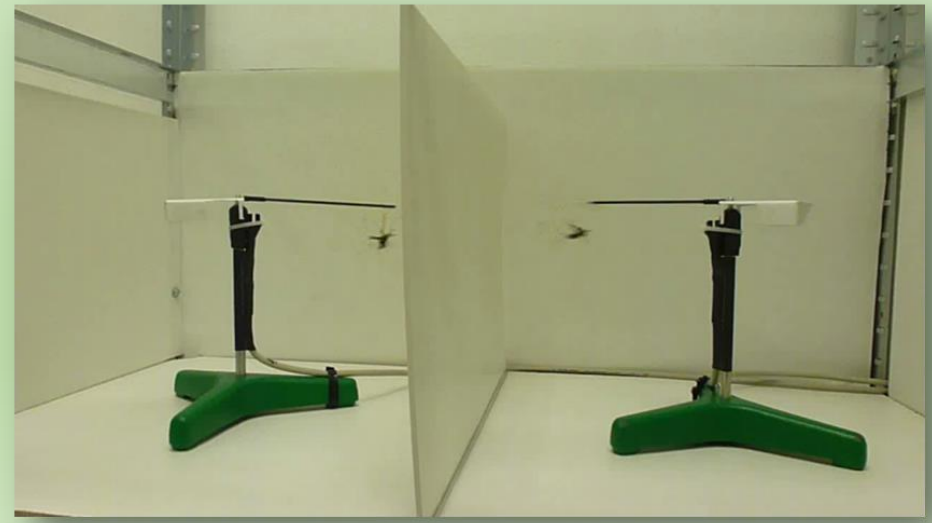
JOURNAL OF APPLIED ENTOMOLOGY
J. Appl. Entomol.
ORIGINAL CONTRIBUTION
2014

Dispersal capacity of *Monochamus galloprovincialis*, the European vector of the pine wood nematode, on flight mills

G. David[1,2], B. Giffard[1,2], D. Piou[1,2,3] & H. Jactel[1,2]

Mean flight performances

- 1 km / individual flight
- 2 km / day
- 16 km / entire adult life



Immature beetles

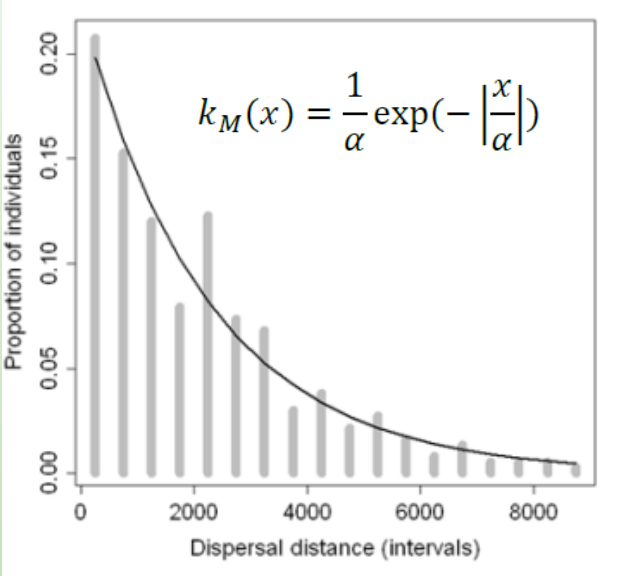
Bulletin of Entomological Research, Page 1 of 8
© Cambridge University Press 2015
doi:10.1017/S0007485315000553
2015

Energy allocation during the maturation of adults in a long-lived insect: implications for dispersal and reproduction

G. David[1,2]*, B. Giffard[1,2,3], I. van Halder[1,2], D. Piou[1,2,4] and H. Jactel[1,2]

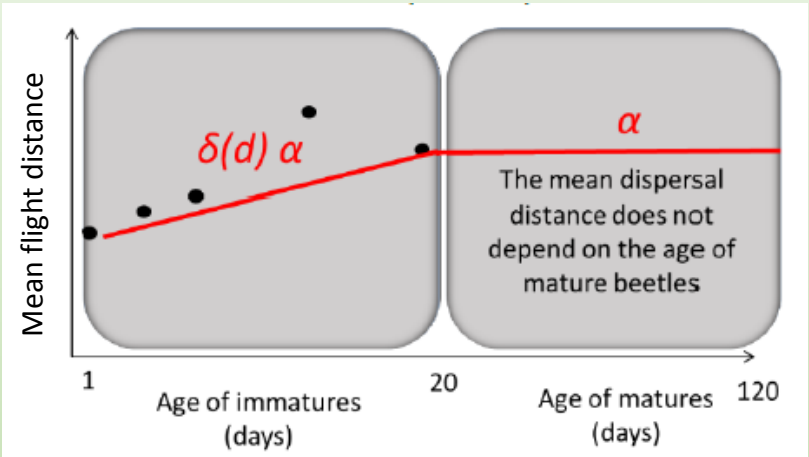
FLIGHT MILL *(Monochamus galloprovincialis)*

Mature beetles



Negative exponential distribution with mean α (300 – 2000 m / day)

Immature beetles



$$k_I(x,d) = \frac{1}{\delta(d)\alpha}\exp(-\left|\frac{x}{\delta(d)\alpha}\right|)$$

$$\delta(d) = 0.67 + 0.016 \times d$$

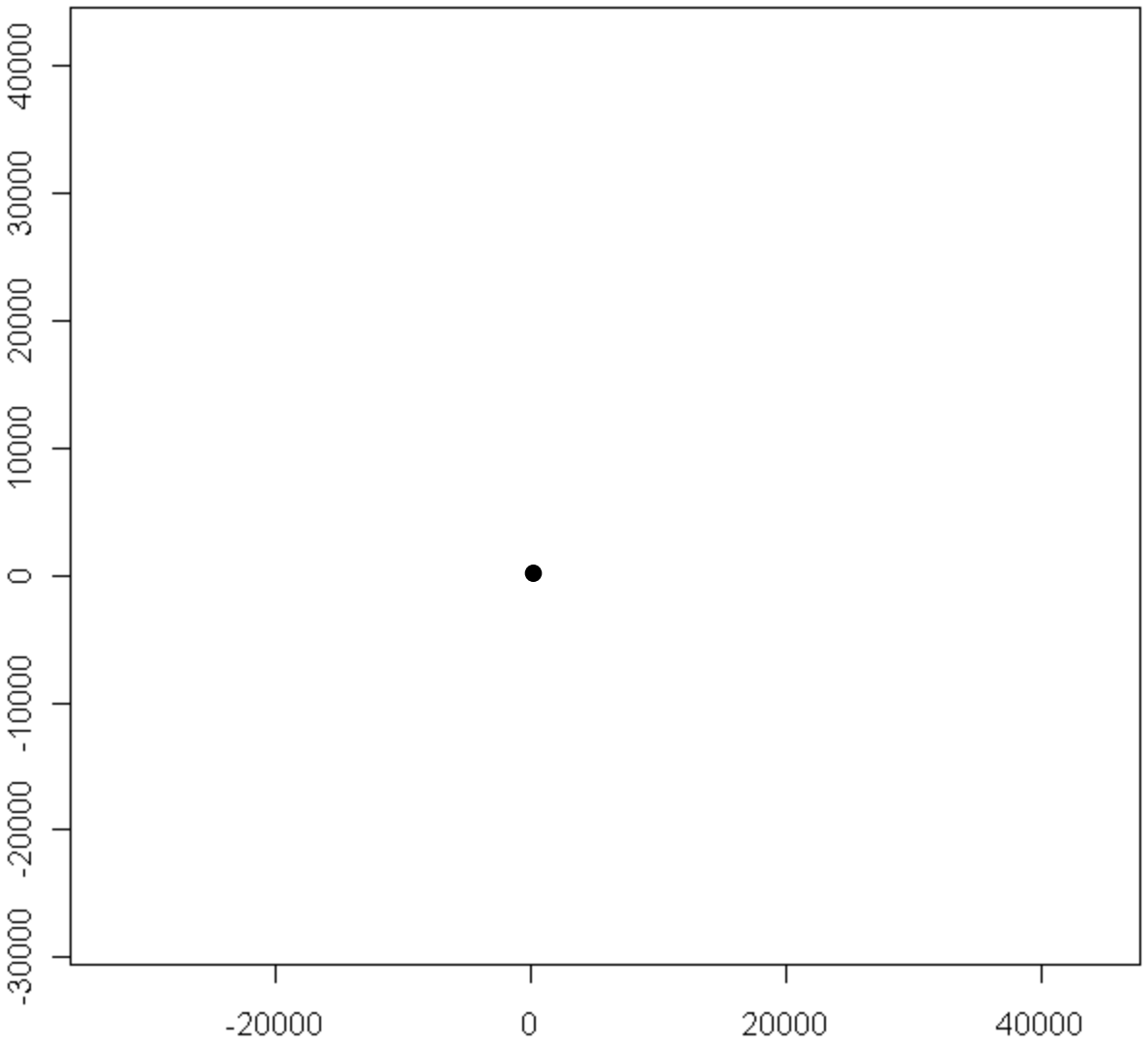
To simulate the beetle trajectory each day, we select at random :

- distance : from the negative exponential kernel
- direction: between 0 and 360°

FLIGHT MILL *(Monochamus galloprovincialis)*

Day 0

- insect
- trajectory



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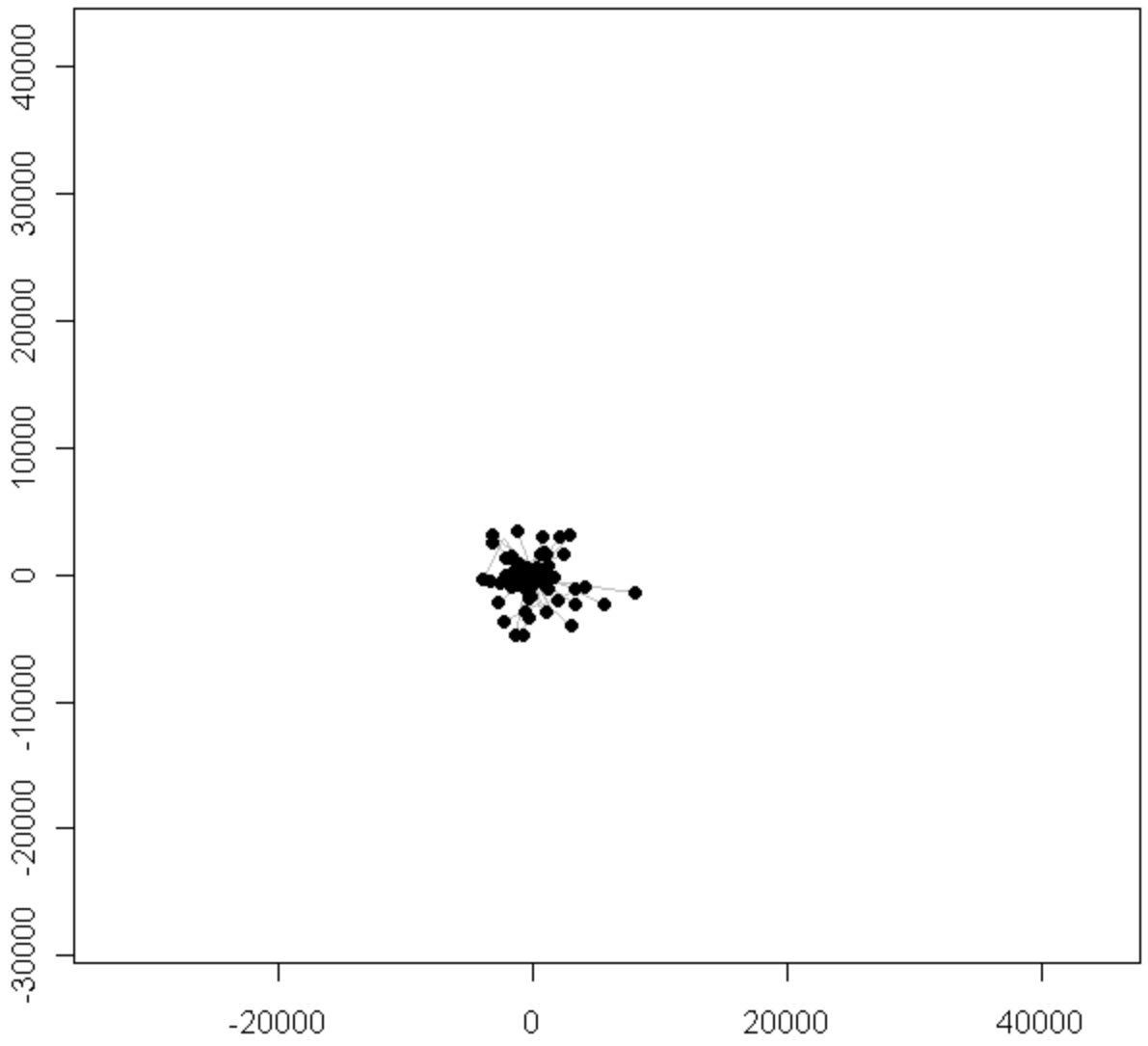
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 2

- insect
- trajectory



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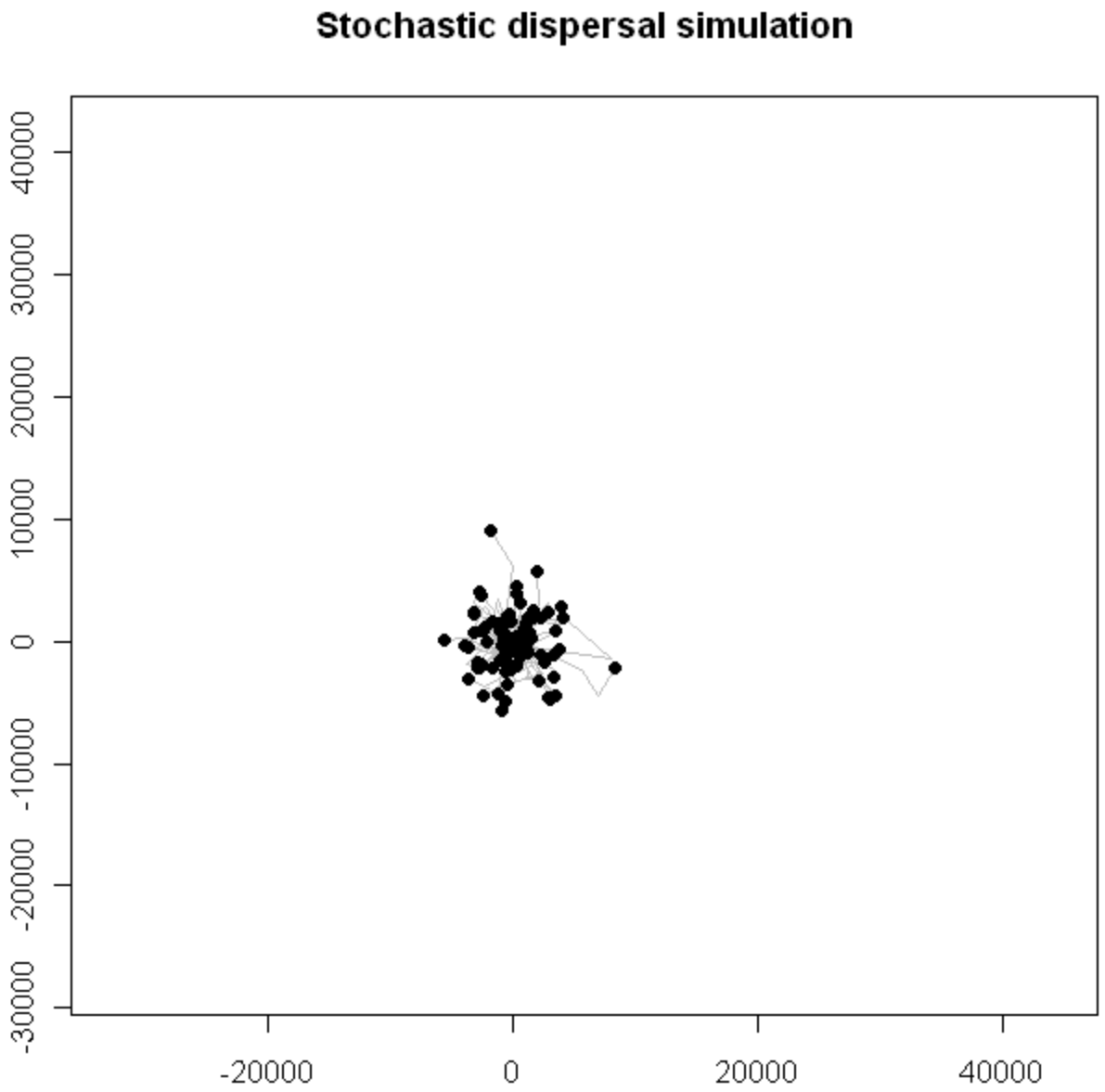
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 4

- insect
- trajectory



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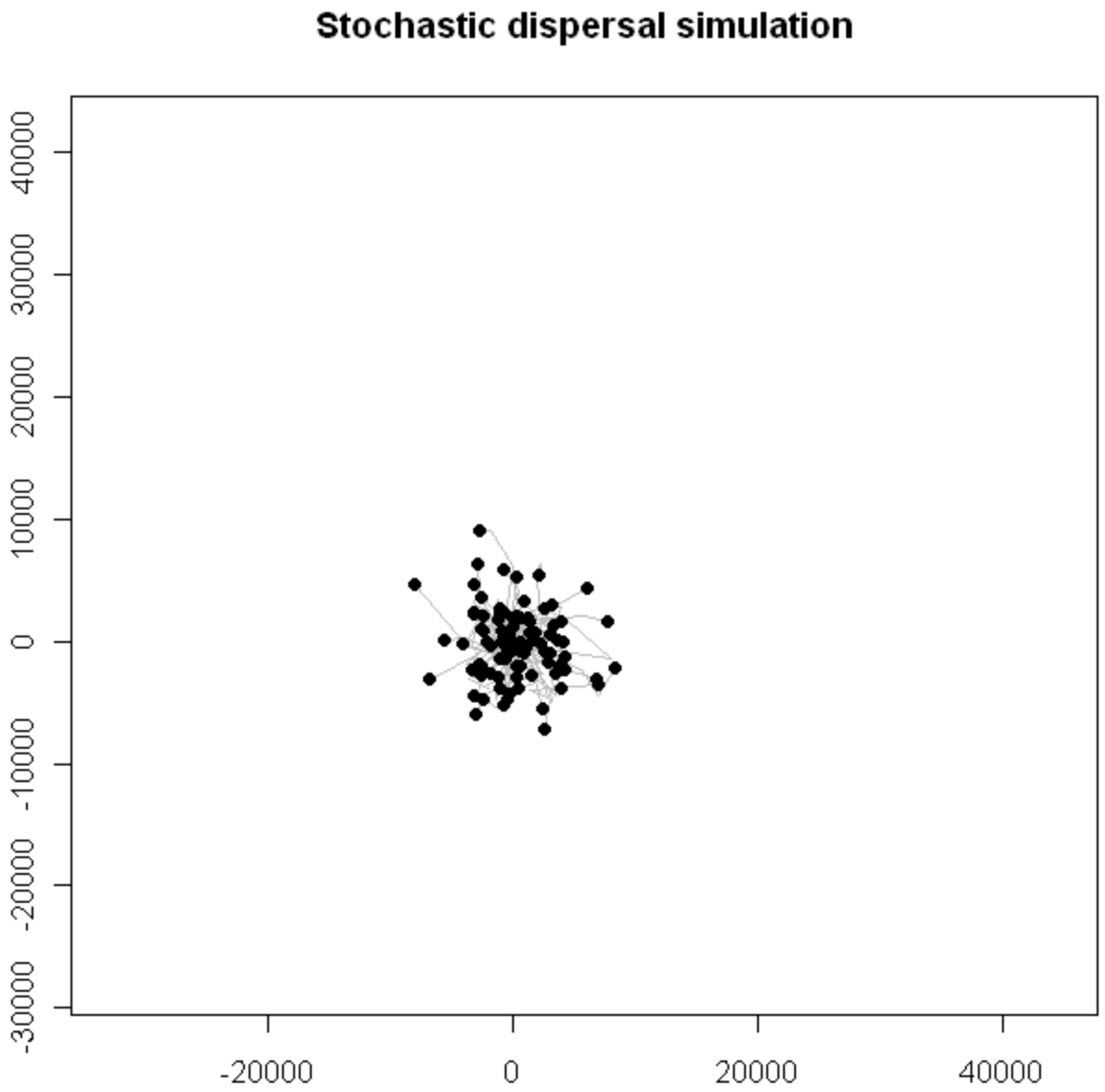
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 6

- insect
- trajectory



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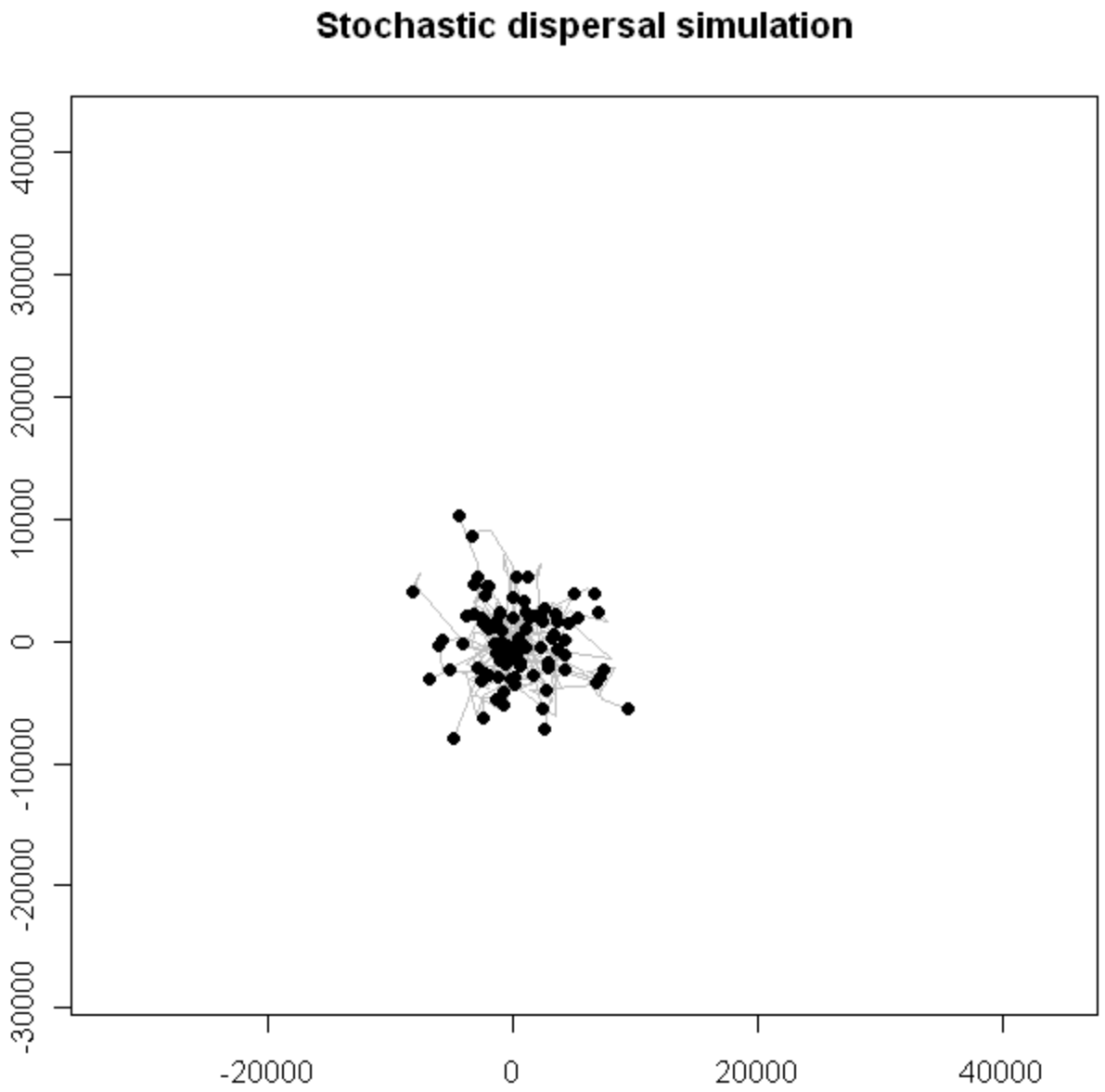
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 8

- insect
- trajectory



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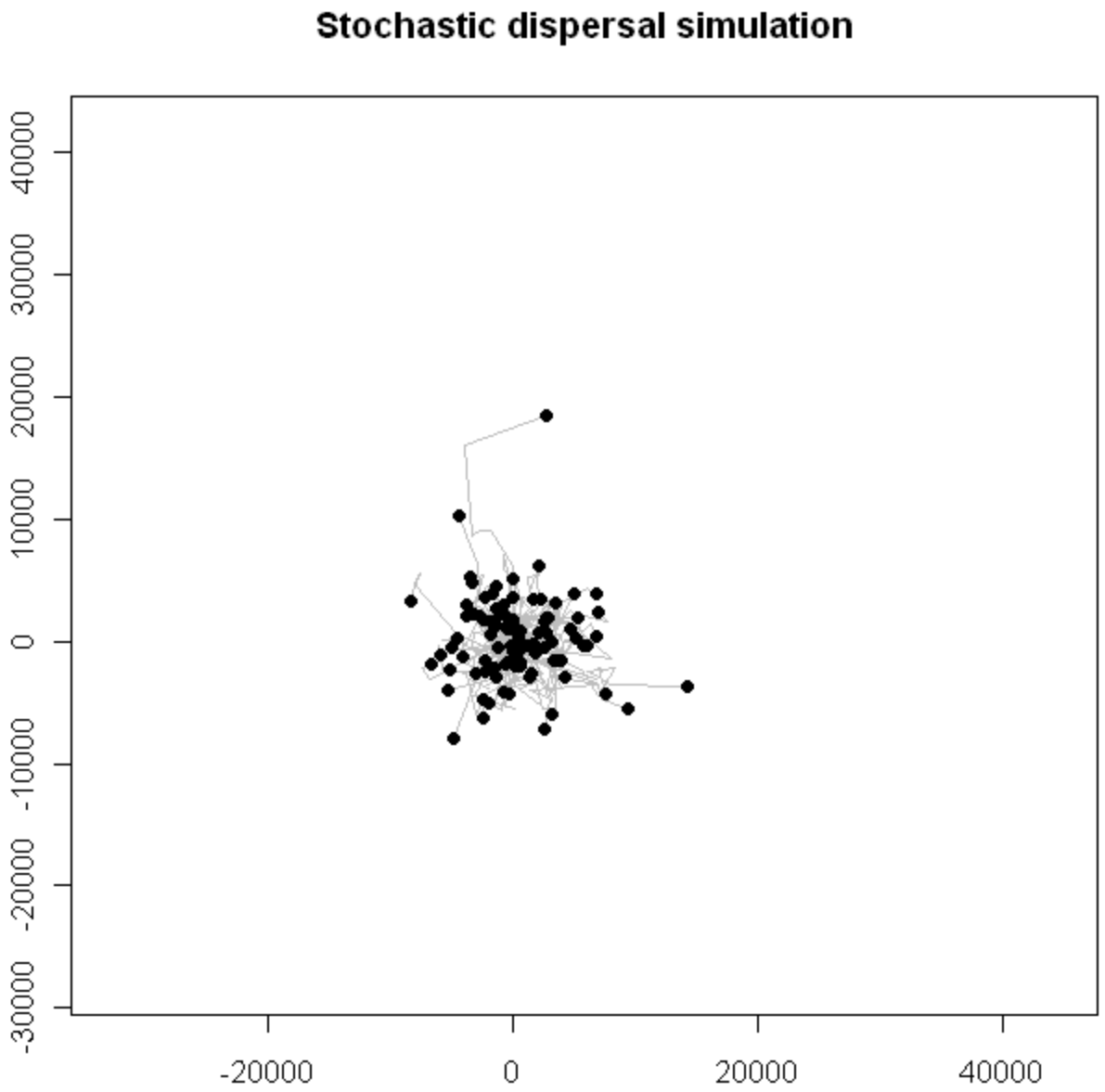
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 10

- insect
- trajectory



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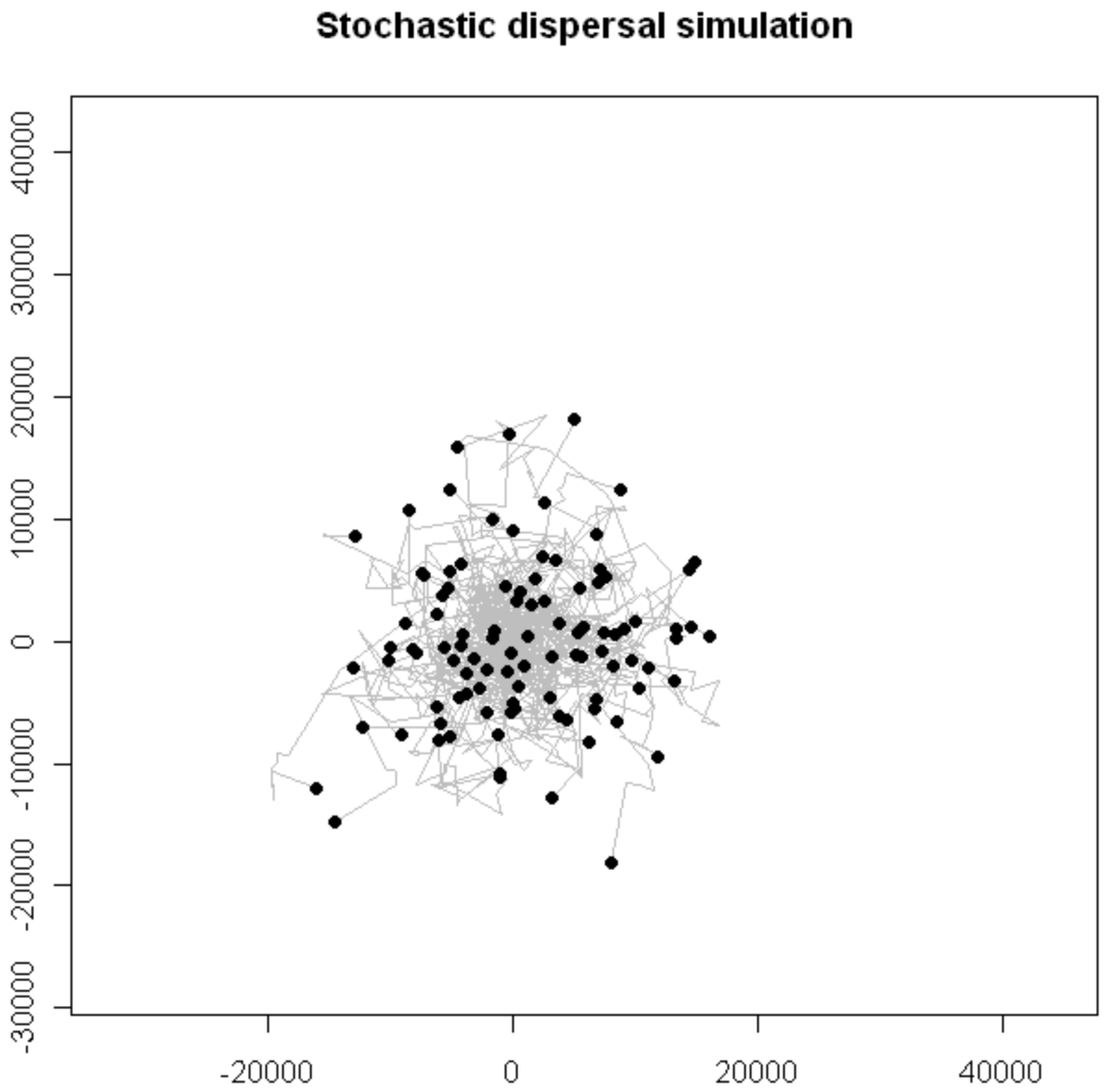
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 30

- insect
- trajectory



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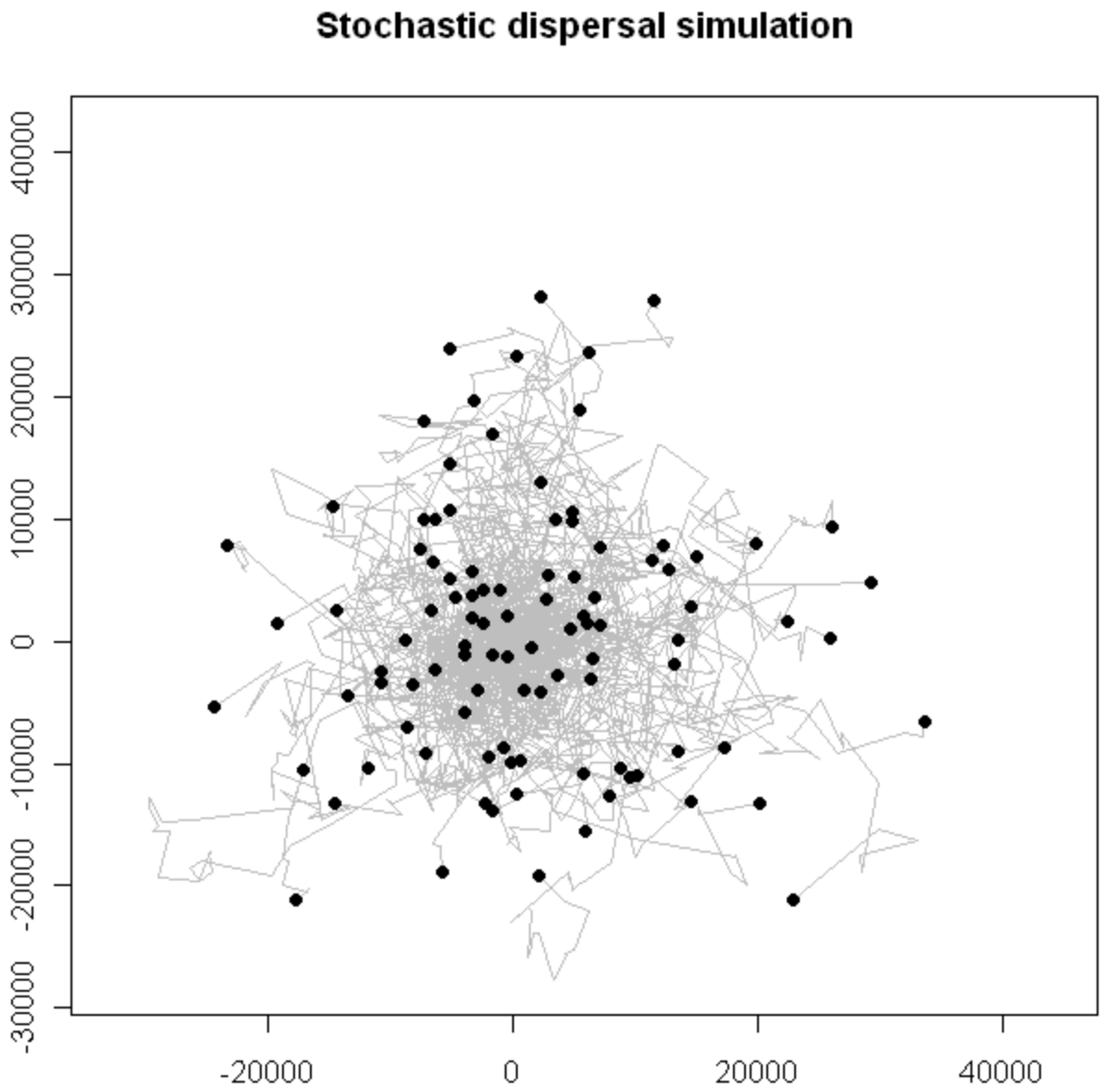
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 60

- insect
- trajectory



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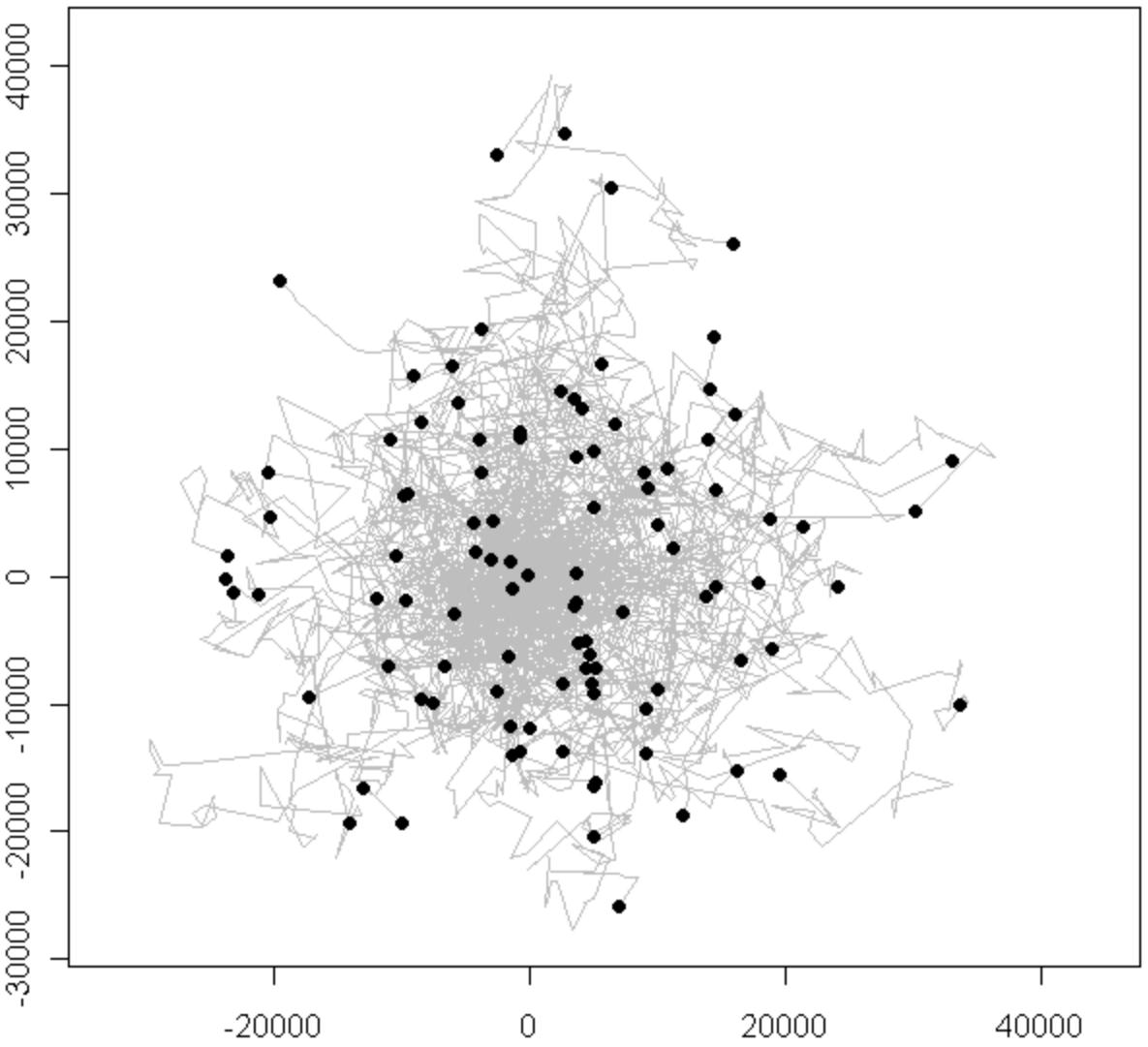
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 80

- insect
- trajectory



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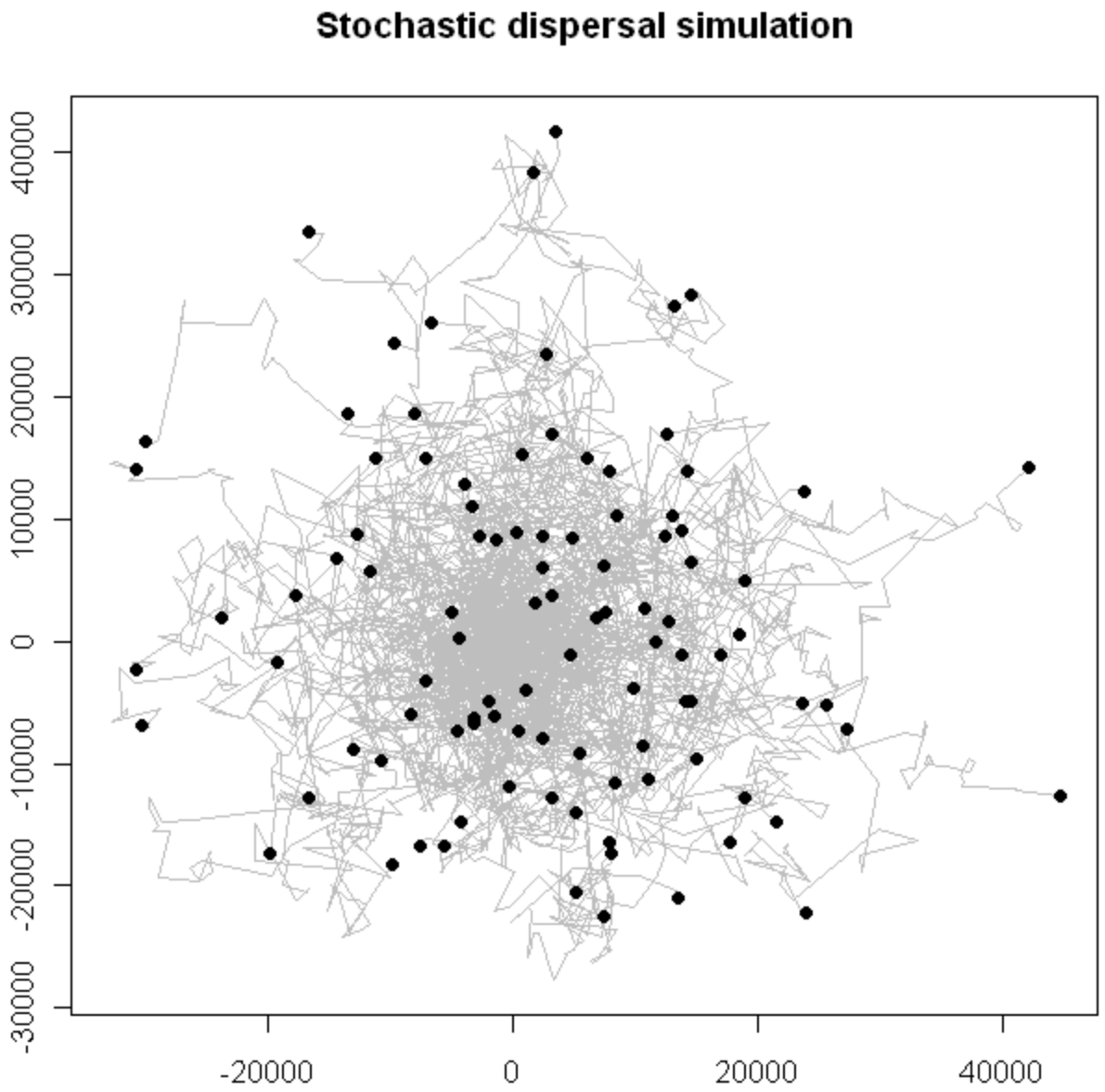
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 120

- insect
- trajectory



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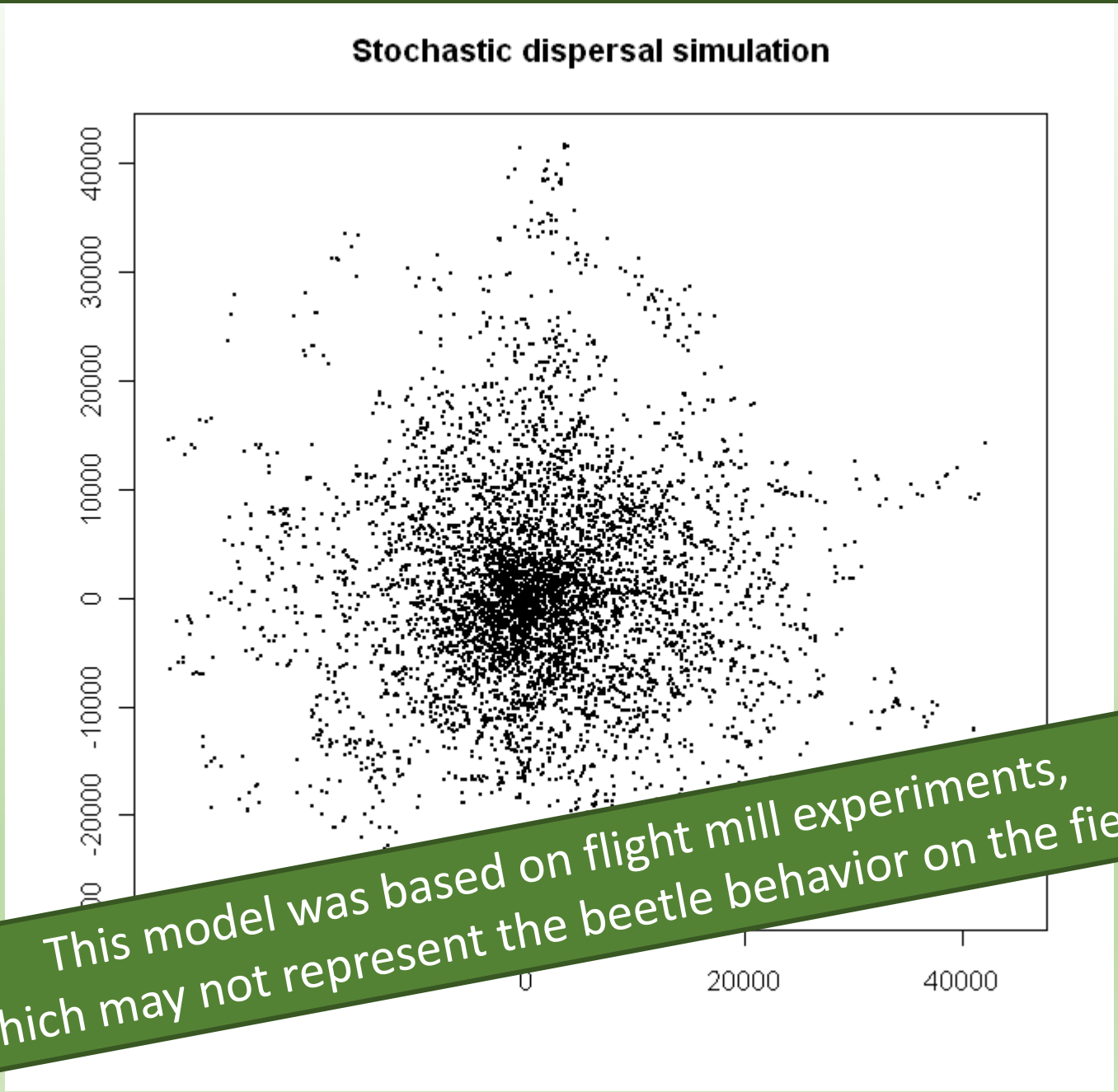
FLIGHT MILL *(Monochamus galloprovincialis)*

Day 120

- **All stops**



This model was based on flight mill experiments, which may not represent the beetle behavior on the field.

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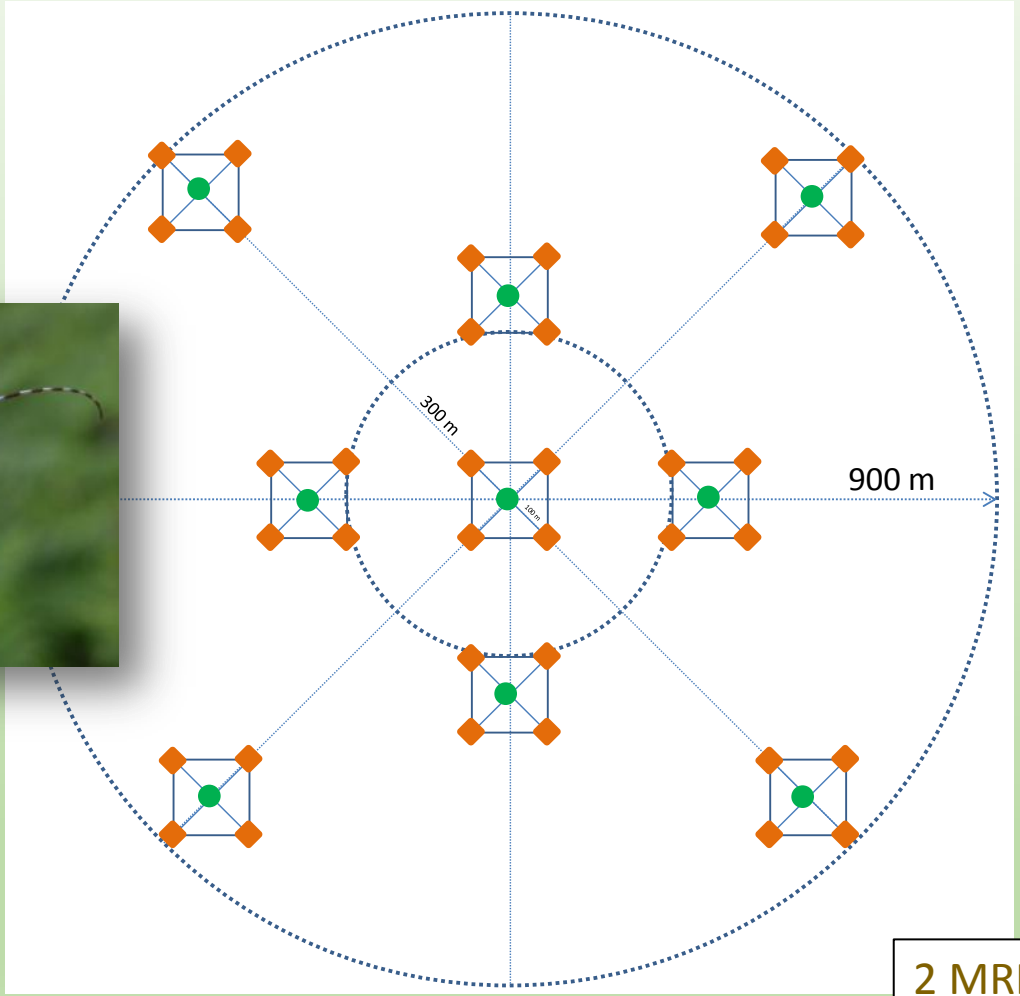
- Trap
- Release point



36 pheromone traps (9 clusters of 4 traps)

2 MRR experiments:
- 500 immature beetles
- 3000 mature beetles

Mark, release and recapture experiment was simulated

Mark, release and recapture
experiment was simulated

→ Simulation of the beetles' dispersal and capture
given an attraction distance of the pheromone traps (100 m)

Mark, release and recapture
experiment was simulated

→ Simulation of the beetles' dispersal and capture
given an attraction distance of the pheromone traps (100 m)

8 outputs

- → release of matures & release of immatures
- → recapture rates & recapture times
- → intra & inter cluster

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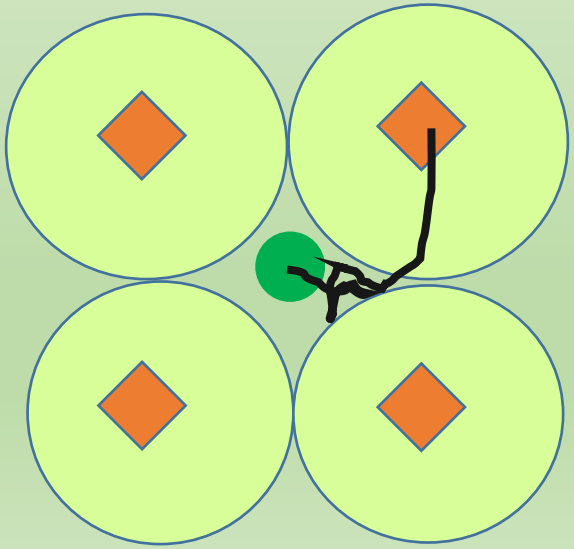
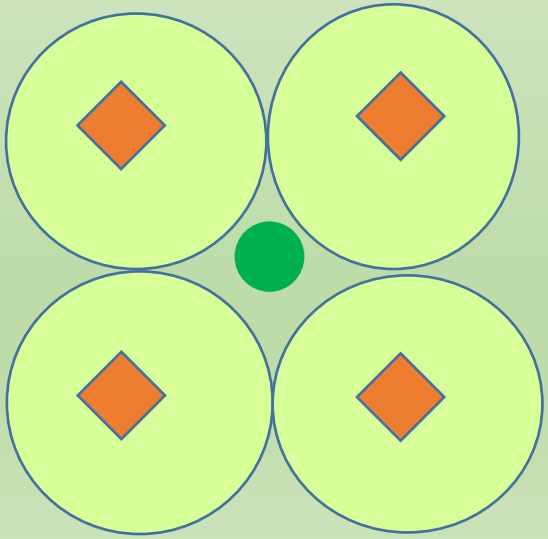
◆ Trap

● Release point

Capture intra-cluster





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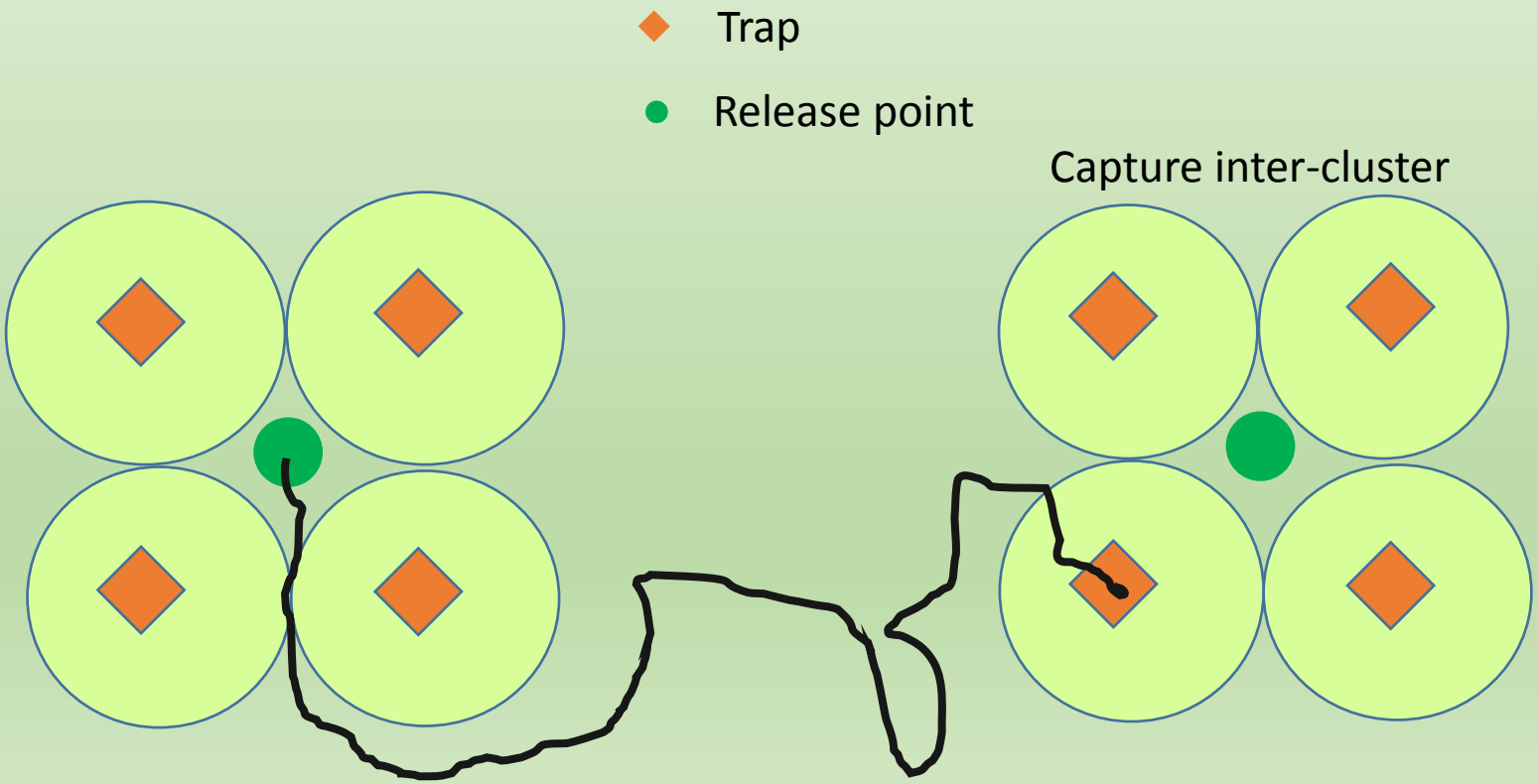

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→ Testing several parameters' values:

180 combinations

- → α = 500, 1000, 1500, 2000, 2500 m
- → *eff* = 0.5, 1, 2 %
- → *response time* = 4, 8, 12 days
- → *rest between 2 flights* = 0, 1, 2, 3 days

Mark, release and recapture
experiment was simulated

→ Simulation of the beetles' dispersal and capture
given an attraction distance of the pheromone traps (100 m)

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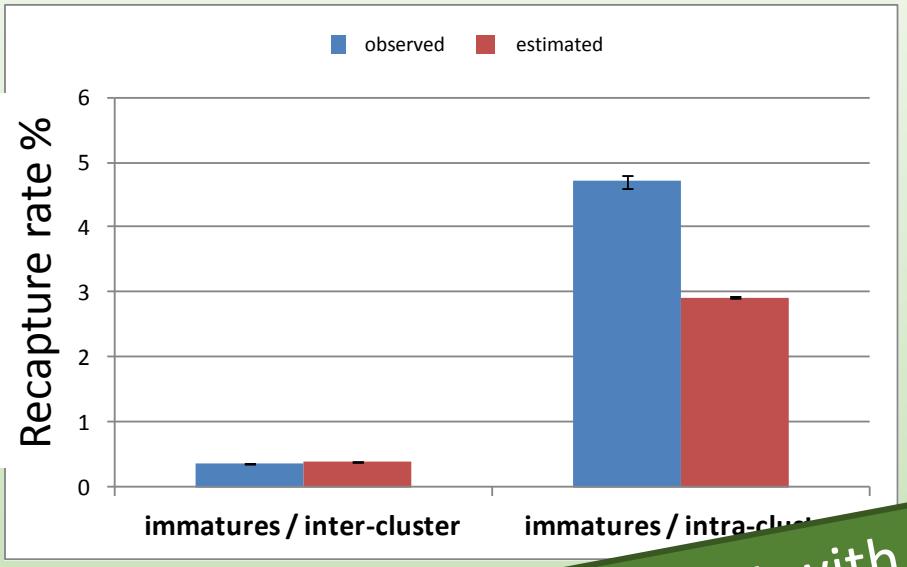
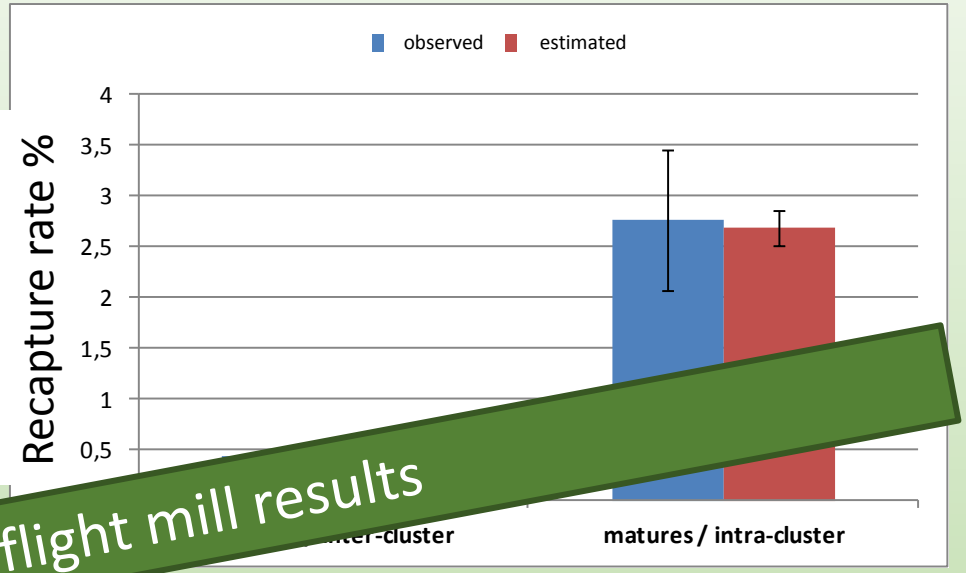
→ 2 estimators of the error:
- relative bias = |mean predicted - mean observed| / mean observed
- root mean square error: $\sqrt{[\text{mean (predicted value - observed value)}^2]}$

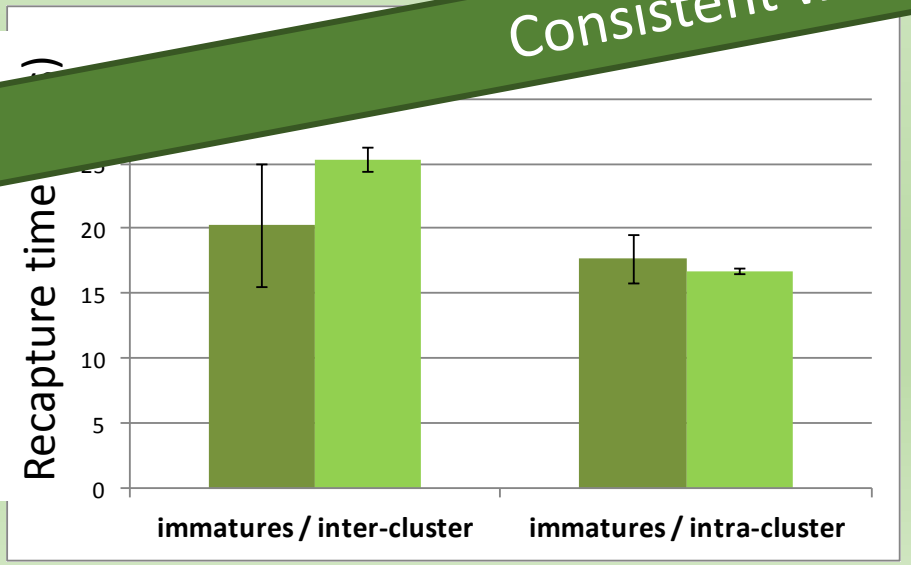
Multi-criteria analysis (PROMETHEE algorithm)
to determine the best combination

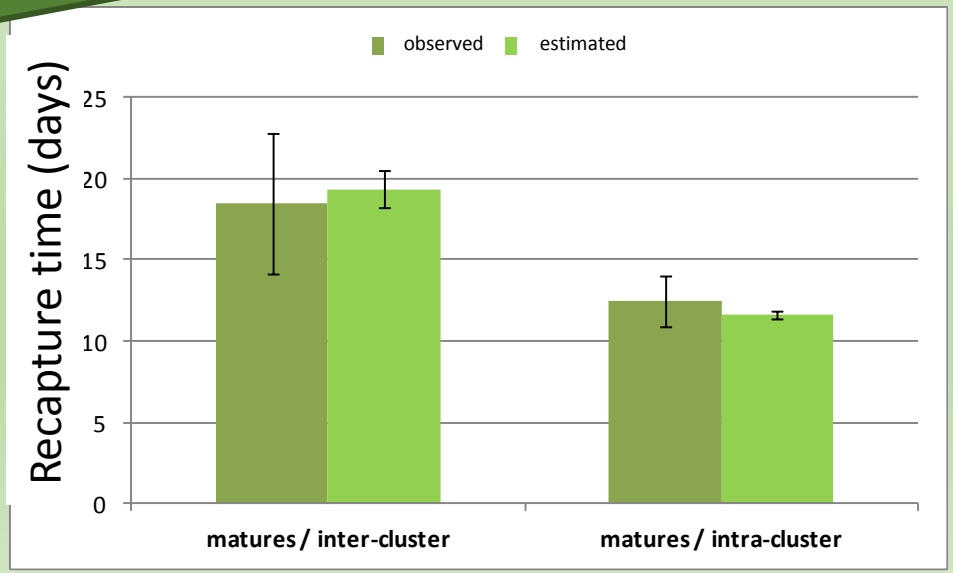
α = 2000 m / day; eff = 1 %; response time = 12 days (immatures) and 8 days (matures);
rest between 2 flights: 1 day





Consistent with flight mill results





The questions:
- Effectiveness of clear cutting?
- Optimal radius of the clear cut zone?

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- Effectiveness of clear cutting?
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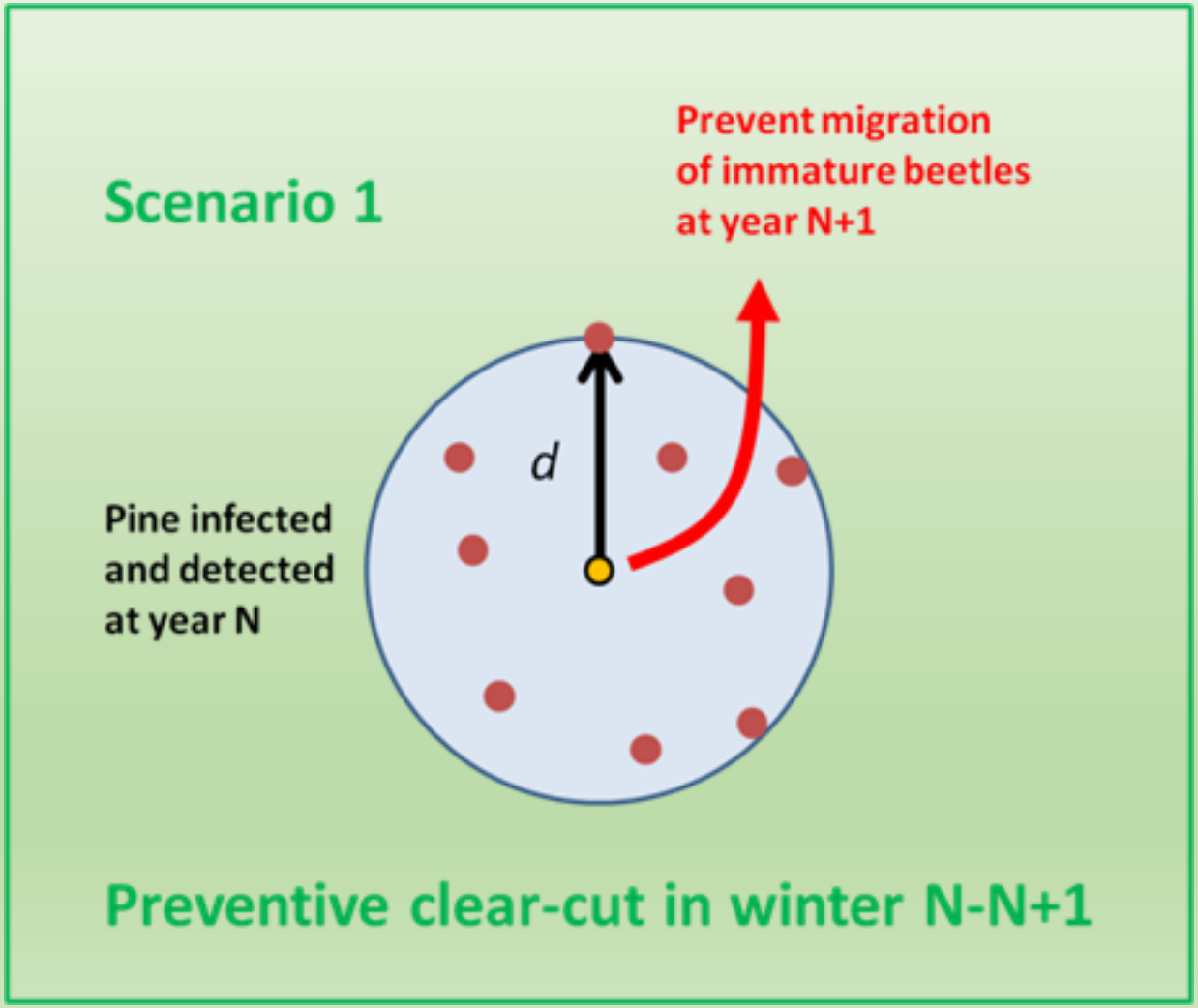
2 scenarios: 1- preventive scenario



The questions:
- Effectiveness of clear cutting?
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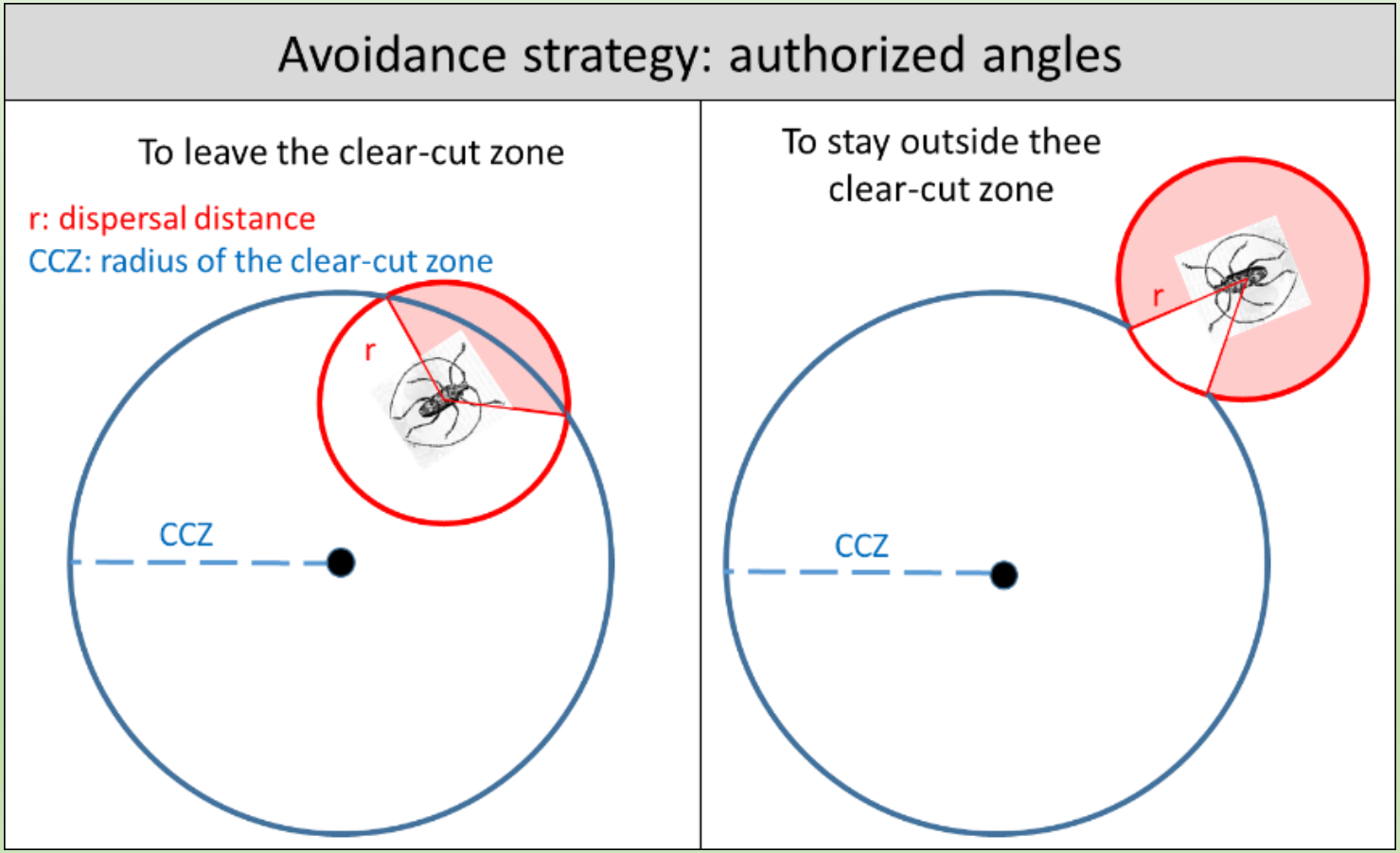
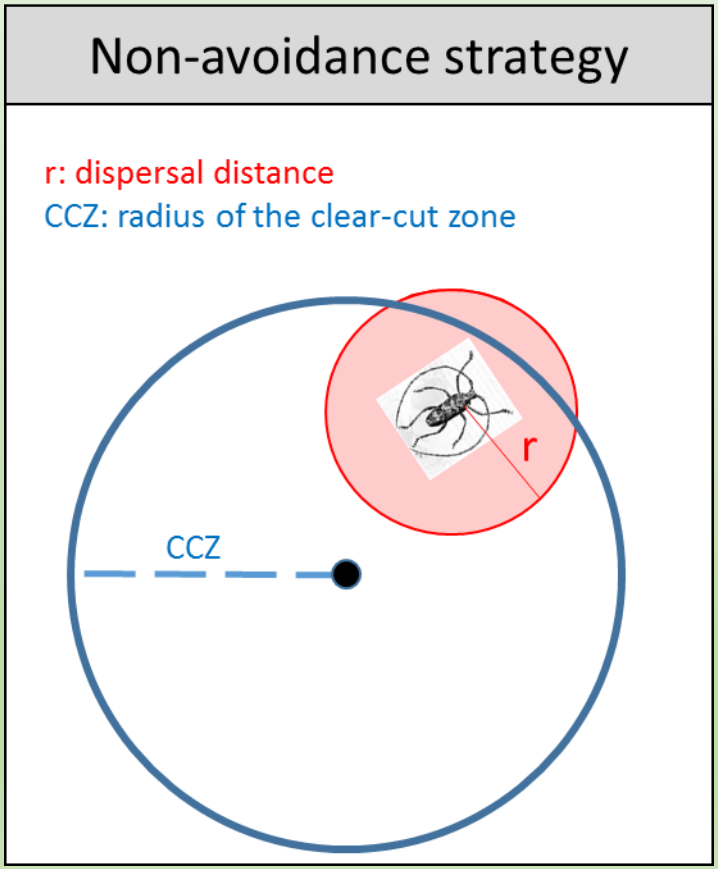
2 scenarios: 1- preventive scenario
→ 2 strategies: avoids the CCZ



The questions:
- Effectiveness of clear cutting?
- Optimal radius of the clear cut zone?

2 scenarios: 1- preventive scenario

→ 2 strategies: avoids the CCZ
or no effect of CCZ on flight behavior

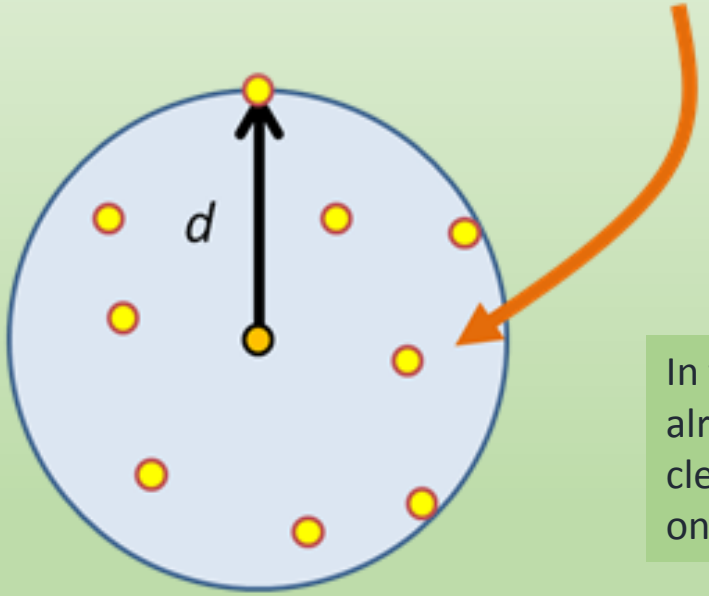


The questions:
- Effectiveness of clear cutting?
- Optimal radius of the clear cut zone?

2 scenarios: 1- preventive scenario
→ 2 strategies
2- curative scenario

Scenario 2

Destroy overlooked, asymptomatic trees in the surroundings of the detected infected tree



Pine infected and detected at year N

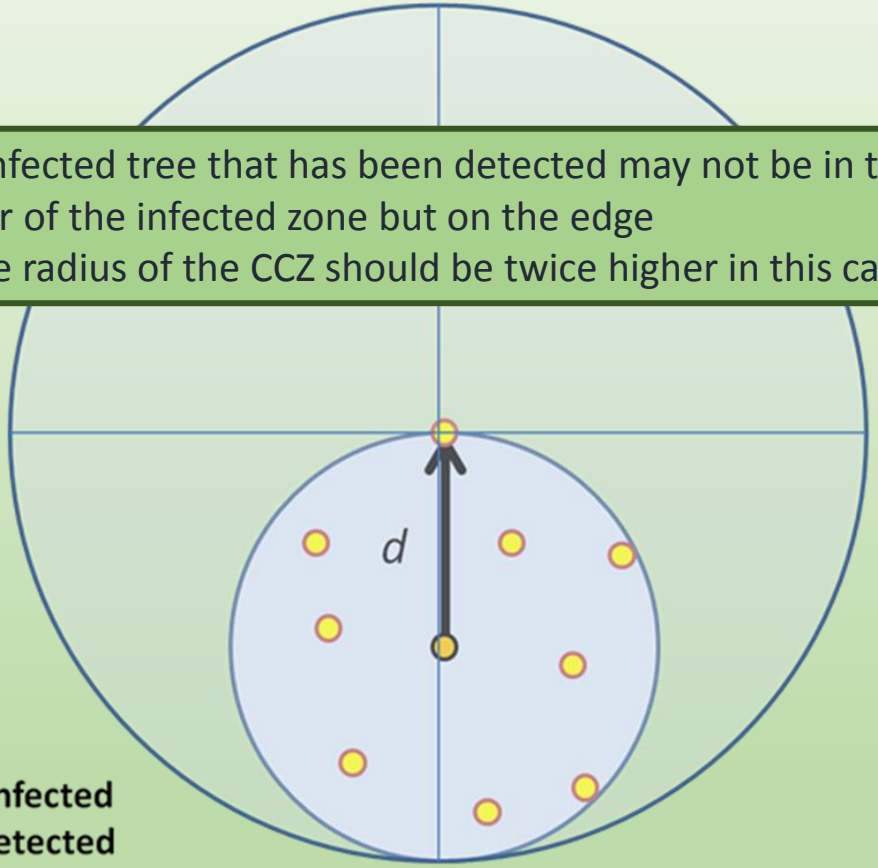
In this case, the beetles have already dispersed so the clear cutting has no effects on their dispersal behavior.

Curative clear-cut since detection of first infected tree

The questions:
- Effectiveness of clear cutting?
- Optimal radius of the clear cut zone?

2 scenarios: 1- preventive scenario
→ 2 strategies
2- curative scenario

The infected tree that has been detected may not be in the center of the infected zone but on the edge
=> the radius of the CCZ should be twice higher in this case.

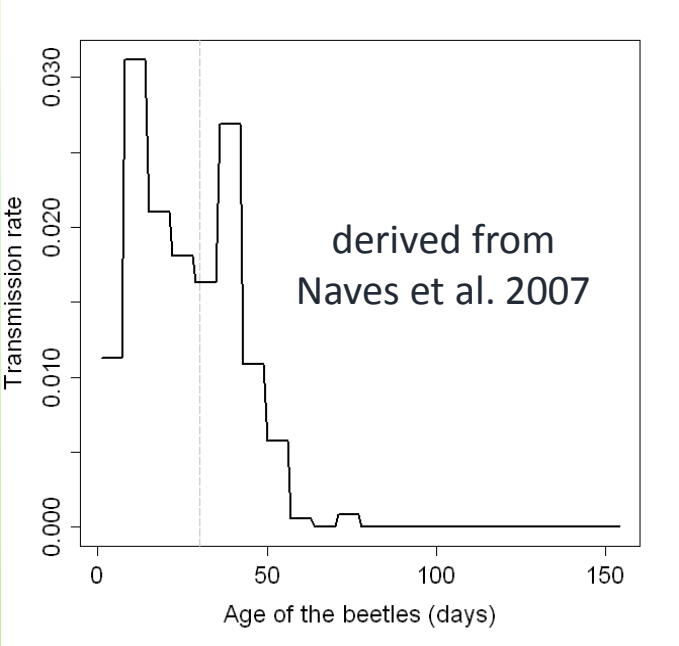


Pine infected and detected at year N

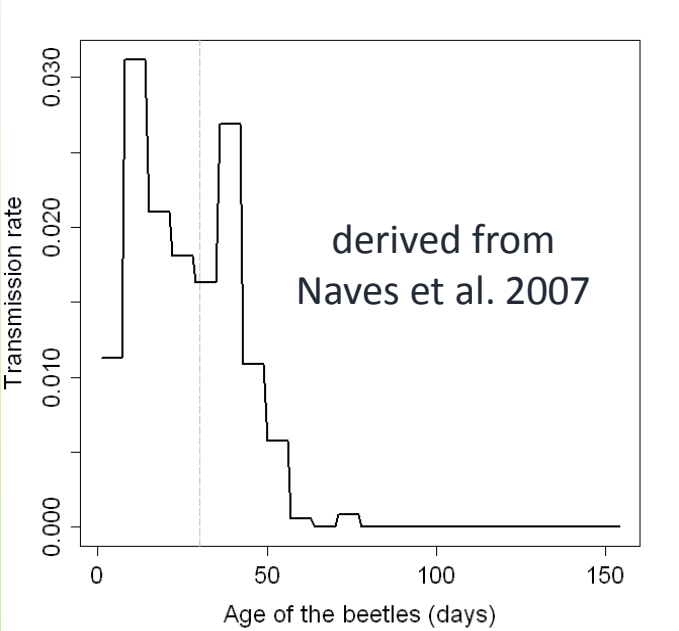
Destroy overlooked, asymptomatic trees in the surroundings of the detected infected tree

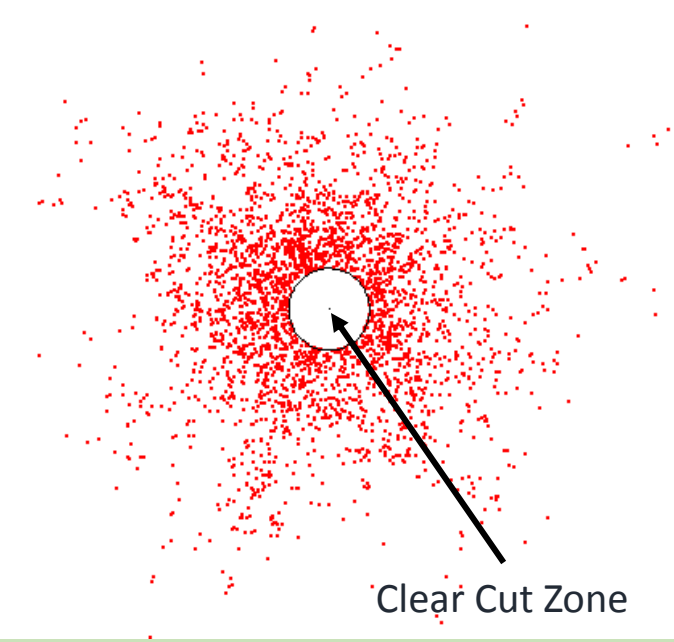
Curative clear-cut since detection of first infected tree

Simulating the PWN transmission along the trajectory of the infected beetle



Simulating the PWN transmission along the trajectory of the infected beetle



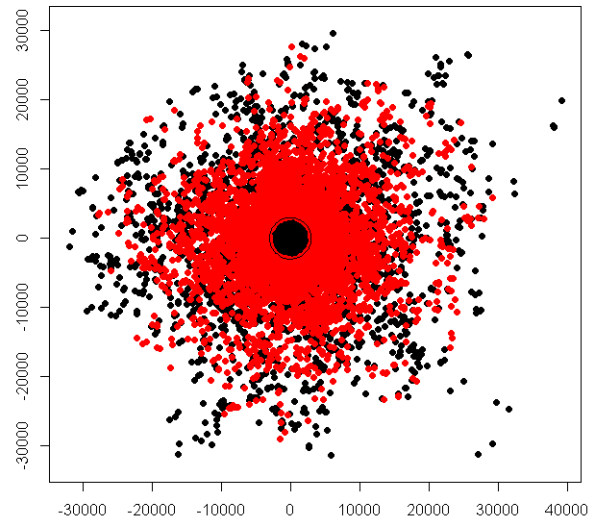


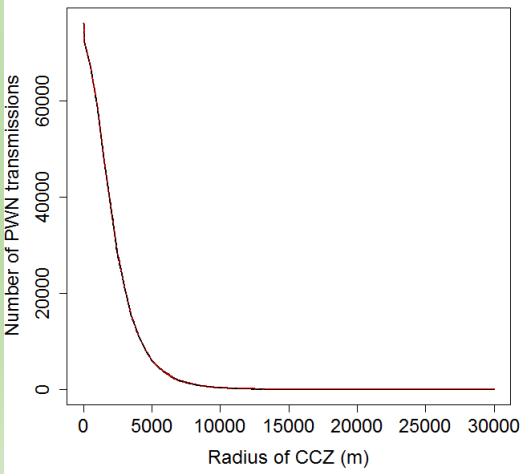
- Testing several radius values for the CCZ: 0 – 40 km
- Calculation of the number of transmissions outside the CCZ

Important assumption: dispersal was simulated in a non-fragmented pine forest (pines are present everywhere outside the CCZ)
Note that flight mill experiments and mark & recapture experiments were done in the forest of maritime pines in Les Landes (non-fragmented pine forest)

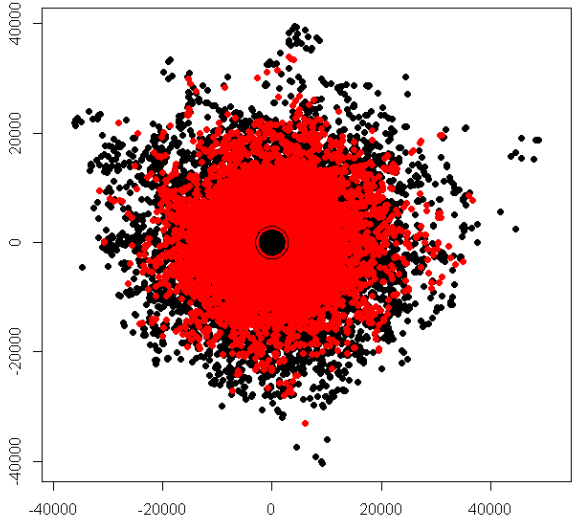
Model outcomes for the PWN transmission (example CCZ radius = 3000 m)

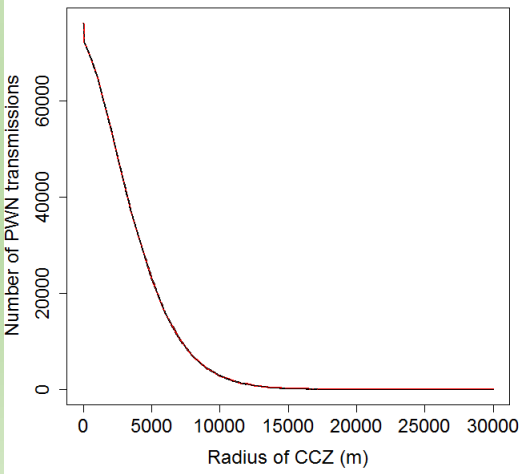
Scenario 1a
Preventive – non avoidance



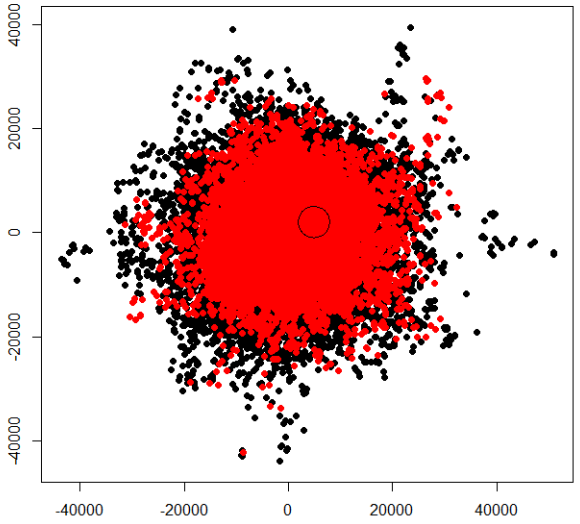


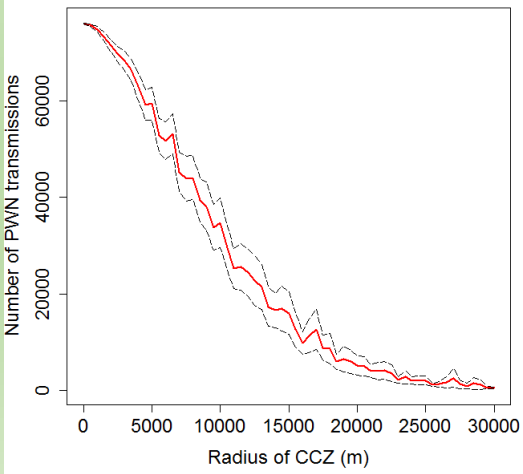
Scenario 1b
Preventive – avoidance





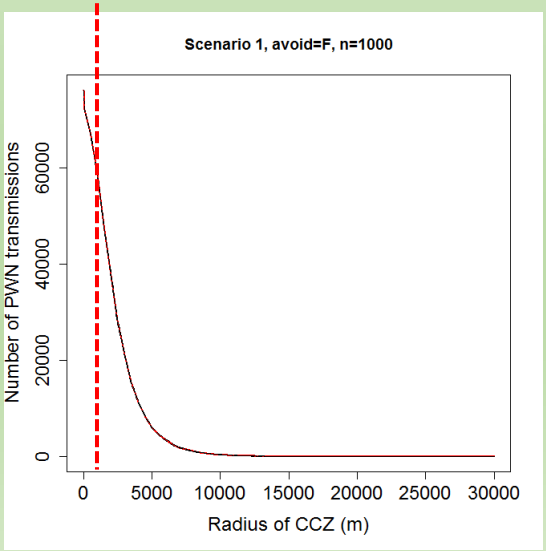
Scenario 2
Curative

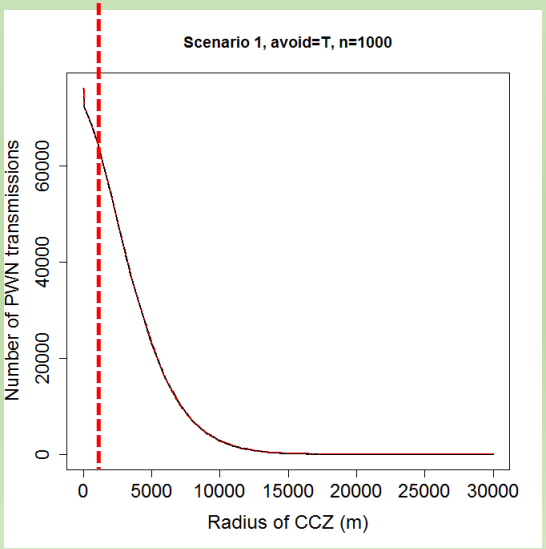


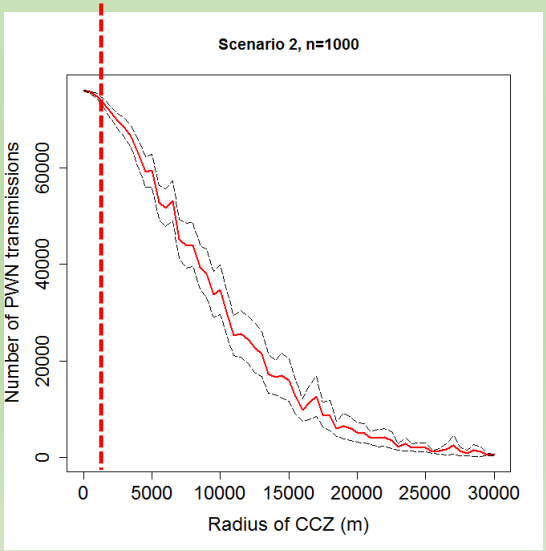


Avoided PWN transmission with a CCZ radius = 500 m (1000 emerging insects)

Scenario 1a Preventive – non avoidance	Scenario 1b Preventive – avoidance	Scenario 2 Curative
11 % avoided transmissions	9 % avoided transmissions	< 1 % avoided transmissions
500 m	500 m	500 m







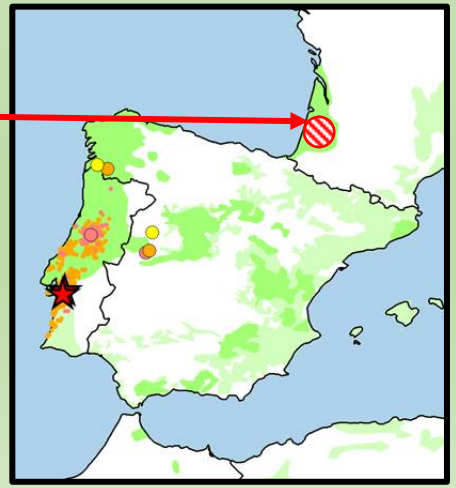
Recommended radius for the CCZ with a probability of 99.9 % of eradication

Scenario 1a Preventive – non avoidance	Scenario 1b Preventive – avoidance	Scenario 2 Curative
R = 14.5 km (± 0.5)	**R = 17.5 km (± 1.0)**	**R = 38.0 km** (± 1.5)

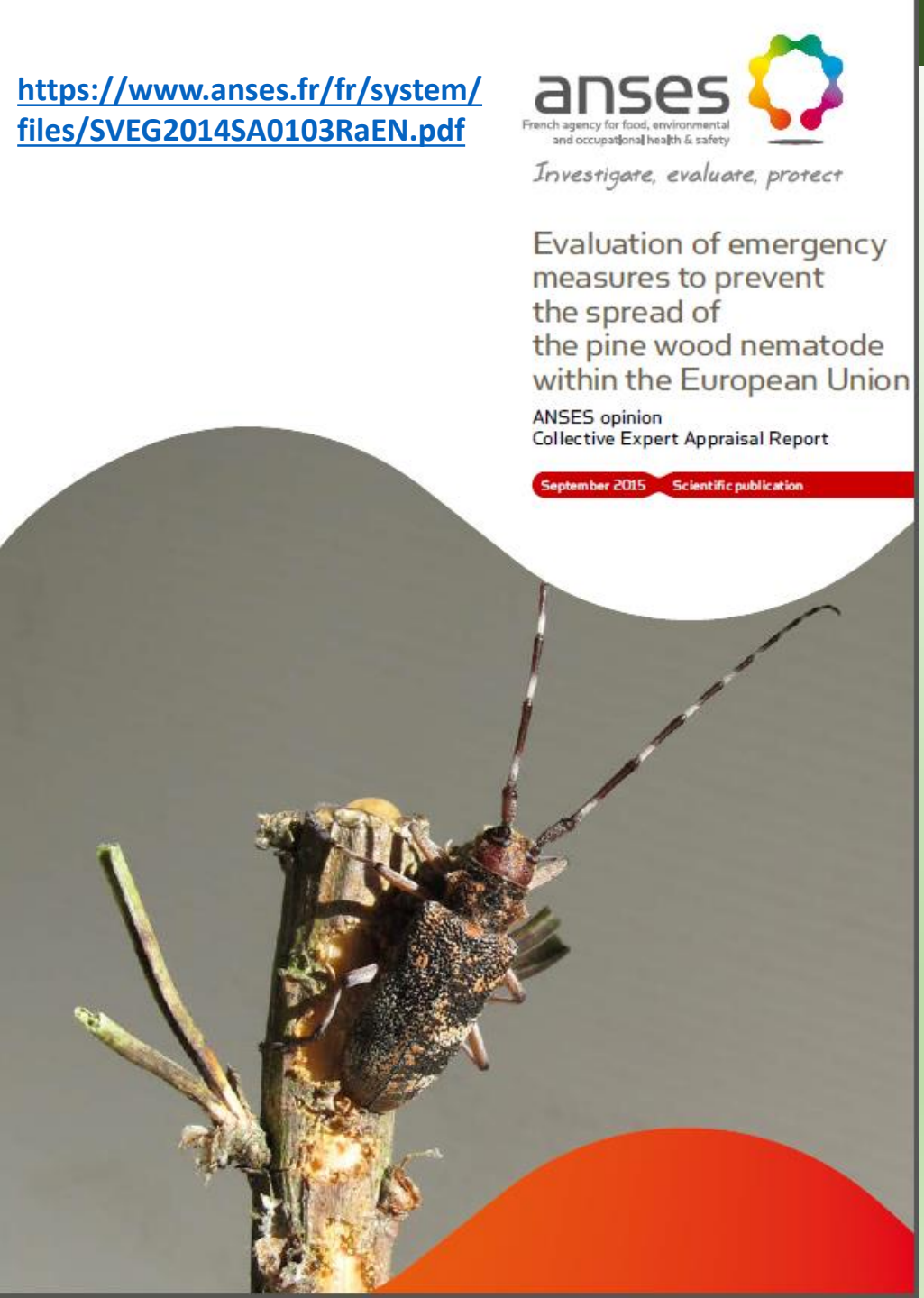
A clear-cut zone of 40 km ?

Not technically and ethically realistic ….

= 50% of Les Landes



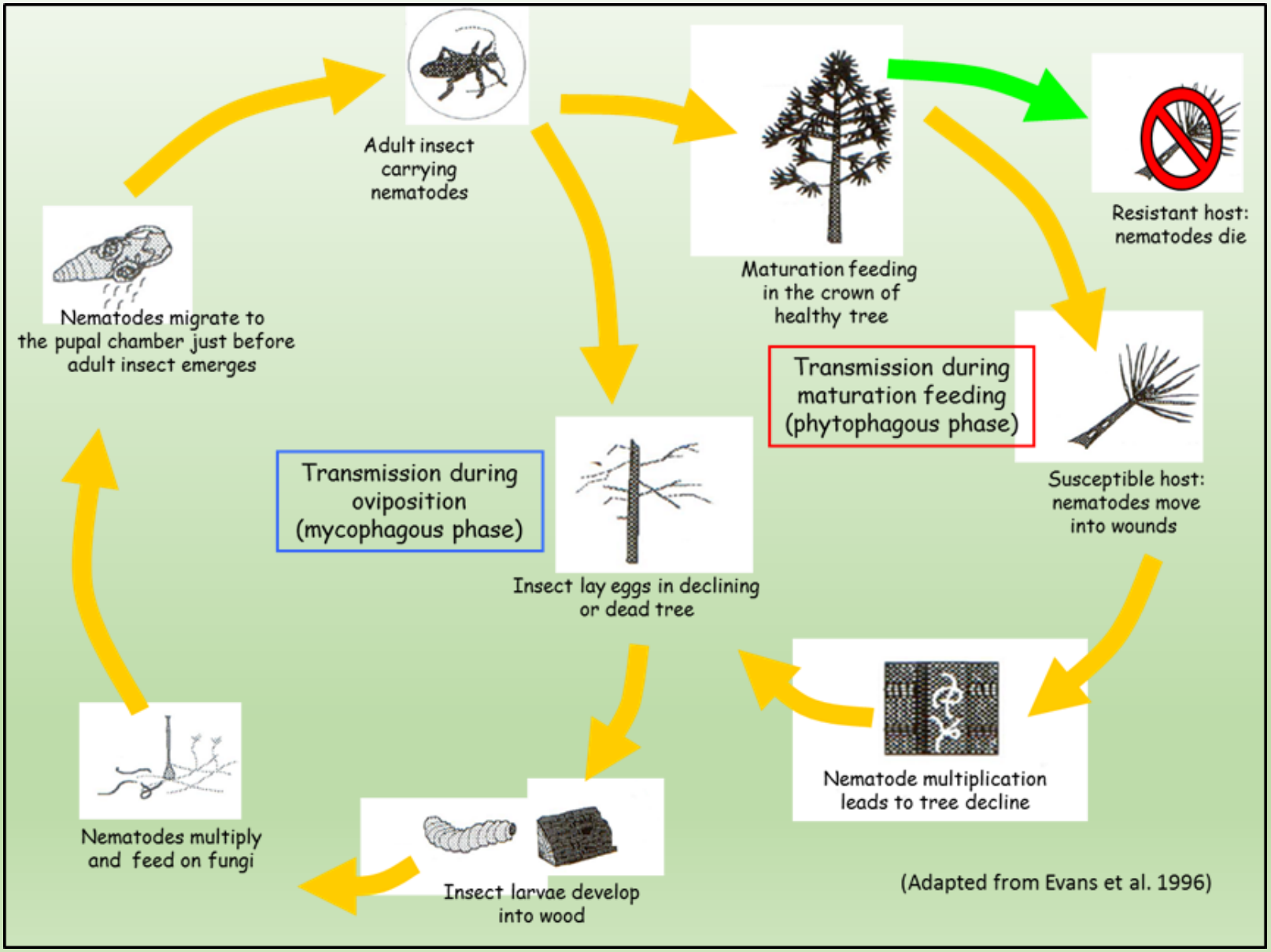
https://www.anses.fr/fr/system/files/SVEG2014SA0103RaEN.pdf



THANK YOU

This study was supported by :
- ANSES
- European Union, project REPHRAME

Thanks for your attention


Adult insect carrying nematodes
Maturation feeding in the crown of healthy tree
Resistant host: nematodes die
Transmission during maturation feeding (phytophagous phase)
Susceptible host: nematodes move into wounds
Nematodes migrate to the pupal chamber just before adult insect emerges
Transmission during oviposition (mycophagous phase)
Insect lay eggs in declining or dead tree
Nematode multiplication leads to tree decline
Nematodes multiply and feed on fungi
Insect larvae develop into wood
(Adapted from Evans et al. 1996)