SMARTIES:

Surveillance and Management of multiple Risks to Treescapes: Integrating Epidemiology and Stakeholder behaviour

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JUNIPER workshop 10th June 2024
Warwick University

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ROTHAMSTED RESEARCH
WARWICK THE UNIVERSITY OF WARWICK
SEI Stockholm Environment Institute
Forest Research
UKRI Natural Environment Research Council

Aim:
To elucidate the key epidemiological and behavioural factors that govern the invasion and spread of threats to tree health and so determine how to develop successful surveillance

Photo by Vasthi Alonso Chavez

EAB characteristics

- EAB lay eggs in bark crevices on ash trees
- Larvae burrow through and create serpentine galleries beneath the bark
- This disrupts the flow of water and nutrients to parts of the tree, causing them to wither and die.
- Adults exit leaving a characteristic D-shaped hole
- Adults fly short distances and colonies other ash trees
- They can spread further through “hitch hiking”

EAB surveillance methods

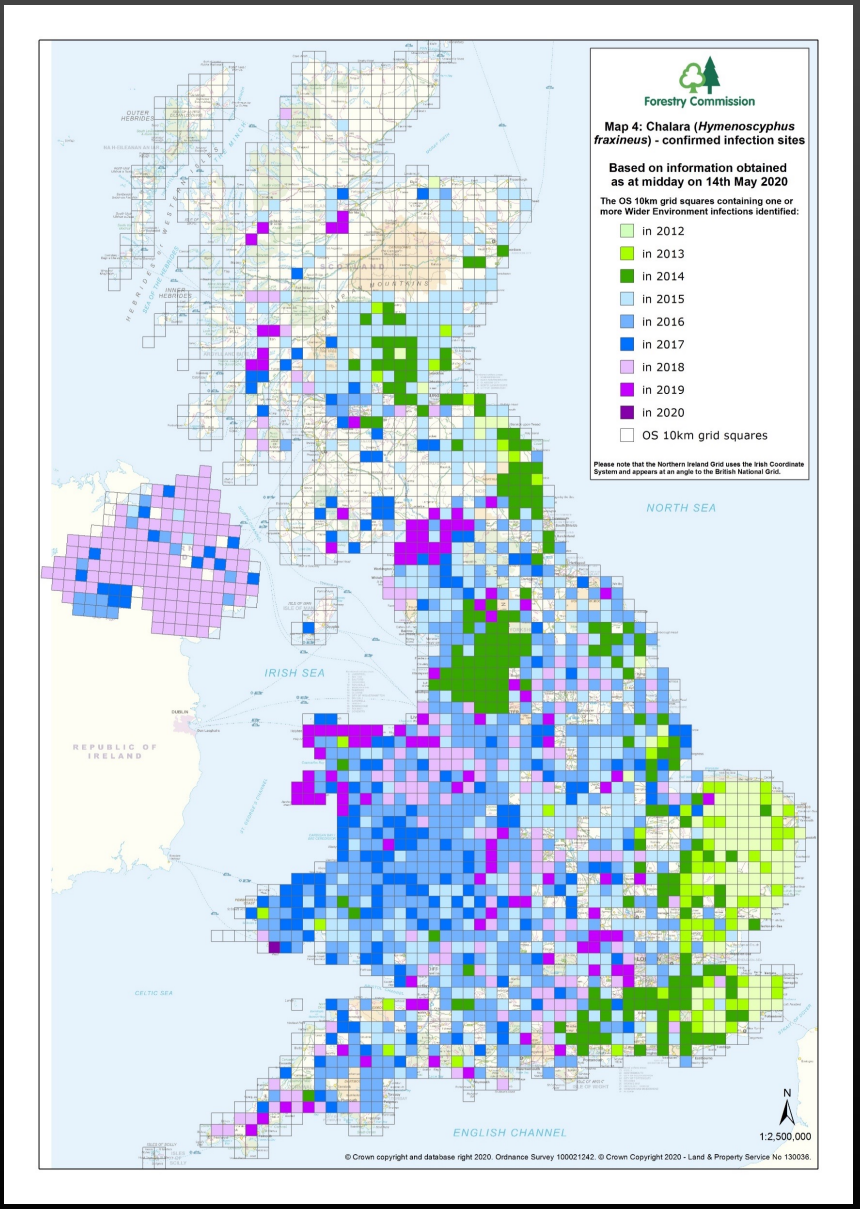
Traps

Girdled tree

- It is essential to detect the pest early so that it can eradicated or more effectively managed
- This requires sound surveillance strategies and **land manager buy-in!**

EAB is not the only threat to European ash

- Symptoms of ash dieback (ADB) disease were first noticed in Poland in the early 1990s.
- The causal agent of the disease is the ascomycete fungus *Hymenoscyphus fraxineus*.
- By the time the pathogen had been identified, it had already spread across much of Europe. It was officially detected in GB in 2012.



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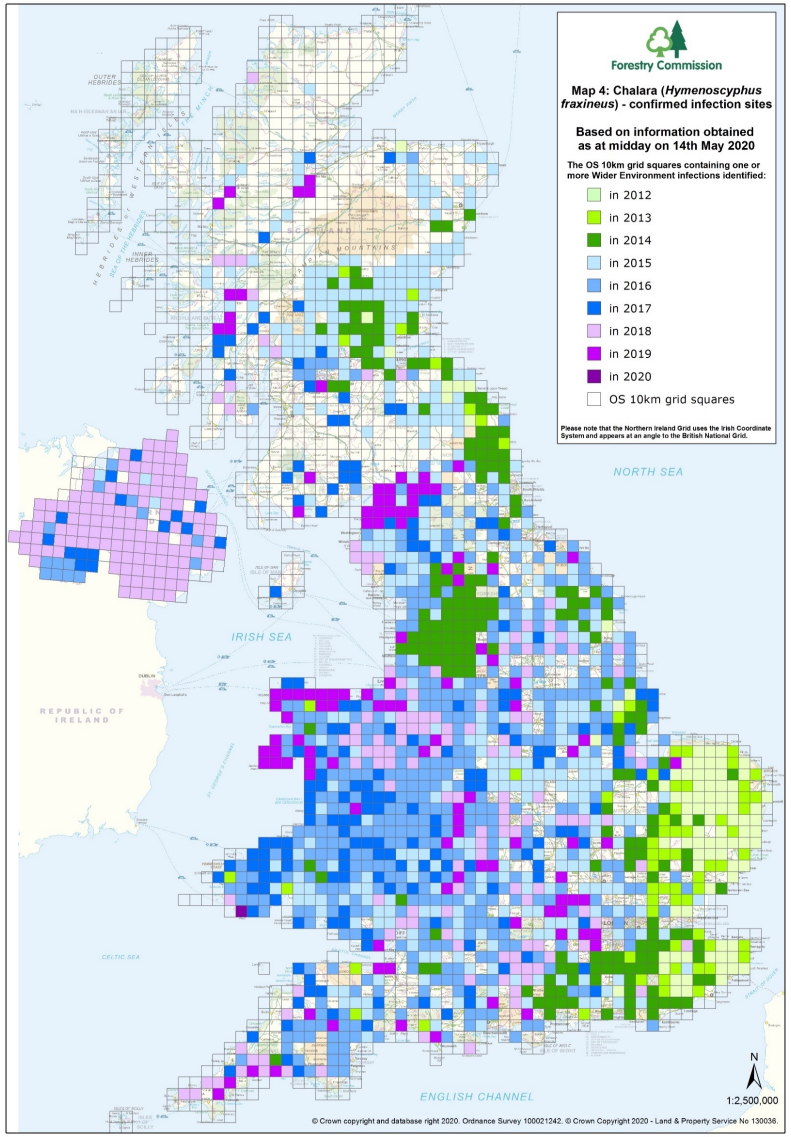
To understand the impact of EAB, we must understand its interaction with ADB



The Plan!

1. Develop a mathematical model on the current range of ash dieback, the potential spread of EAB and the interaction between the two.

2. Develop a model on social values and acceptability of surveillance and management as a response to ash dieback and EAB.

3. Link the two models to elucidate the factors that lead to successful surveillance and management of EAB and ADB

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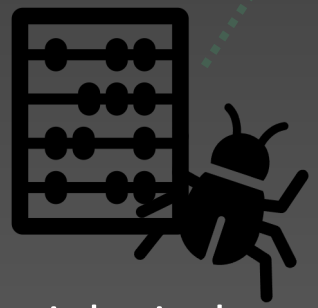

Epidemiological Modellers

Social scientists

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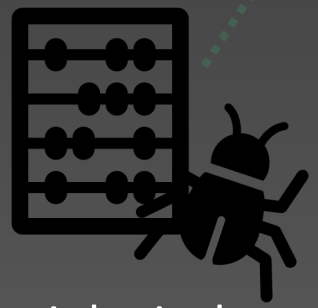


Epidemiological modellers

3. Link the two models to elucidate the factors that lead to successful surveillance and management of EAB and ADB

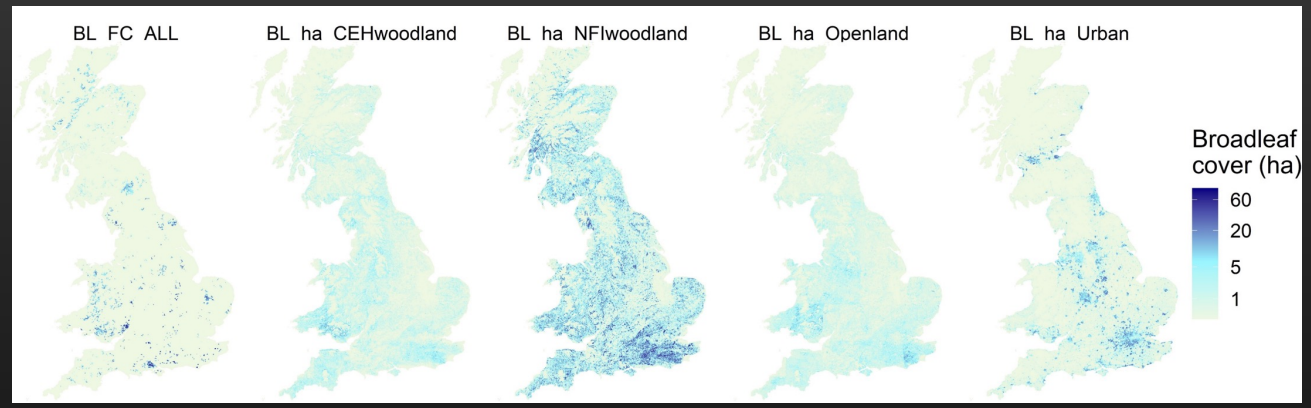
Social scientists

Epidemiological modellers and social scientists understanding each other

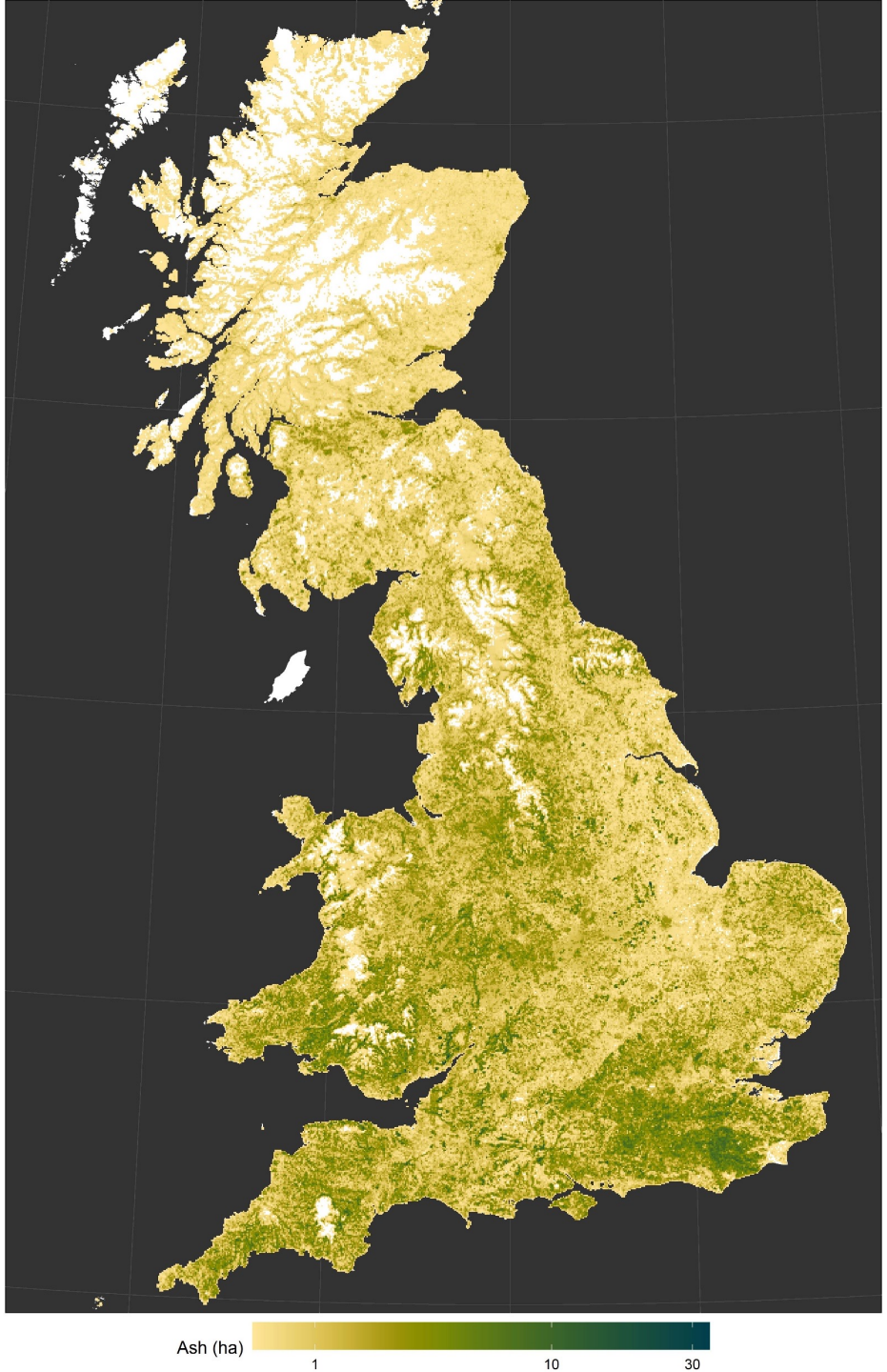
The epidemiological model

Ash distribution map

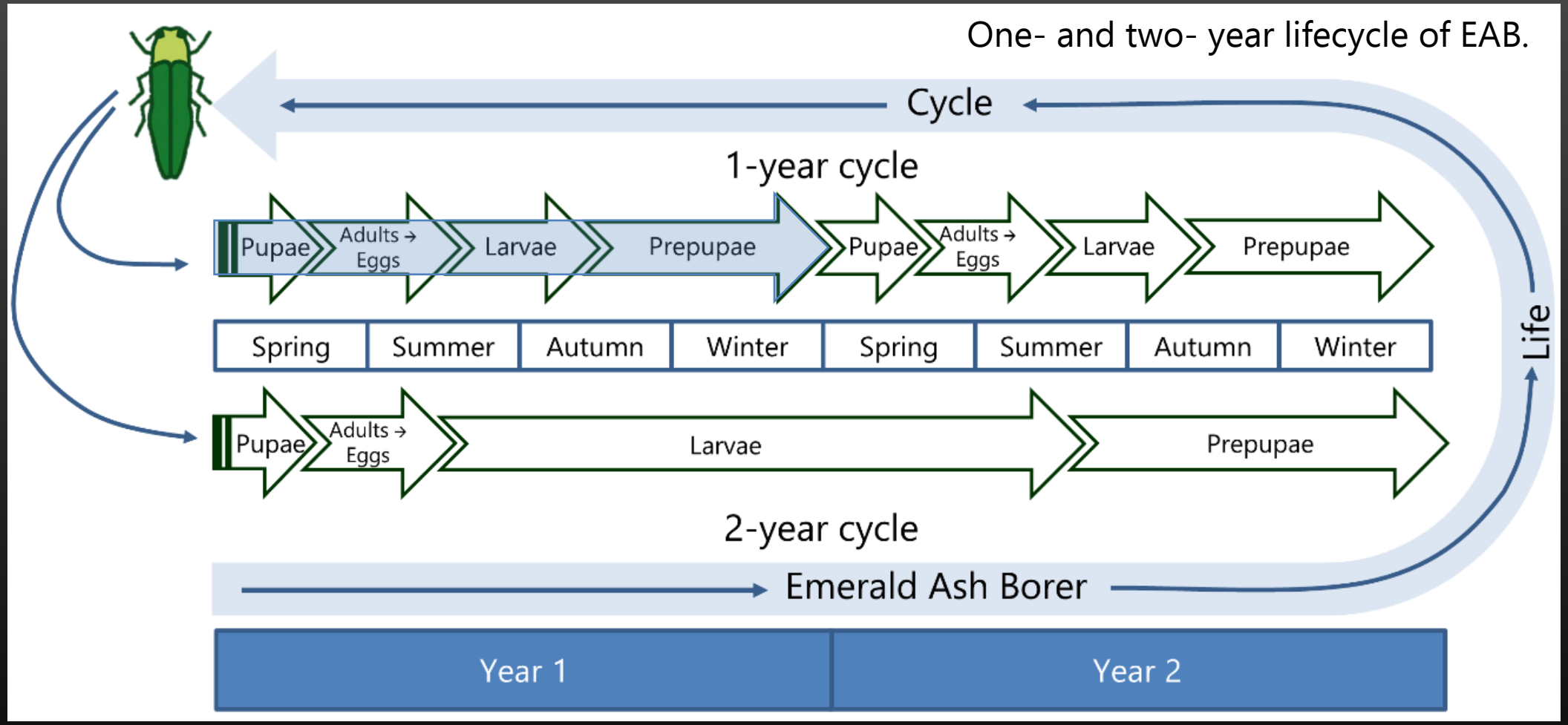
Maps of tree cover in different land uses



Combine with regional estimates of ash abundance in various settings



EAB model: Population dynamics per tree

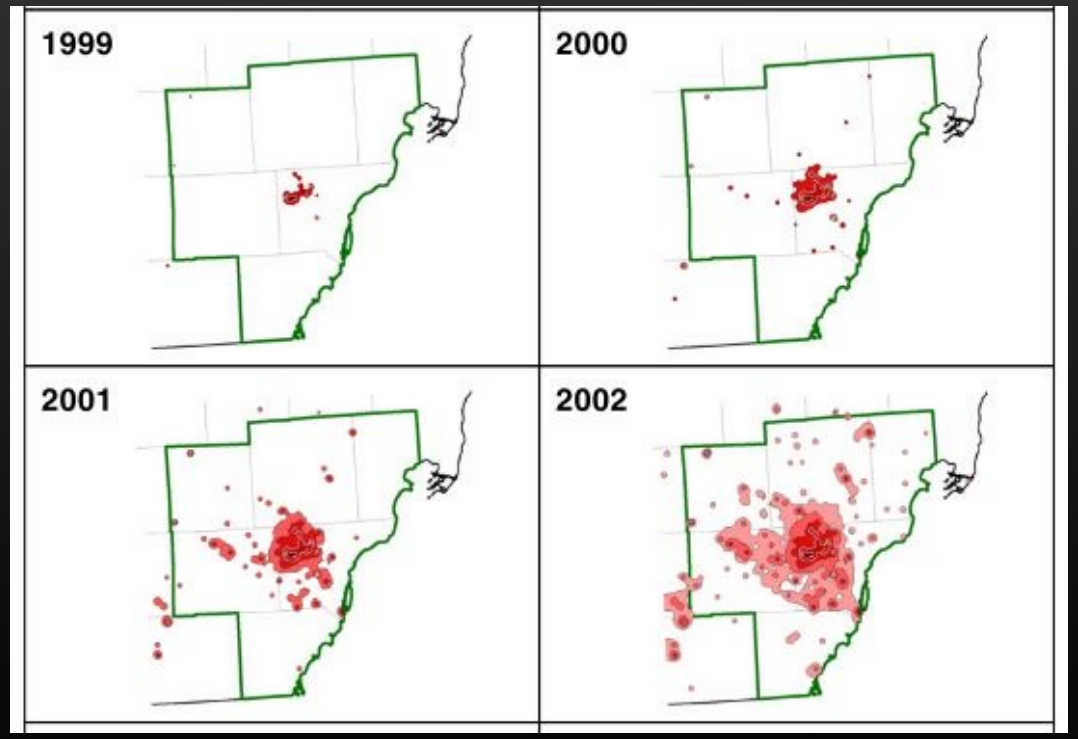


A_n = number of adult EAB in year n
$L1_n$ = number of one year EAB Larvae in year n
$L2_n$ = number of two EAB Larvae in year n

σ = probability of death before reproduction
k = number of eggs produced
β = rate of larval death per year
γ = density dependent death rate
θ = proportion of first years that become adult

EAB model: Dispersal model

- Data from the US were used to parameterise the stochastic dispersal kernel.
- Natural dispersal is short range, but EAB are good hitch hikers!



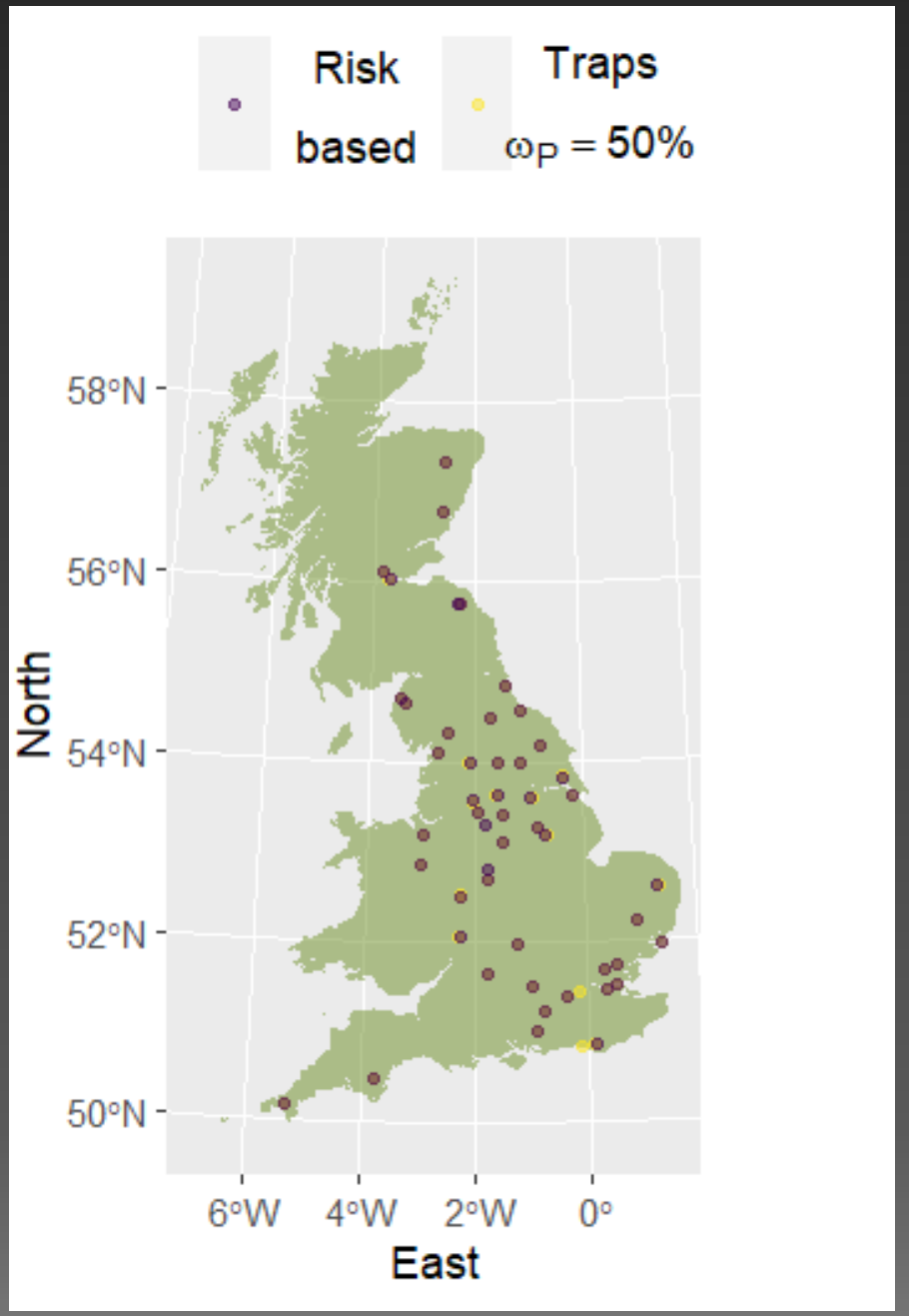
Maps from Siegert et al 2014

Ash dieback model

- Modelled with a compartment model
- Depends on soil and weather variables
- Increases density dependant mortality (EAB population dynamics model)
- ADB may influence attraction of EAB to trees
- Influences land manager behaviour (social dynamics model — see later!)

Models used to derive optimised locations of traps under various scenarios

Key finding: because EAB spreads very slowly risk based-sampling is near optimal for very early detection



The social model

The social model

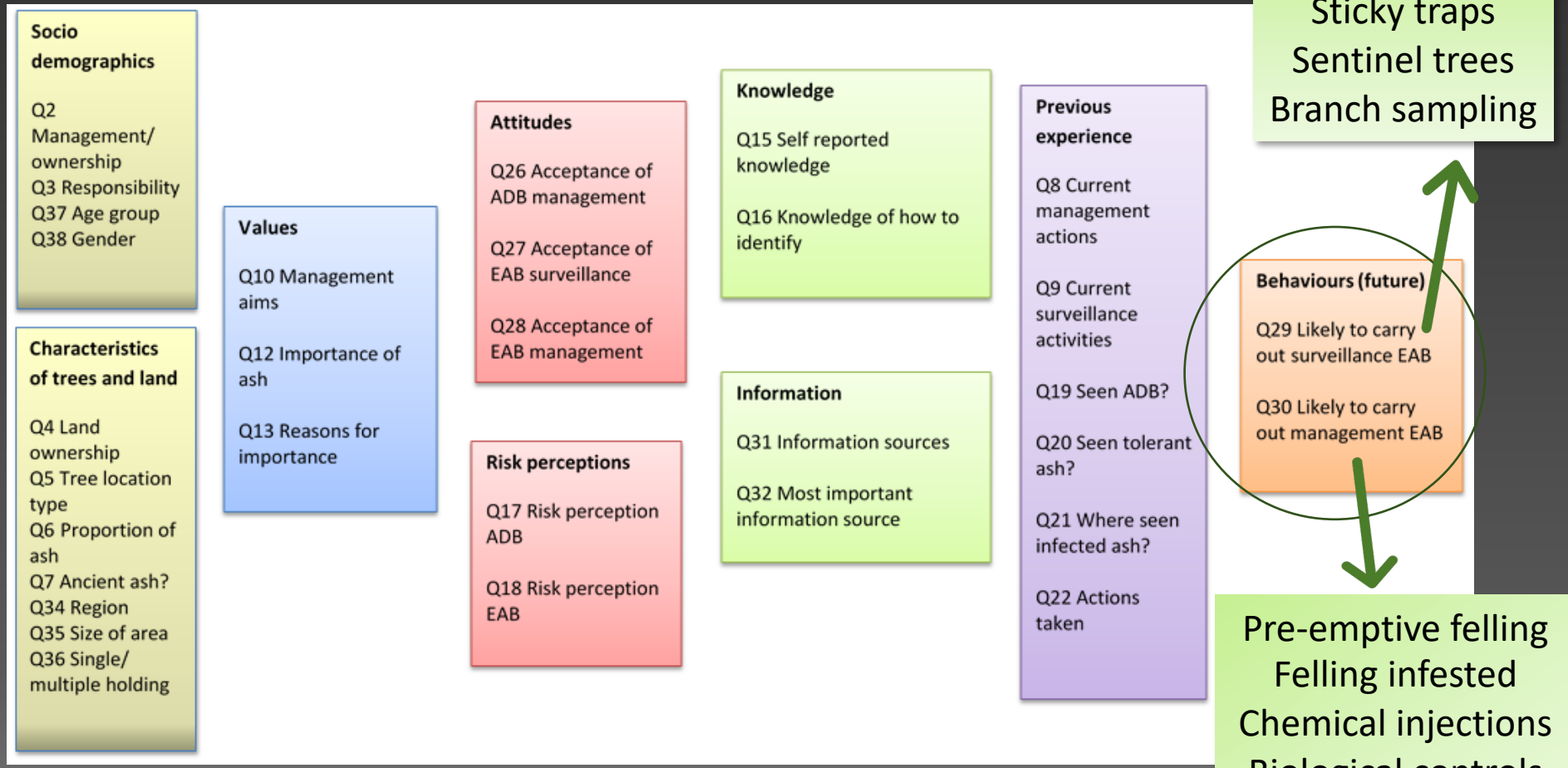
- Evidence review
- Questionnaire
- Interviews
- Deliberative workshops

Evidence Review

- **VALUE:** Emotional impacts of losing ash trees to a pest or disease can determine behaviours and management decisions.
    - The cultural importance of ash trees revealed through art, folklore, mythology, and place names.
    - Ash trees have wide social and environmental value to landscape character, biodiversity, timber uses and cultural practices.
- **RISK PERCEPTIONS** of ADB and EAB vary between stakeholders.
- **HEALTH AND SAFETY** is important where diseased trees pose a hazard, particularly along transport routes and in public spaces.
- Some land managers act against advice for ADB management, perhaps through **LACK OF INFORMATION**.
- **PREVIOUS EXPERIENCES** with other pests and diseases are likely to influence decisions about tree health management.

Questionnaire with land managers and decision makers

What influences the likelihood that land managers will carry out surveillance & management for EAB?



Framework for the questionnaire

Questionnaire with land managers and decision makers

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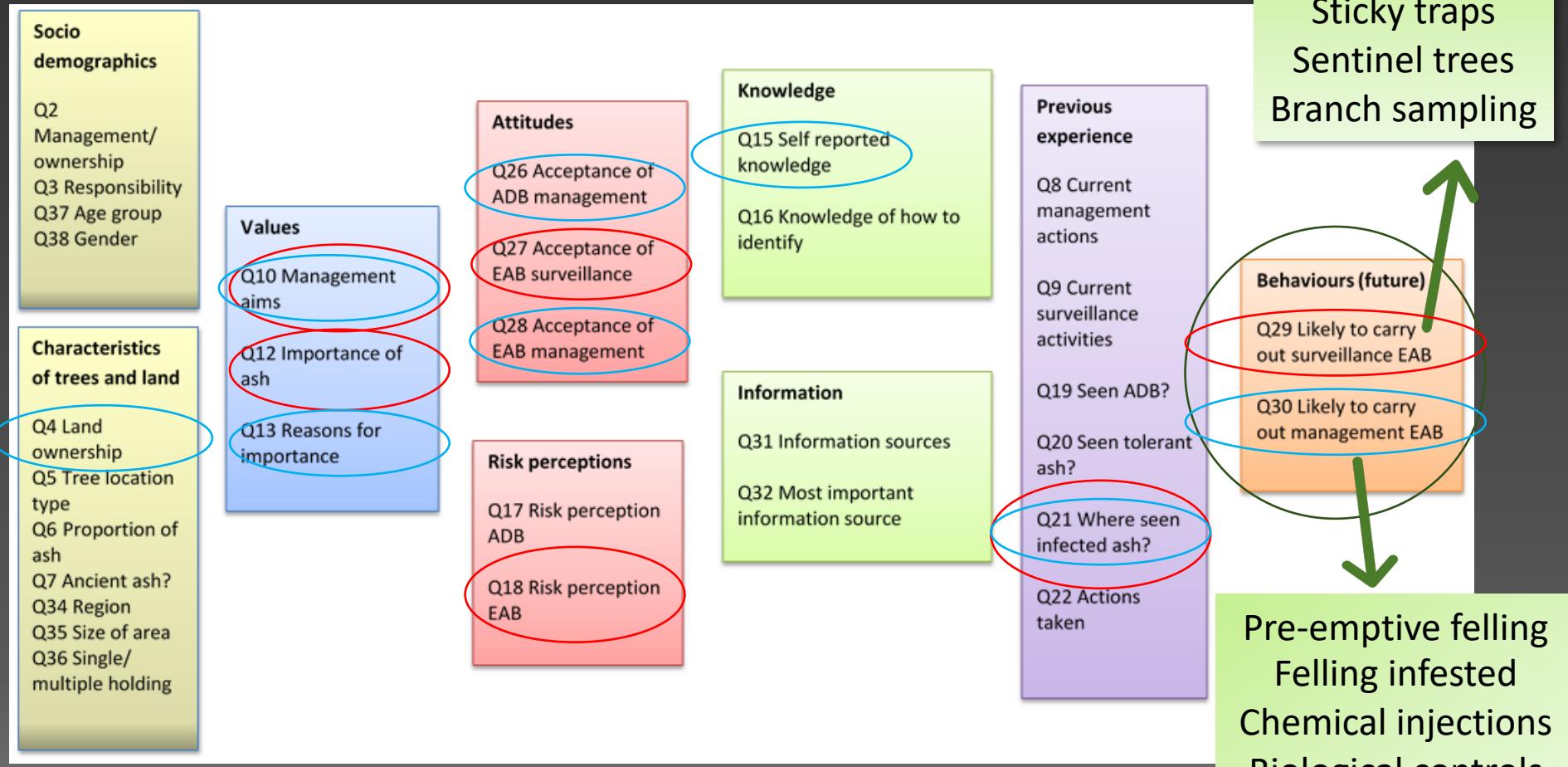


Framework for the questionnaire

Stakeholder interviews

- Knowledge of ADB high
- Little pre-existing knowledge of EAB but interest in knowing more.
- Remaining ash trees more valuable
- Tended to default to familiar actions based on ADB experiences
- Would want to understand costs and benefits of different approaches.

…there have been a few articles on the concerns about importing tree diseases and there were several mentioned for pine and perhaps for ash as well, but I didn't make a big mental note of it to be honest with you

Obviously everybody has a say and wants to voice an opinion. But having said that, most people…once it's explained to them do understand. So I think possibly ash dieback is part of the general consciousness.

so I suggest [the local authority] will keep monitoring ash dieback. I see no reason why…we would not actually just monitor to see whether there's any evidence of invasion by emerald ash borer. I think we'd probably assimilate it into that survey activity.

Image Debbie Miller, USDA Forest Service, Bugwood.org

Workshop: reflections on surveillance

Although there's plenty of information on the actual beetle out there, there's not much information on what to do, and exactly what you're looking for

...once it's here, not much you can do - if one could effectively save the tree somehow, I'd be more keen on monitoring it

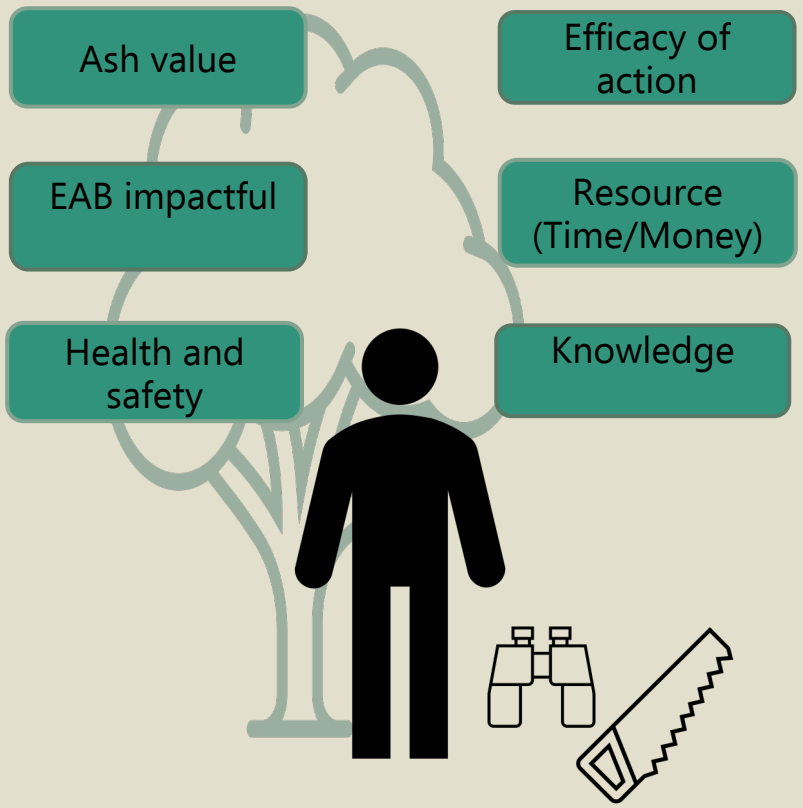
For a small organization with limited resources.. We certainly haven't done any proactive, but management work, and it's basically fire fighting really

I assume that Defra through Afa, etc. will continue diligently doing surveillance at points of entry.. I wouldn't ramp up my advice to my clients. I think. unless there was a confirmed UK outbreak

Girdling seems to be most effective – when we're managing large swathes of woodland we could quite easily afford to lose 5 ash trees per km2, and looking at these cost comparisons that would be my go-to

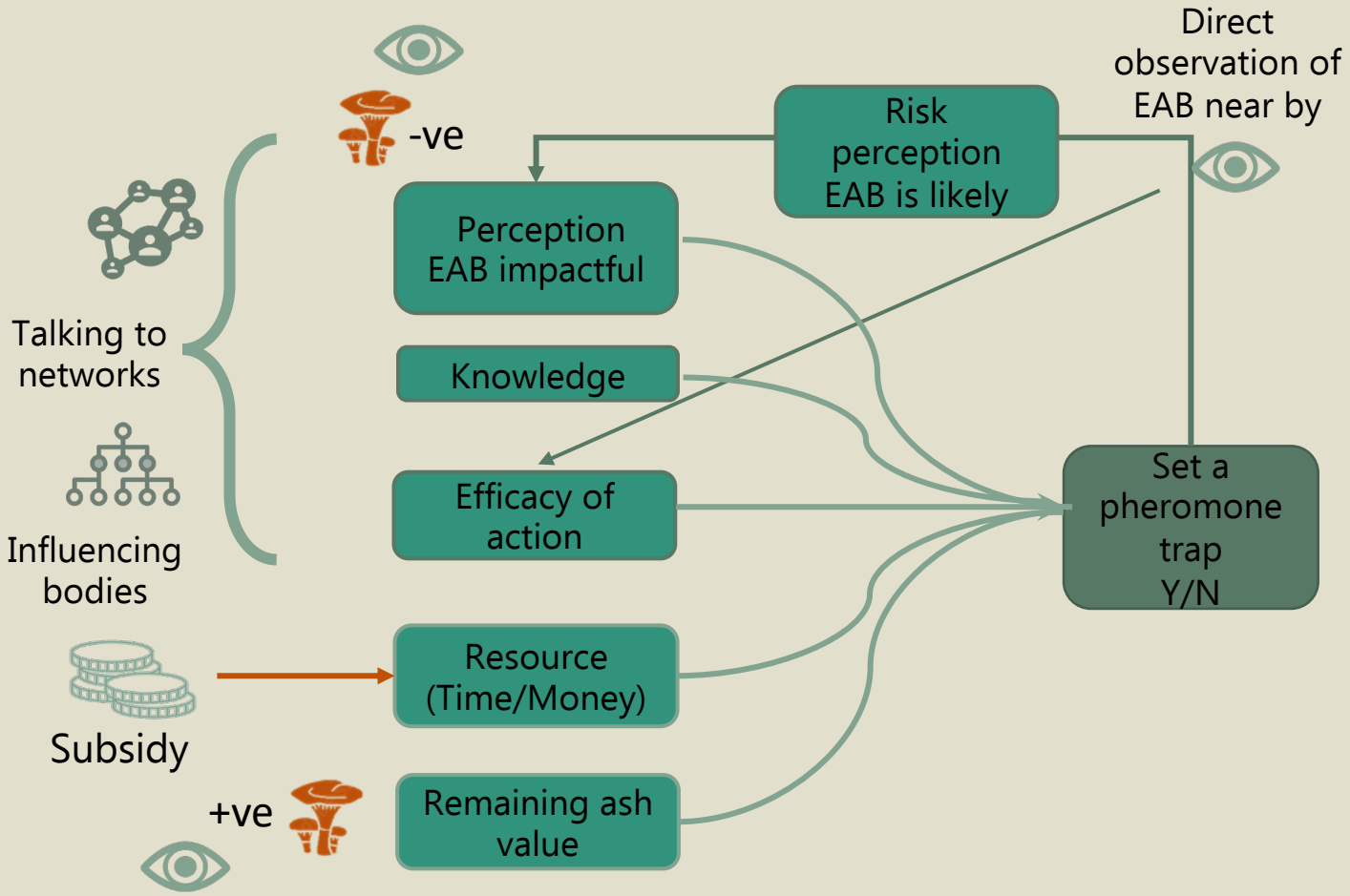
I'm not worried about it...probably not going to have very much ash left... Much more concerned about acute oak decline and oak processionary moth. They're already here

Stakeholder behaviour model (based on surveys, interviews and workshops)



- We use an agent-based approach with Opinion dynamics
- Each agent has a set of variables describing their perceptions of key factors of the decision
- These variables take a value between 0 and 1

Stakeholder behaviour model (based on surveys, interviews and workshops)



Model Dynamics

Perceptions of: Risk perception, knowledge and efficacy are updated by talking to networks and information from influencing bodies and direct observation,

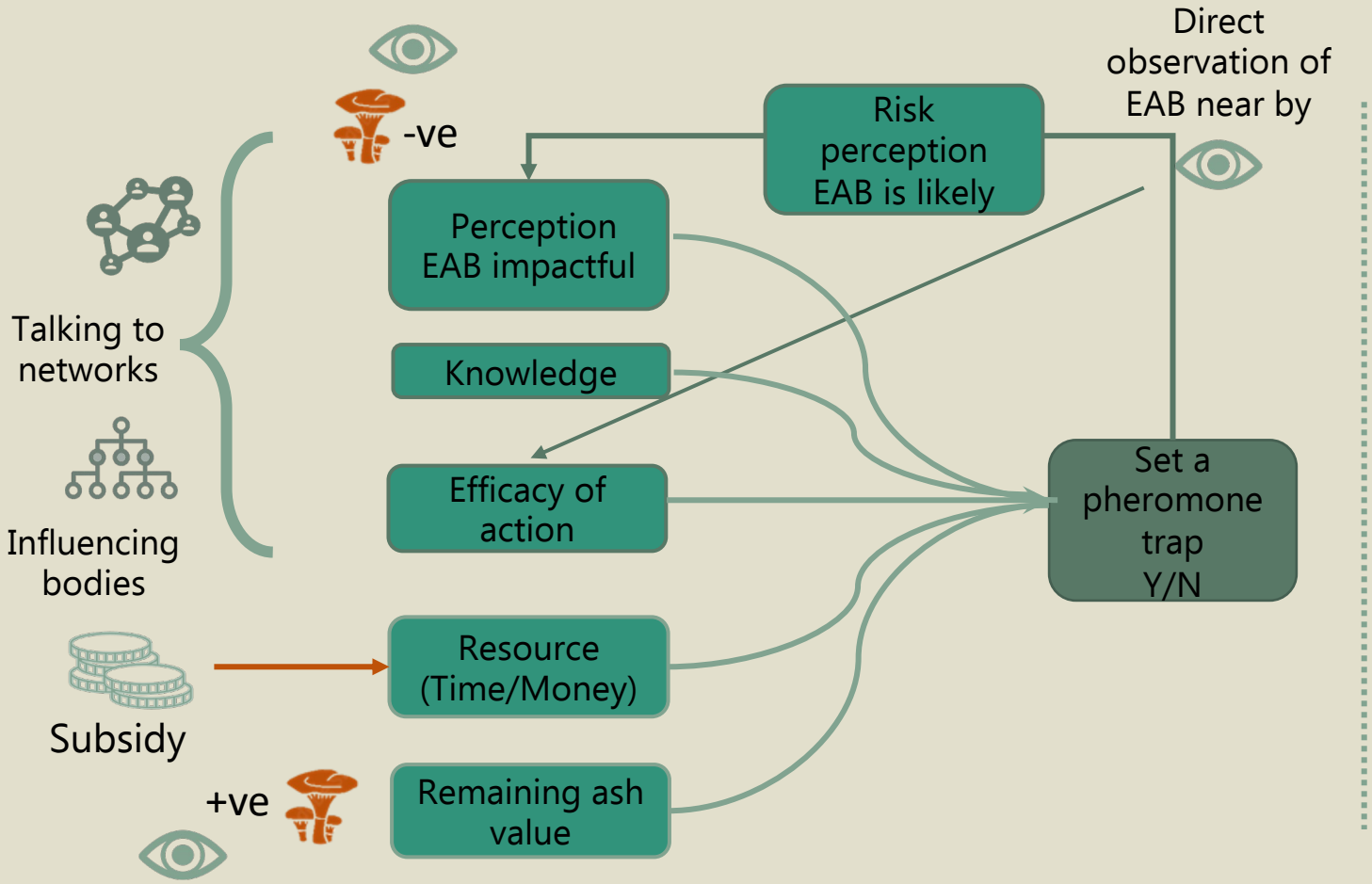
$$x(i,t+1) = \mathrm{M}(i)x(i,t) +$$

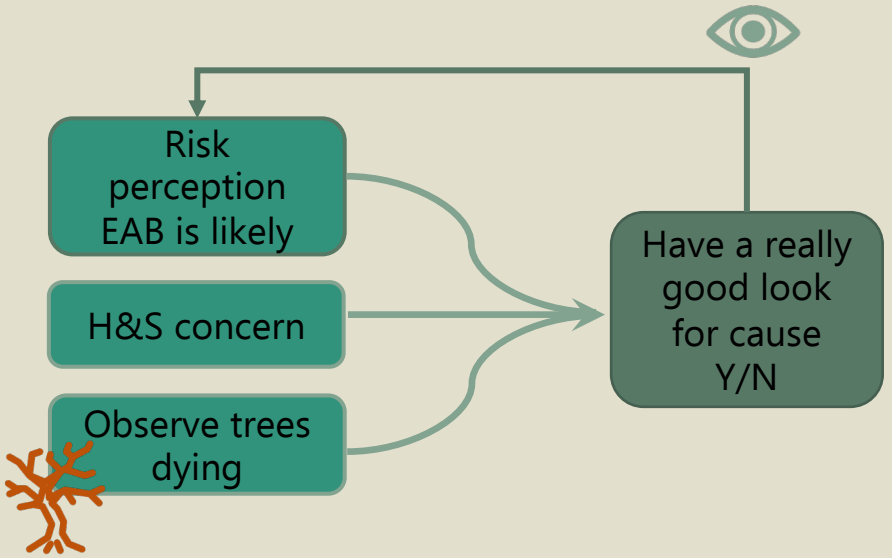
$$\text{e.g.}(1-\mathrm{M}(i))\left\{(1-\omega_G(i))\sum_{\substack{j=1 \\ i\neq j}}^{\eta} w_j x(j,t) + \omega_G(i) I_G\right\}$$

Resource is influenced by subsidy

Value is only influenced by observations of ADB

Stakeholder behaviour model (based on surveys, interviews and workshops)

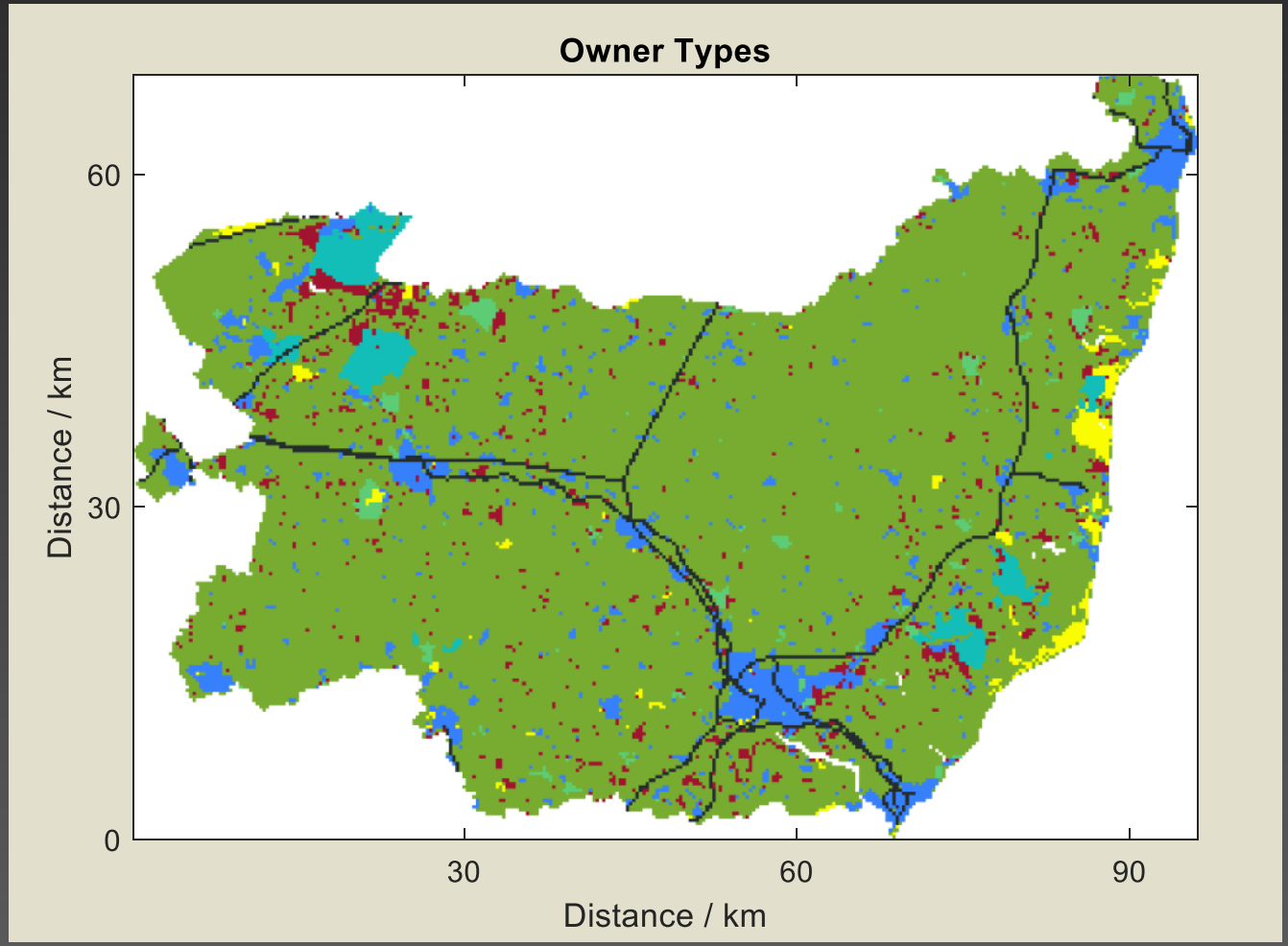


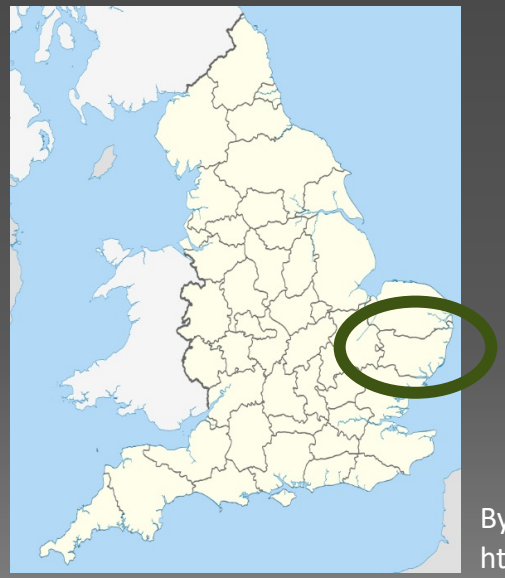


Although H&S is very important, it is unlikely to affect surveillance for early detection [interviews]. However, if landowners/stakeholders have ill trees that represent H&S risks, then, they will look harder for the cause [workshops]

Integrating models
Suffolk case study

Land-manager opinions depend on typologies (social surveys)

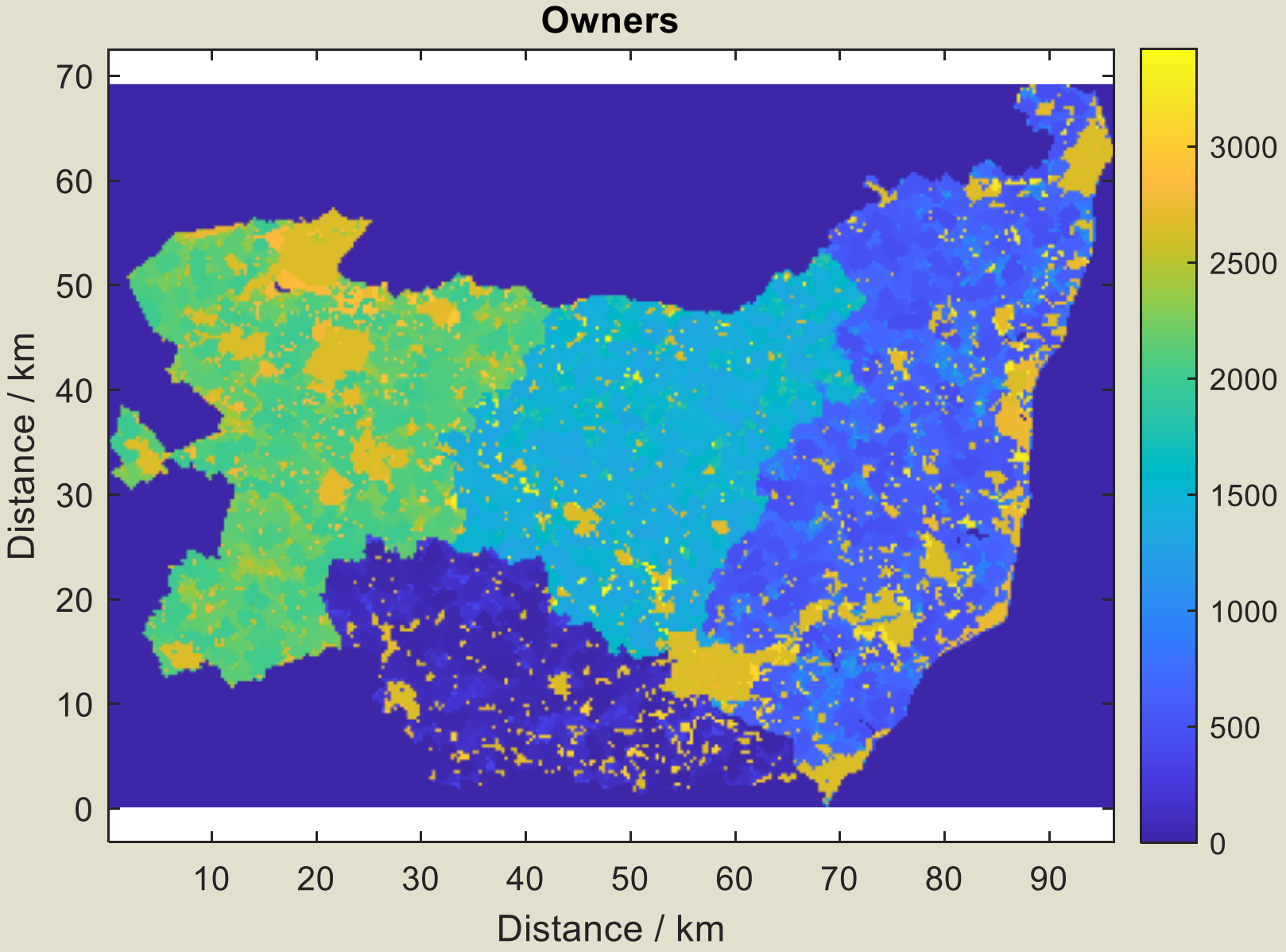




By Nilfanion - Ordnance Survey OpenData:County boundaries
https://commons.wikimedia.org/w/index.php?curid=11890051

- Councils
- Public Forest
- Farmland
- Private woodland
- Third sector
- Highways/transport

Land-manager opinions depend on typologies (social surveys)



Over 3000 land manager agents

Where data available on ownership we used that to allocate areas to an agent

For farmers we stochastically allocated farm areas to agents based on data about the distributions of farm sizes.

Initial conditions for perception variables

25 Which of these influenced your management decisions and how significant were those influences ....?

	1: No influence	2	3	4	5: Major influence	N/A
Health & safety concerns	○	○	○	○	○	○

Initial conditions for perception variables

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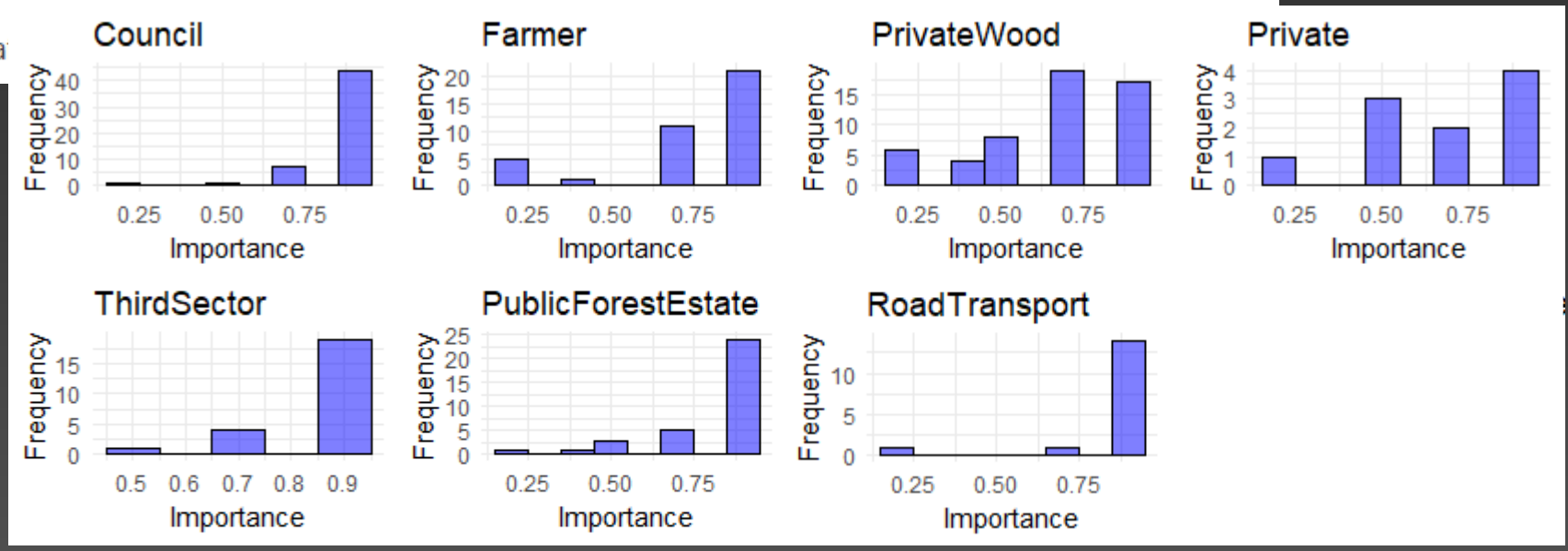

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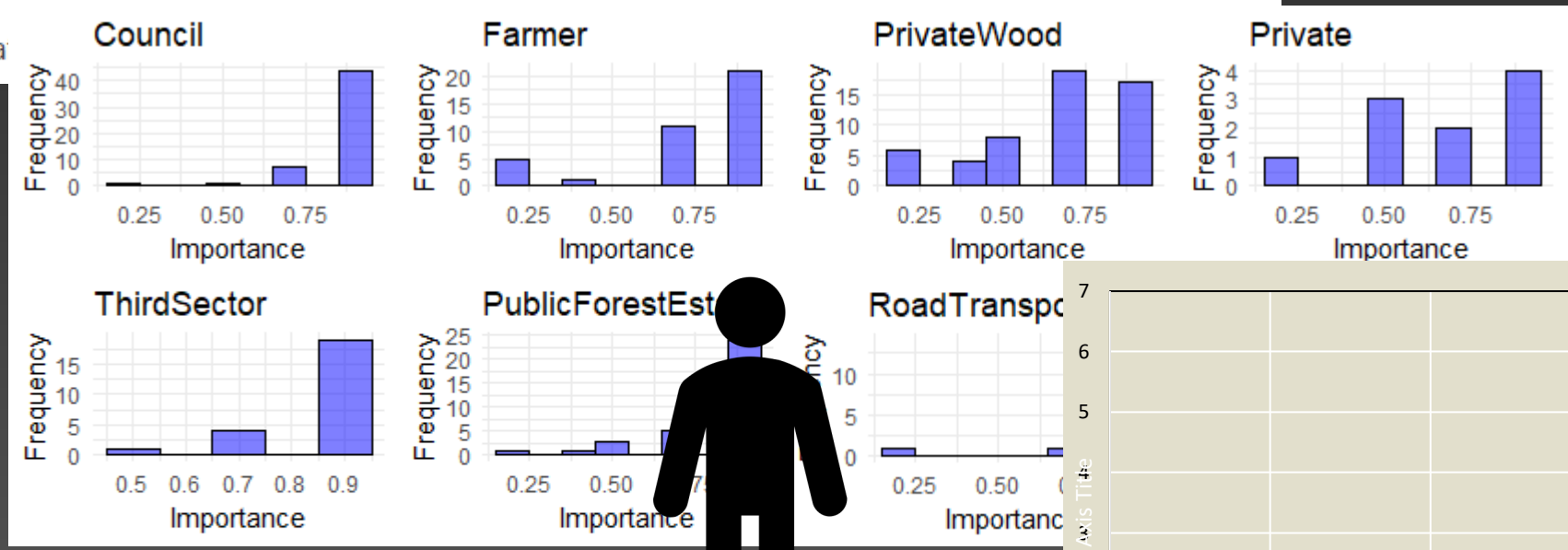
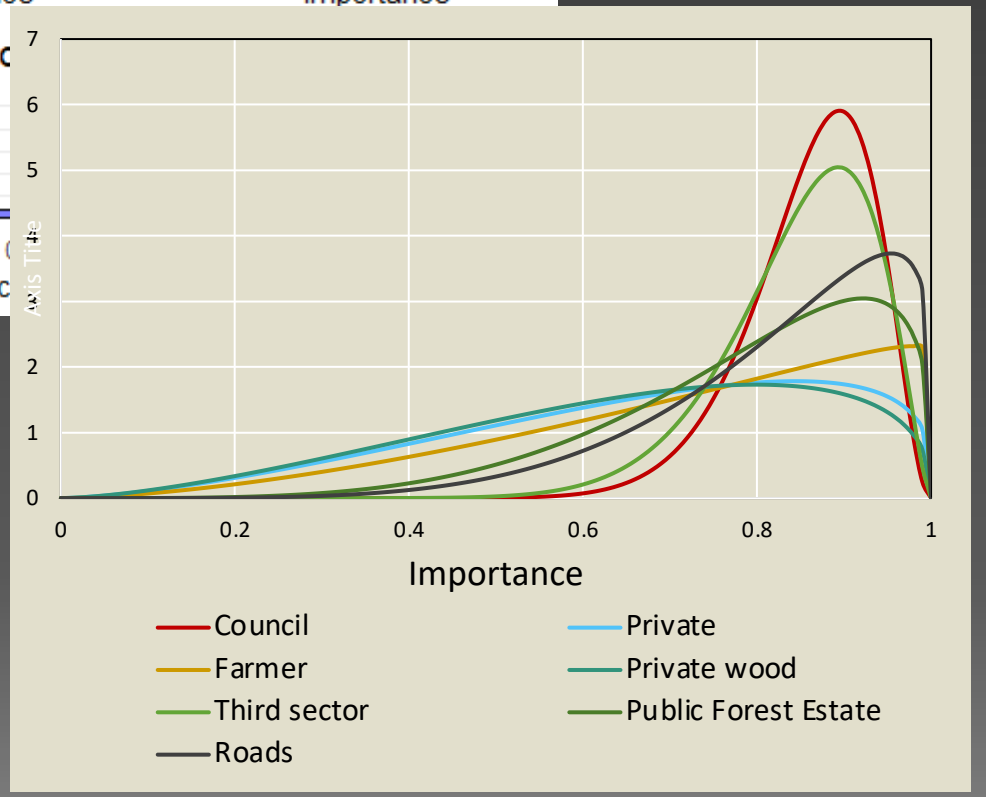
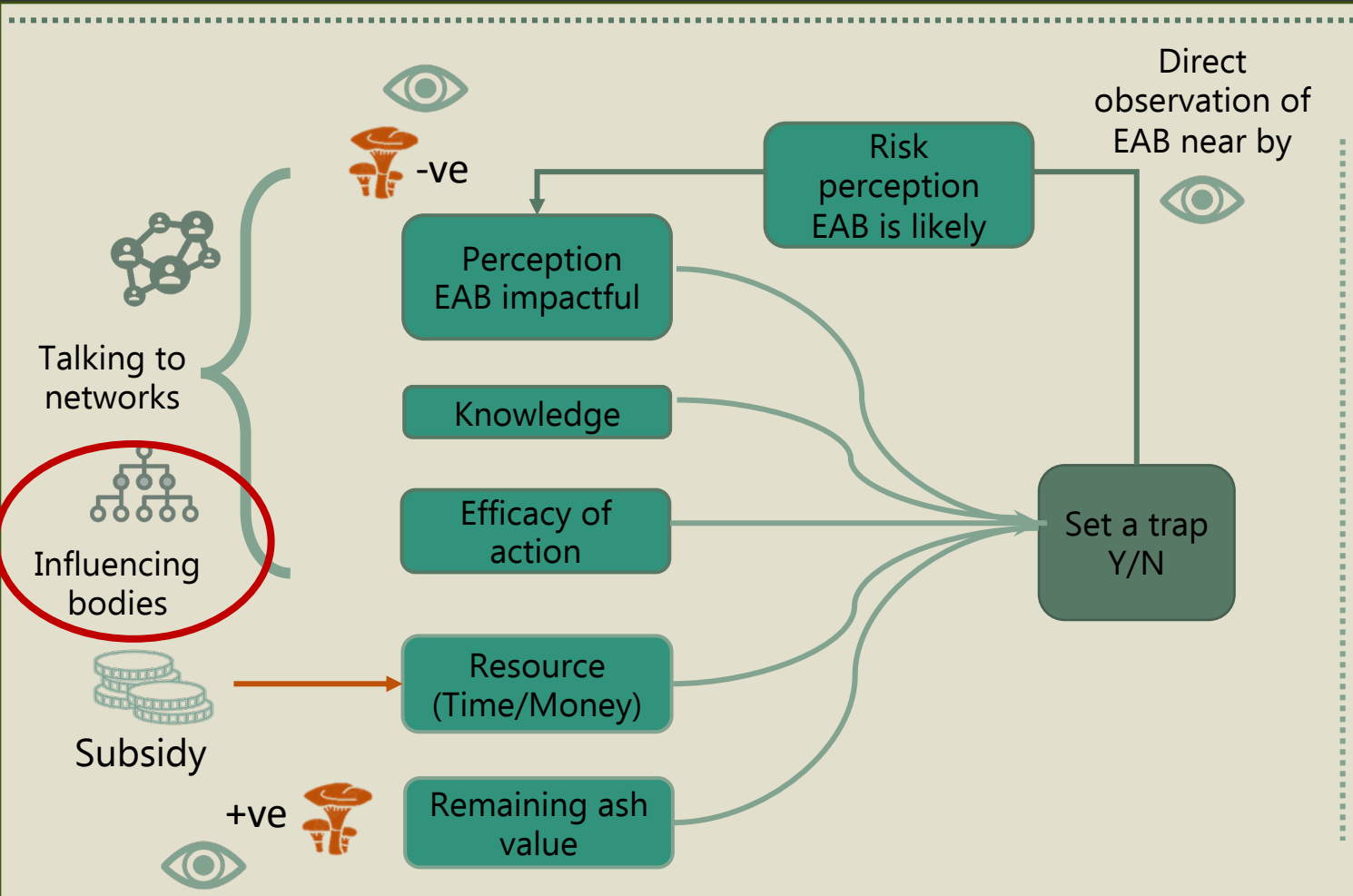
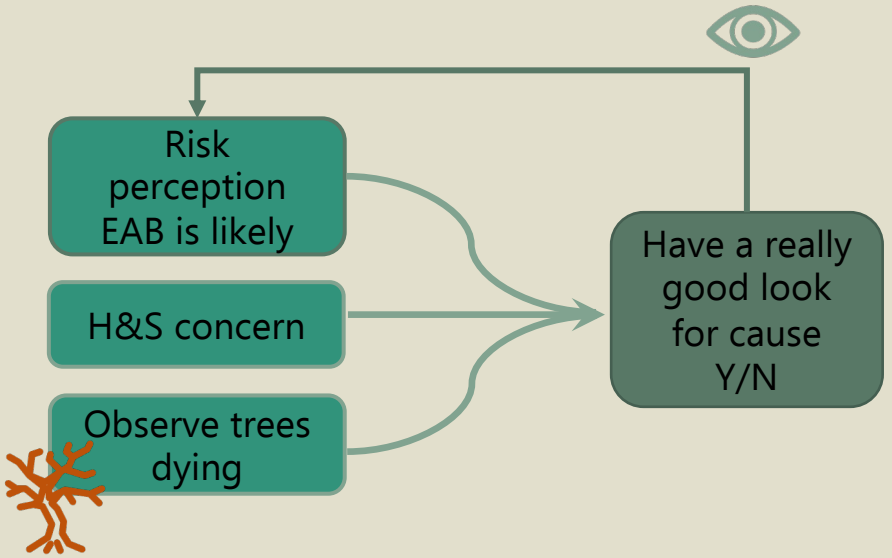


Perceived importance of health and safety sampled from fitted distribution



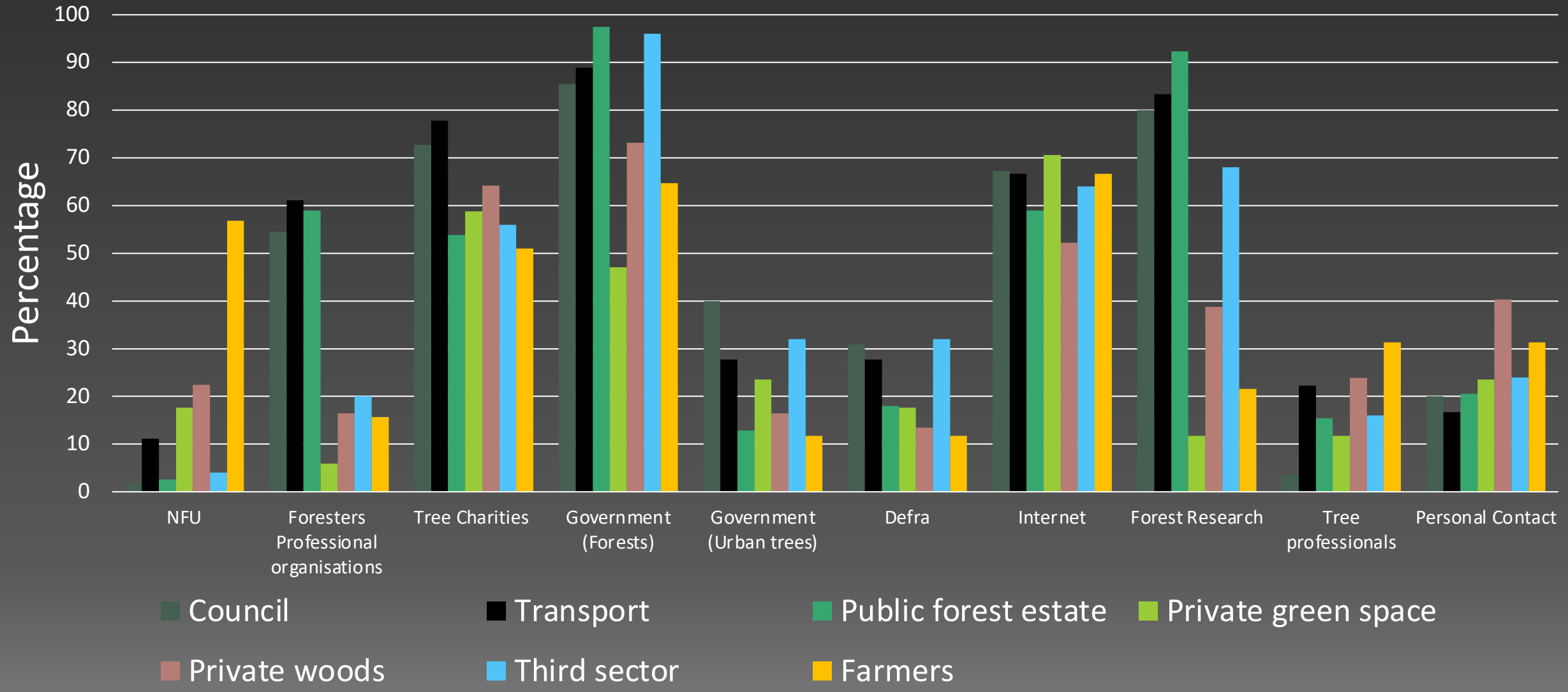
Stakeholder behaviour model (based on surveys, interviews and workshops)



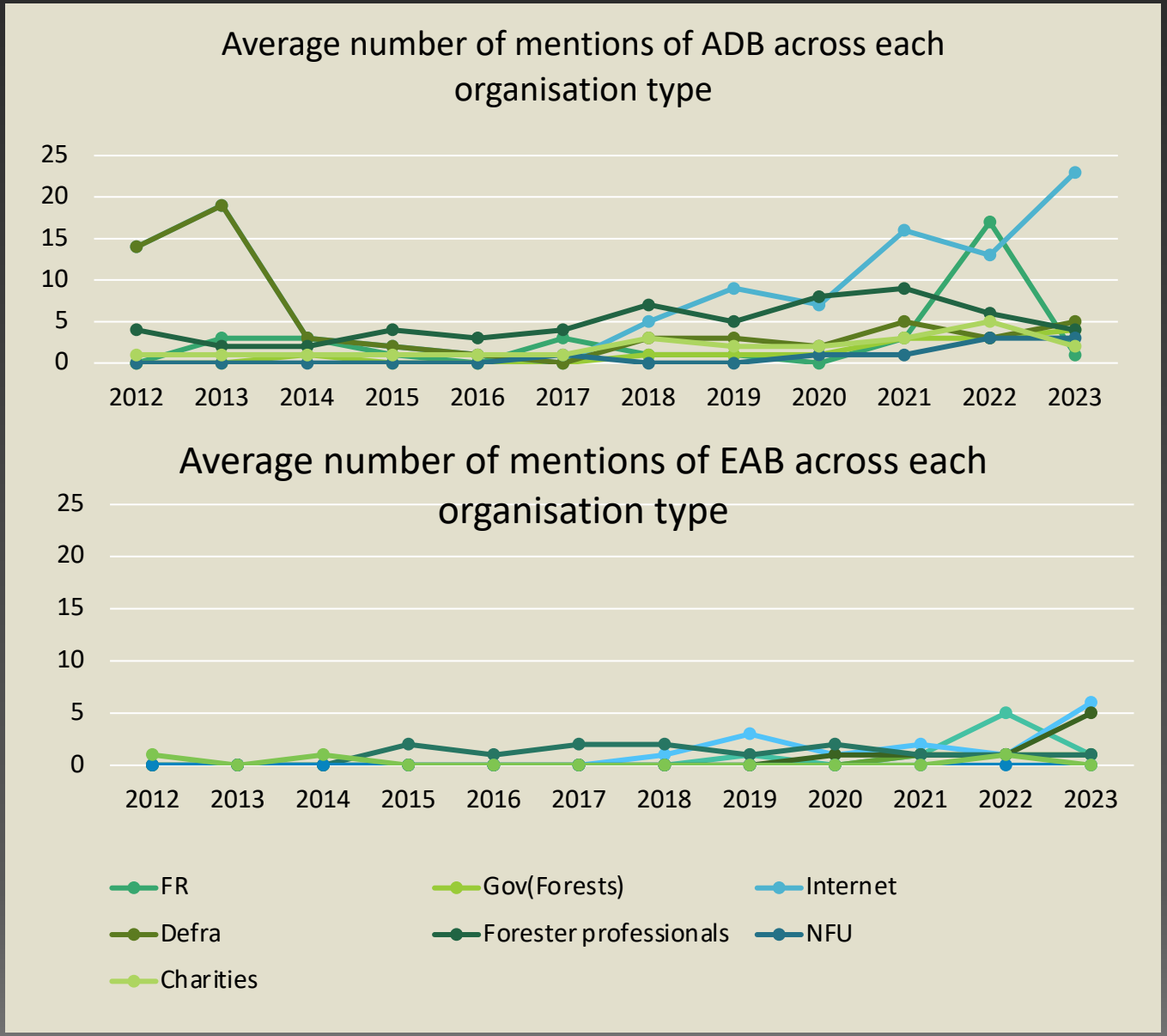


Although H&S is very important, it is unlikely to affect surveillance for early detection [interviews]. However, if landowners/stakeholders have ill trees that represent H&S risks, then, they will look harder for the cause [workshops]

Influencing bodies – where do land managers get information about tree-health ?



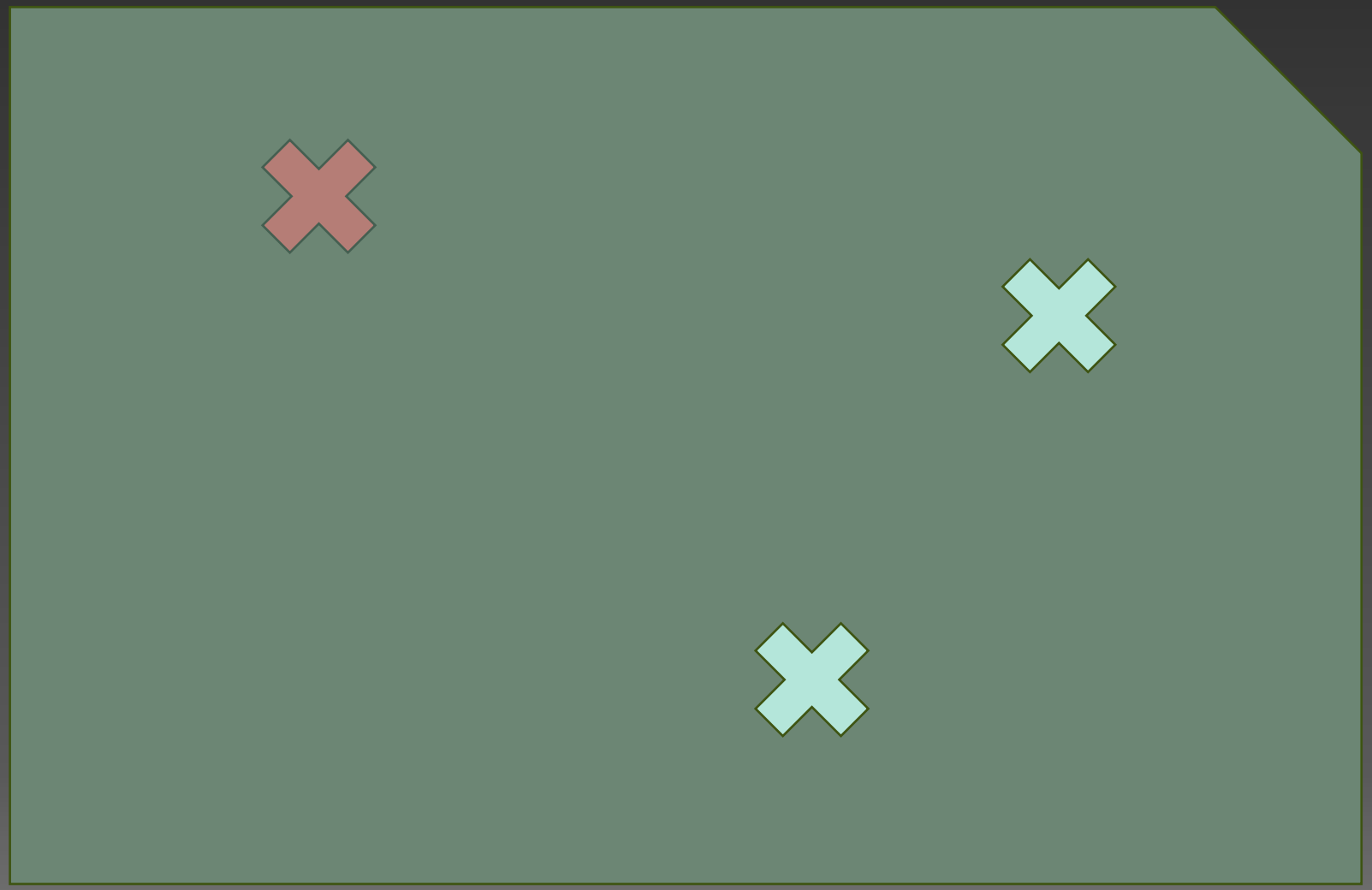
Do influencing bodies talk about new and incoming threats?



Frequency of mention of ADB and EAB used to inform relative likelihood that agents would be receive information on EAB

After 2018 mostly ADB management

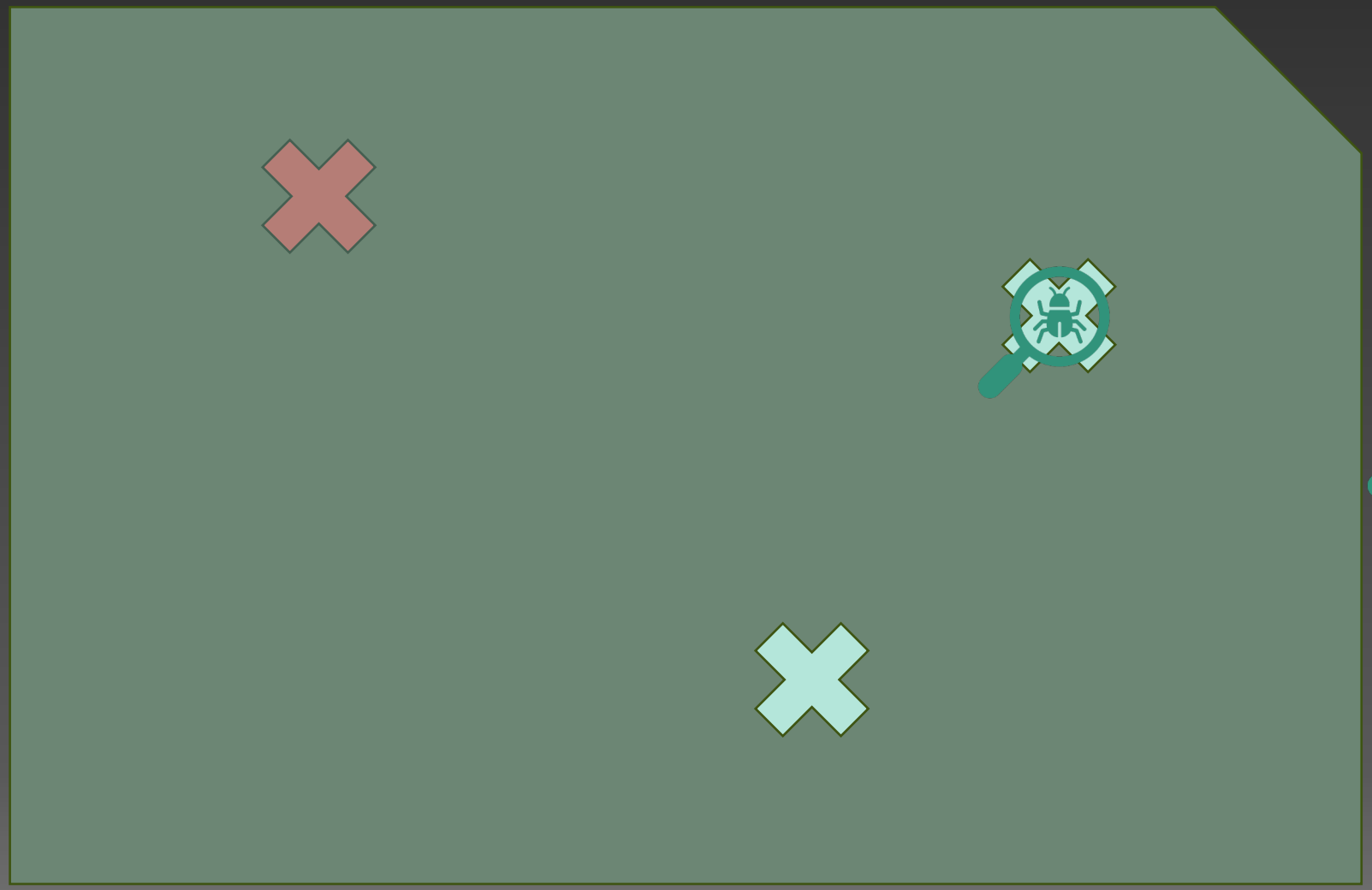
Mechanics of the model follow statutory guidance



Official surveillance location

Land manager observation point (determined by social dynamics model)

Mechanics of the model follow statutory guidance

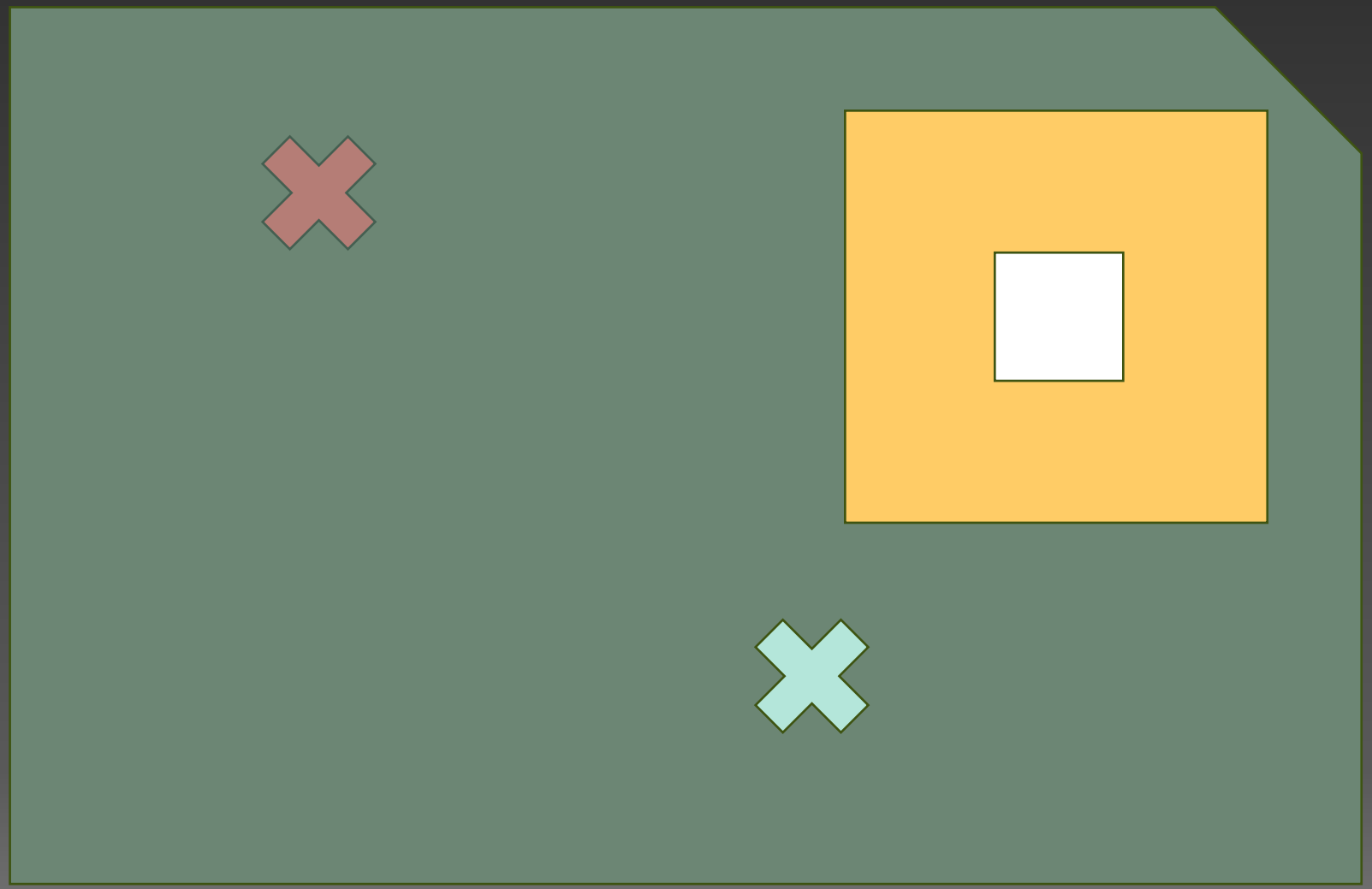


Official surveillance location

Land manager observation point

EAB observed

Mechanics of the model follow statutory guidance



Official surveillance location

Land manager observation point

EAB observed

Sanitation felling (400m around affected point)

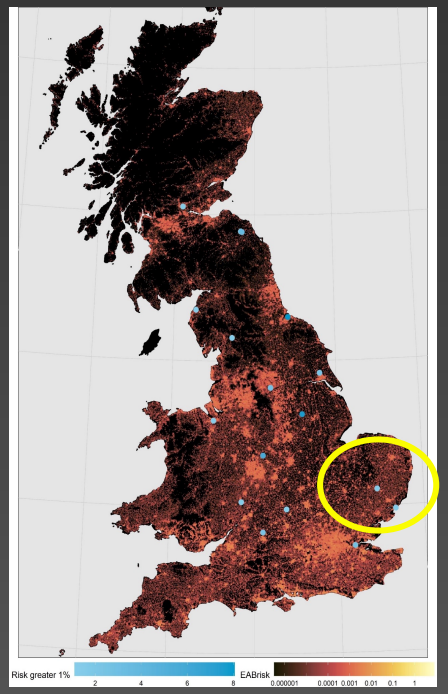
Intensive surveillance (1km from affected point)

If no EAB detected after 4 years measures cease

Model mechanics (cont.)

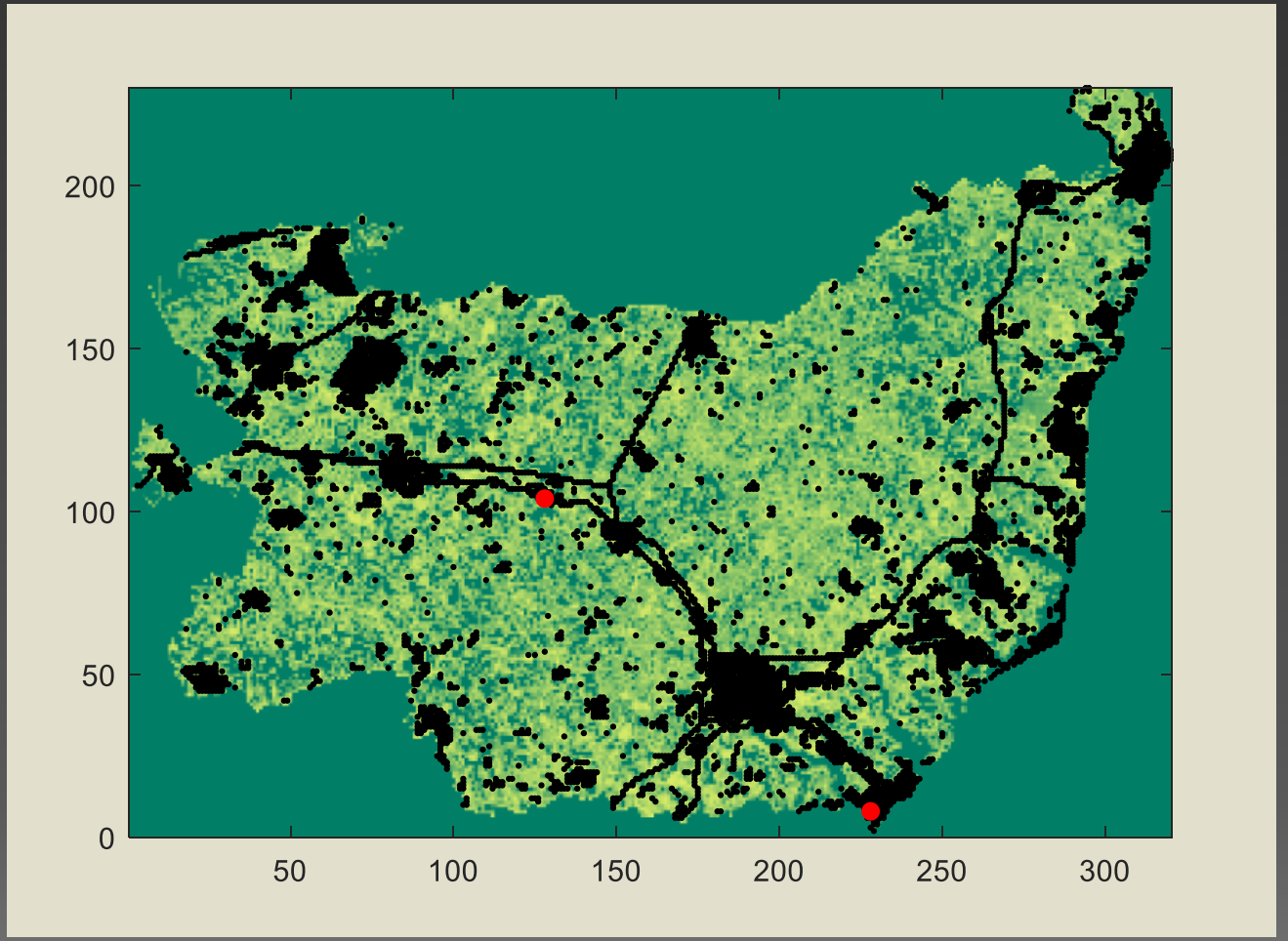
- Spatially explicit grid with cells representing 300m x 300m
- Over 3000 landowner agents all characterised according to land manager type
- Each land manager has “opinion variables” and manages a number of grid cells
- Each cell has a variable describing ash density
- Each ash population has a number of states representing EAB and ADD status
- Model coded in C++ (that makes it faster)
- Takes about 10 minutes to run on a reasonable PC
- (Bugs also invaded code but have hopefully all been eradicated)

Scenario: EAB arrives as expected in a high-risk location



Map of risk of entry
Blue = highest risk

Initial conditions for surveillance

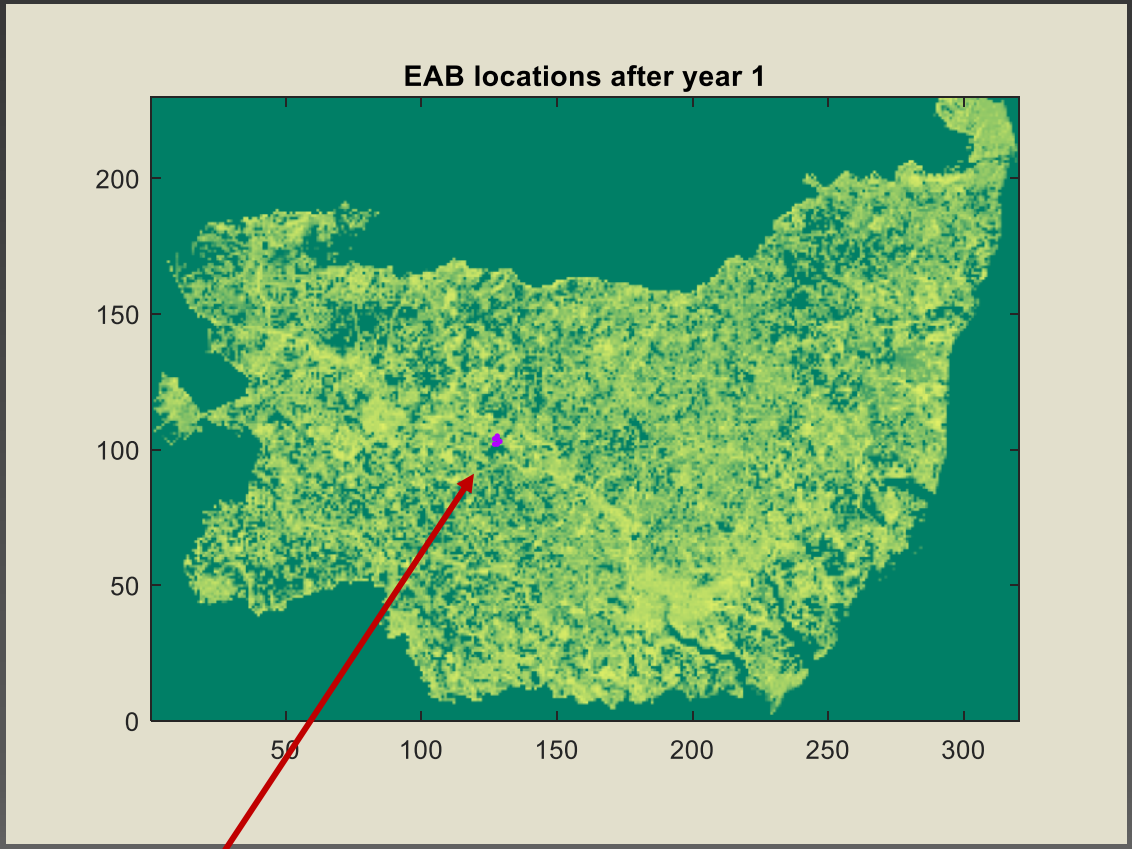


Ash density (yellow)
Official traps (red)
health and safety inspections (black)

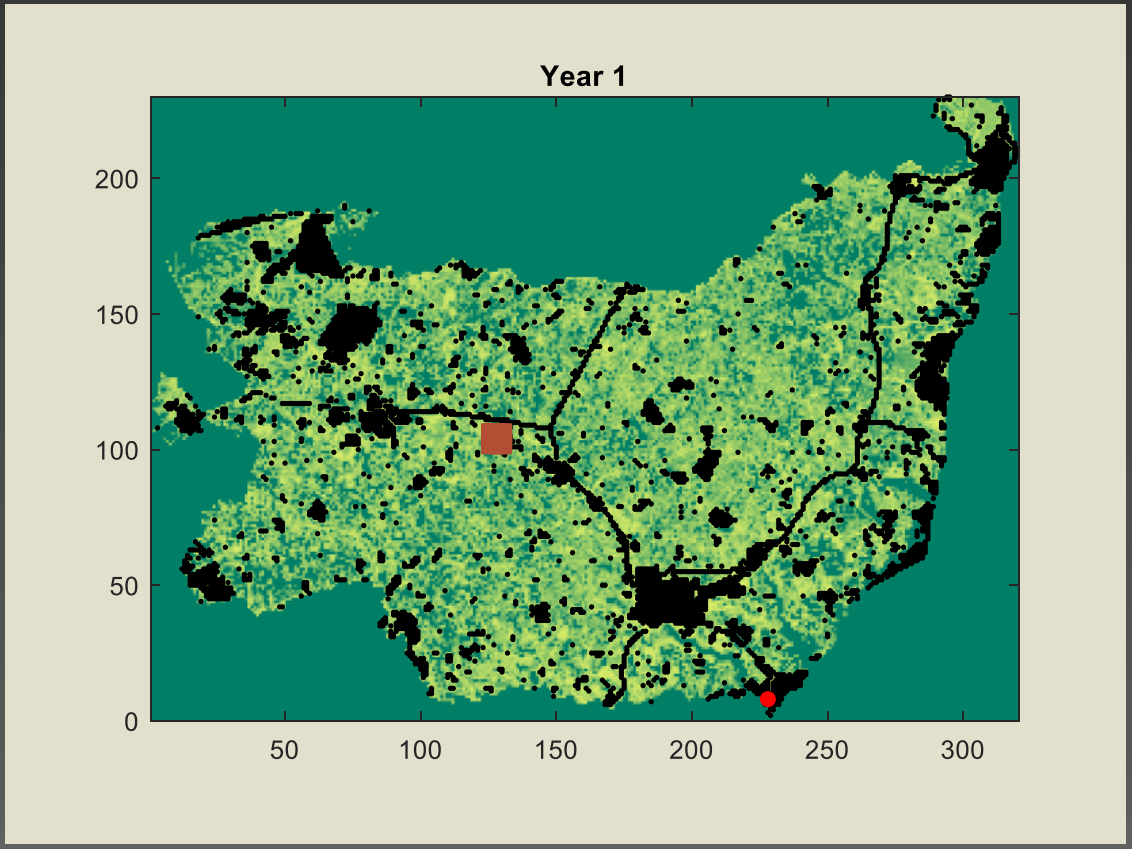
Scenario: EAB arrives as expected in a high-risk location

- Year 1 bug shows up in official trap location

- Statutory management occurs



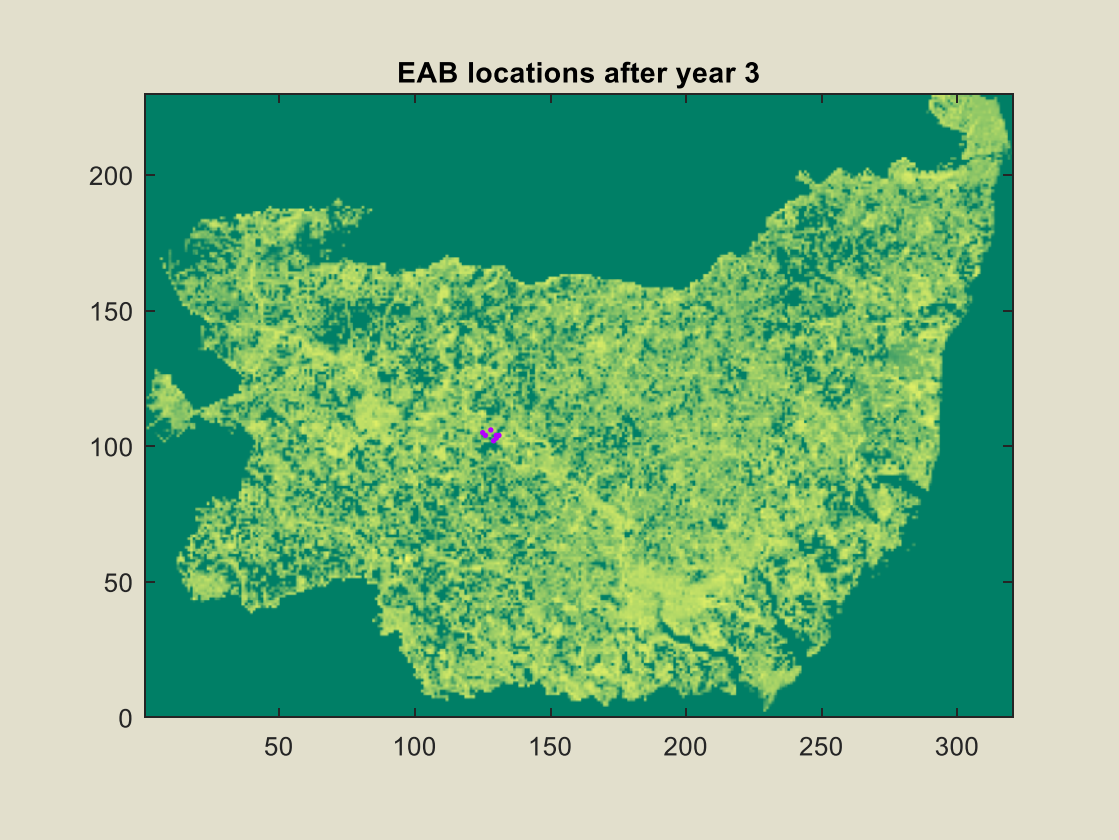
EAB locations (purple)

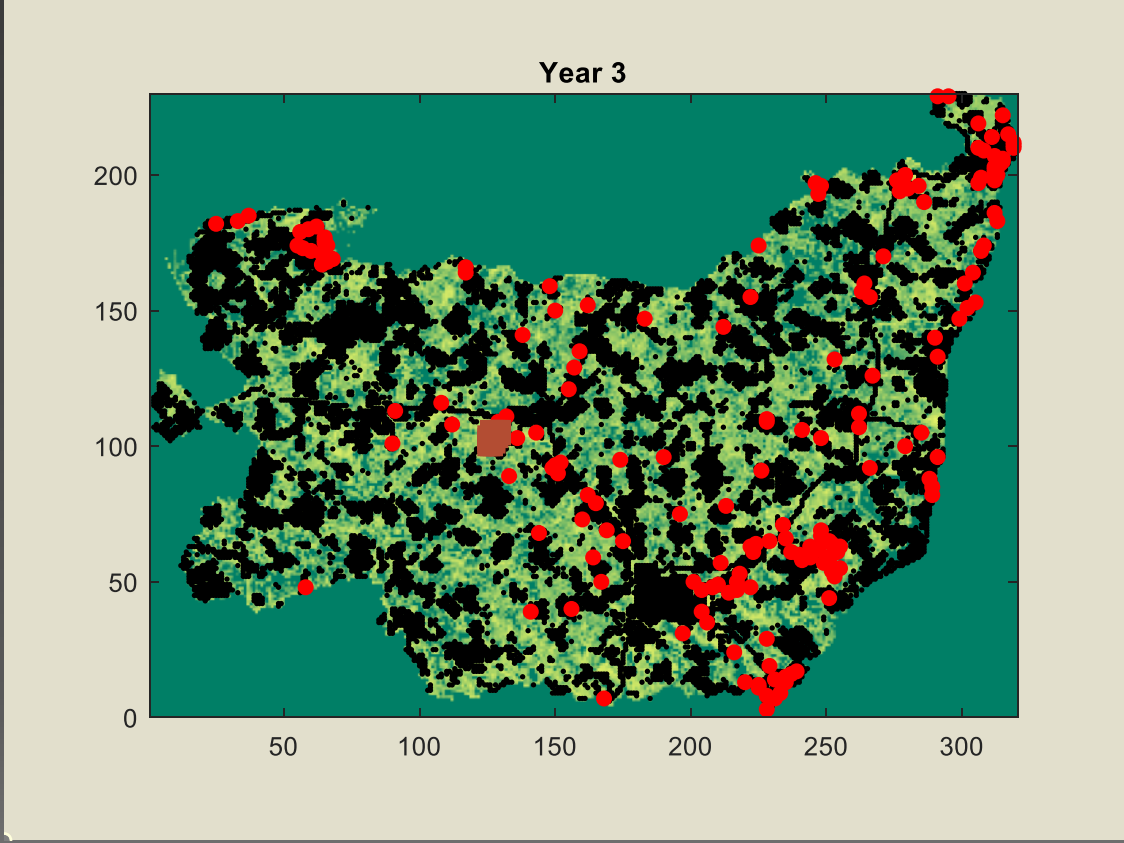


Initial official traps (red),
Health and safety inspections (black)
Statutory surveillance (brown area)

Scenario: EAB arrives as expected in a high-risk location

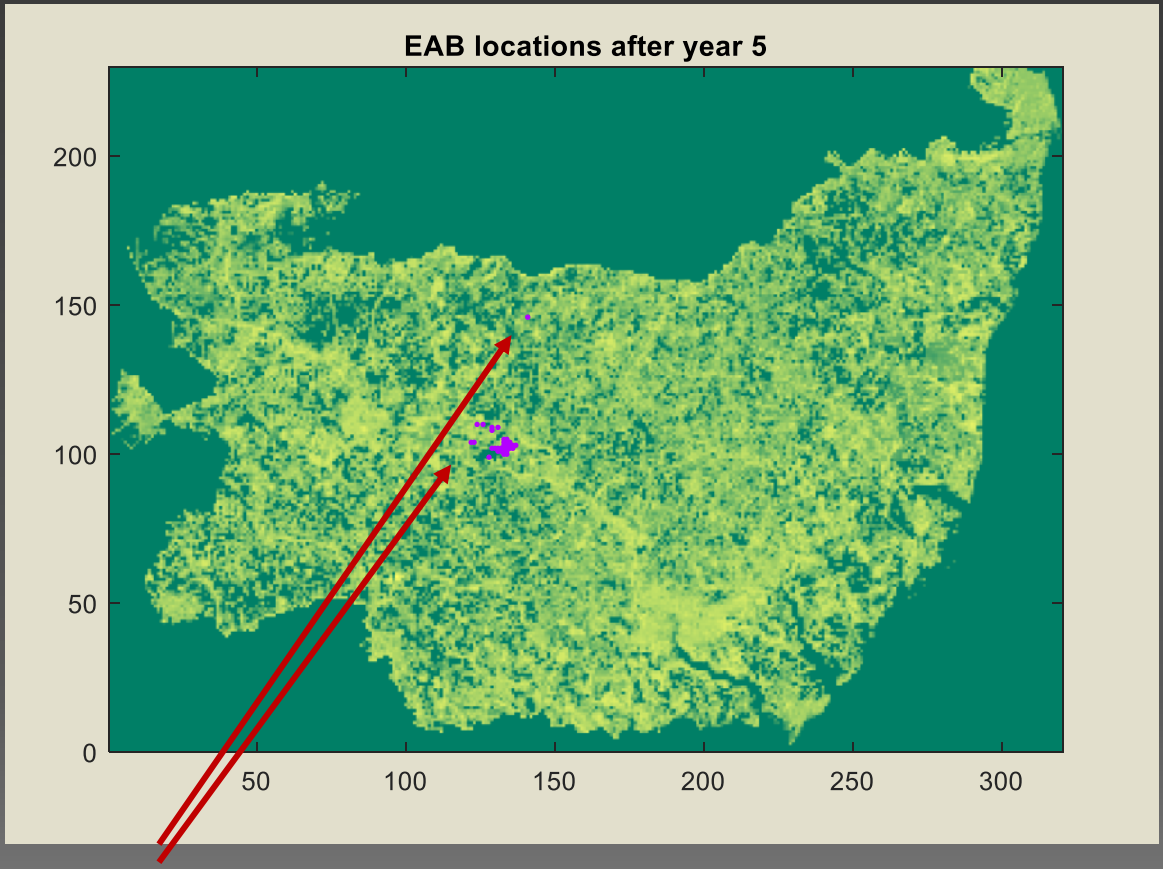
- Despite bests attempts EAB escaped eradication
- The identification of EAB has led to increased concern about EAB and health and safety resulting in more traps and visual inspection



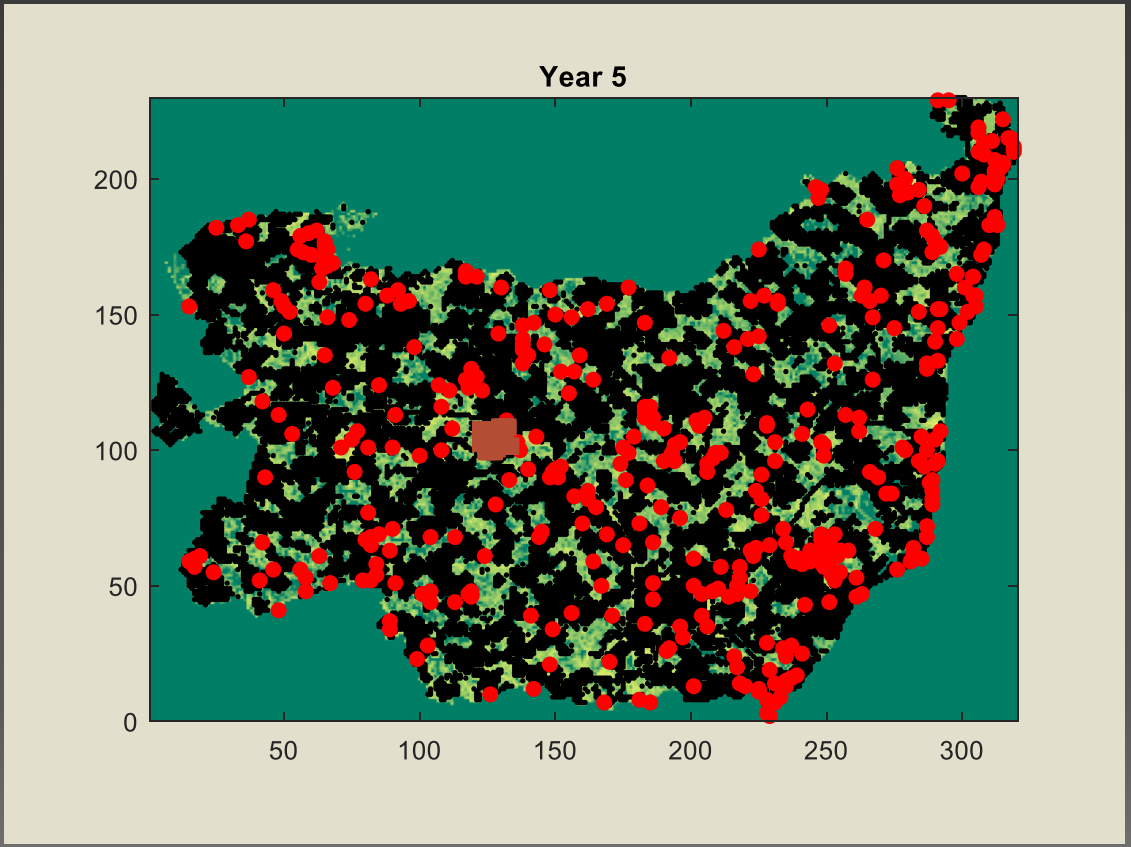


Scenario: EAB arrives as expected in a high-risk location

- EAB continues to escape eradication first jump occurs
- The identification of EAB has led to increased concern about EAB and health and safety resulting in more traps and visual inspection

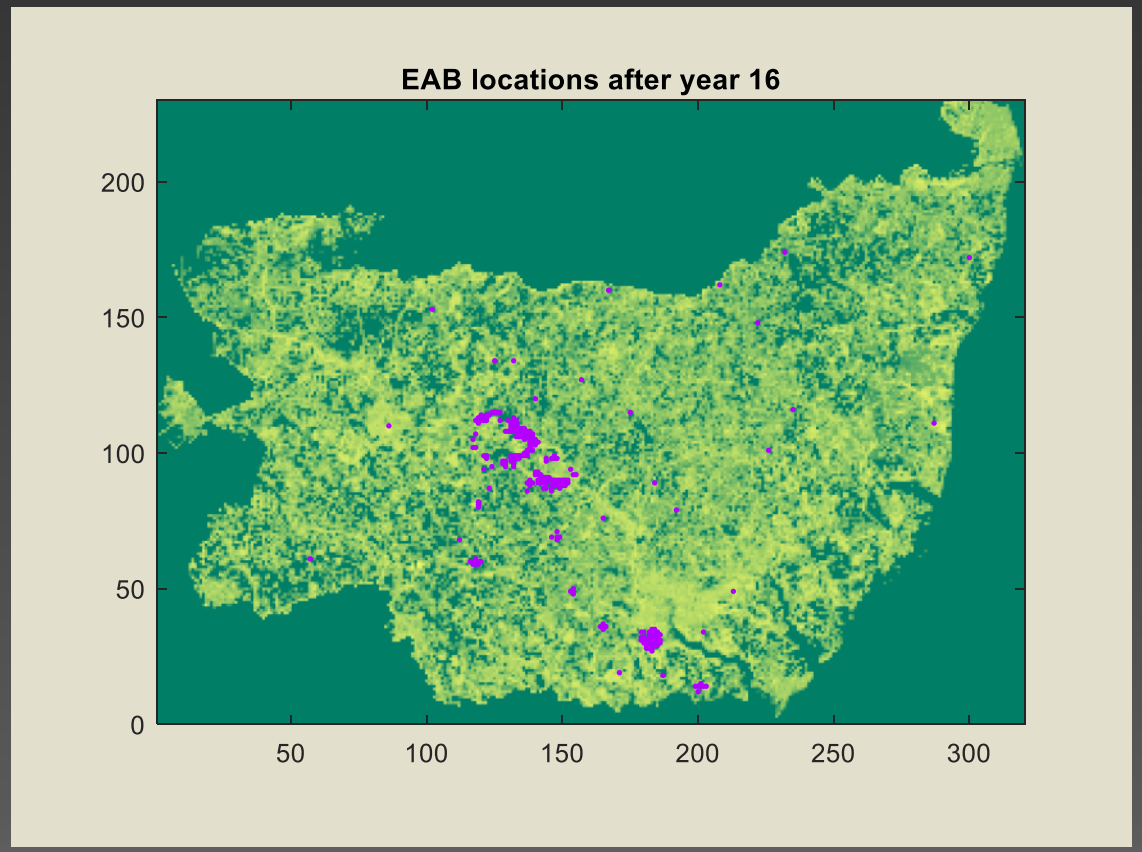


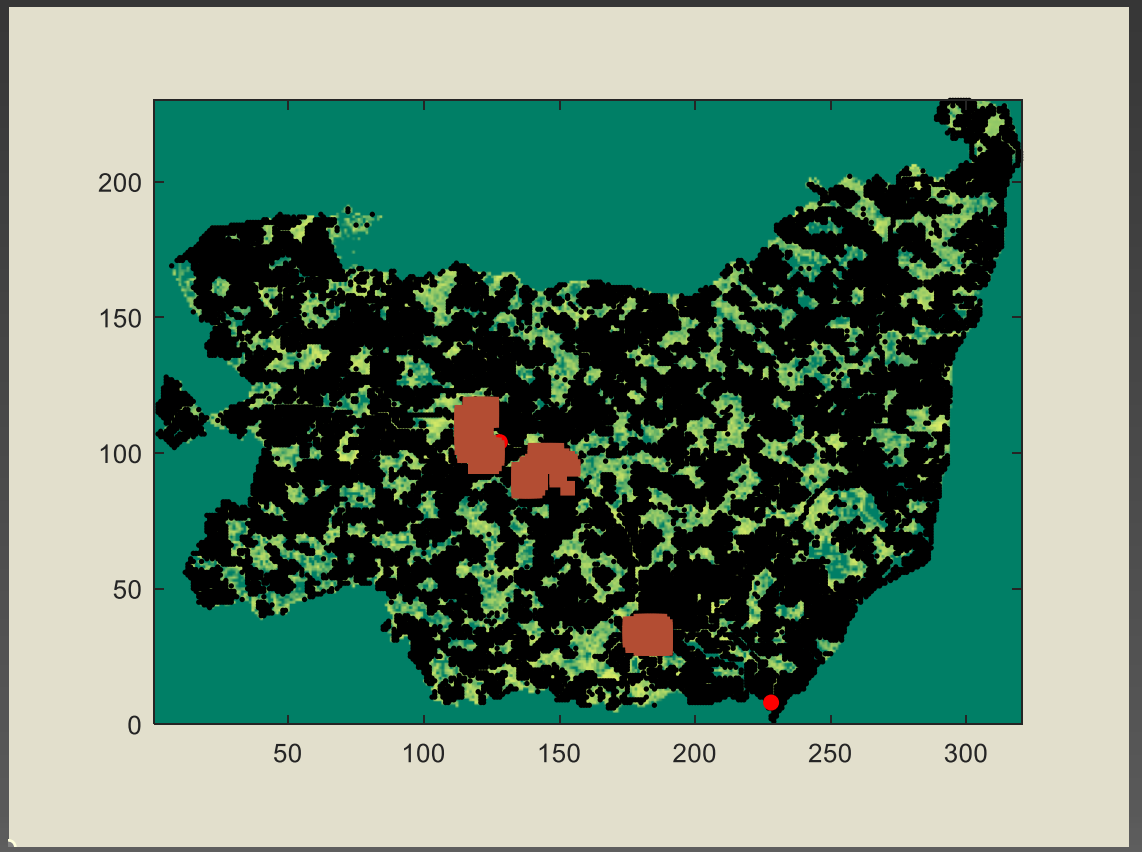
EAB localised cluster and first jump



Scenario: EAB arrives as expected in a high-risk location

- EAB has been discovered several times and resulting action slows spread
- Increasing numbers of detections disincentivise surveillance





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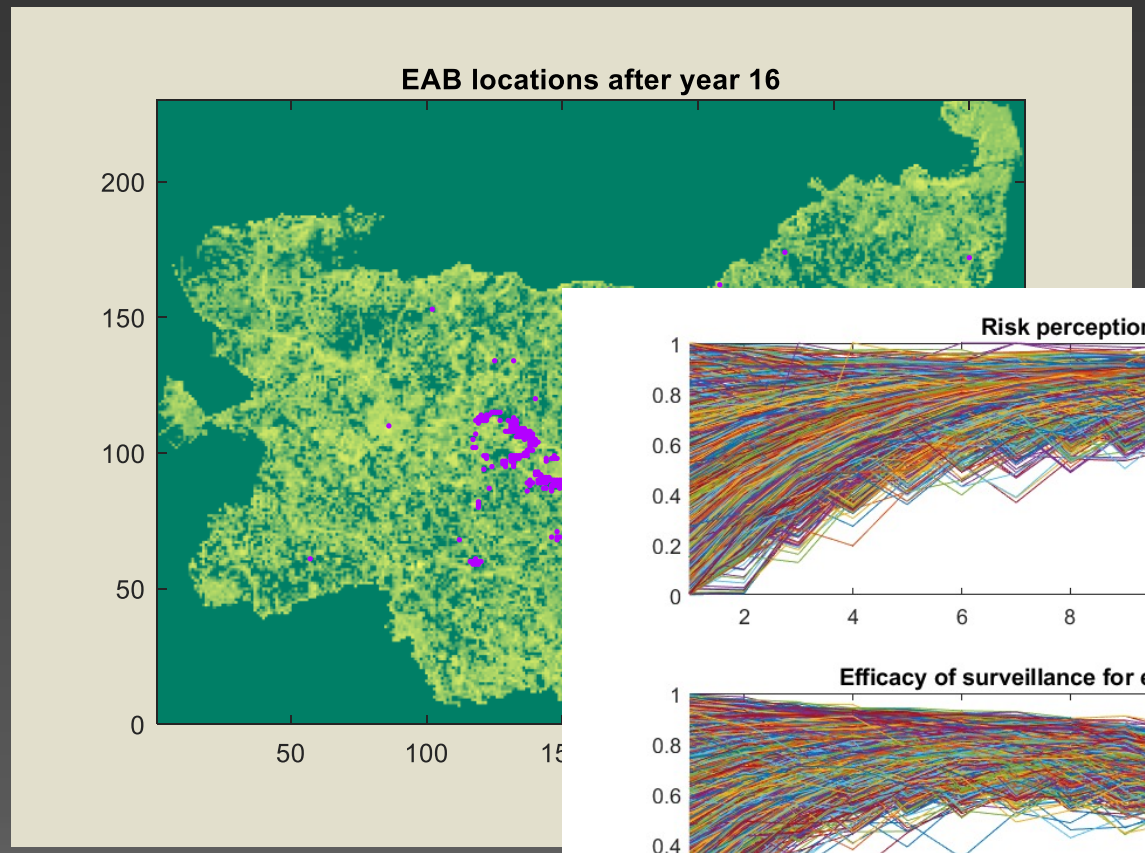
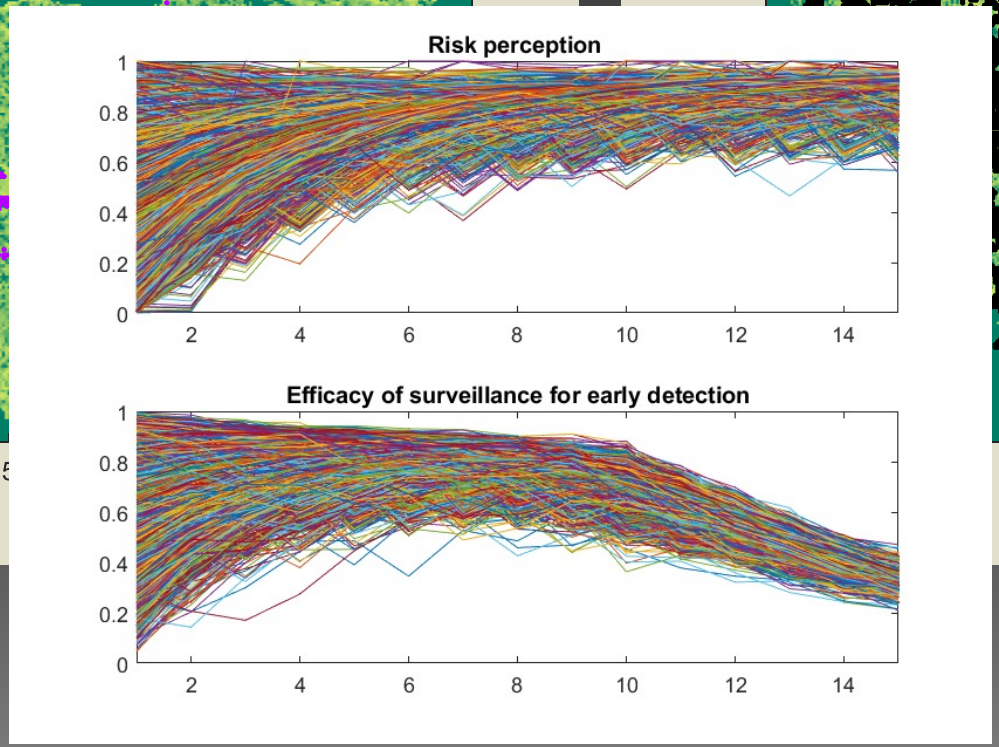
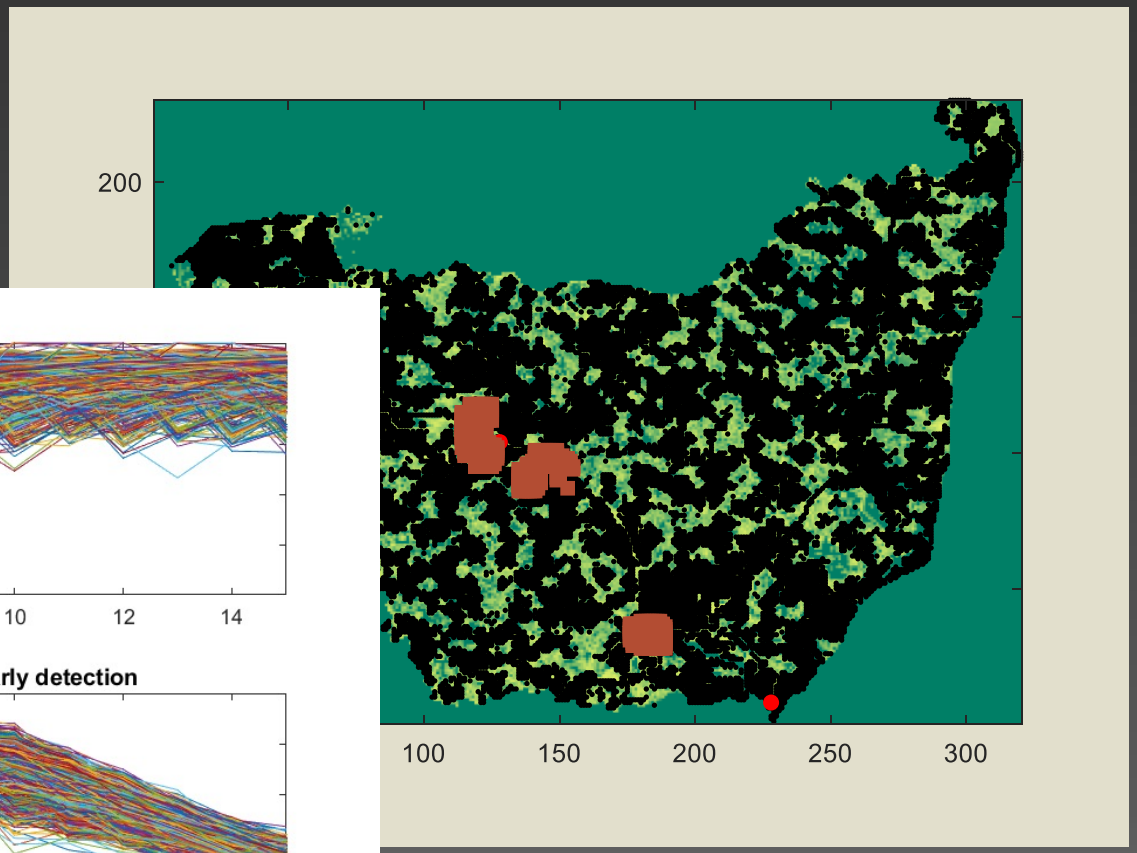
- EAB has been discovered several times and resulting action slows spread
- Increasing numbers of detections disincentivise surveillance





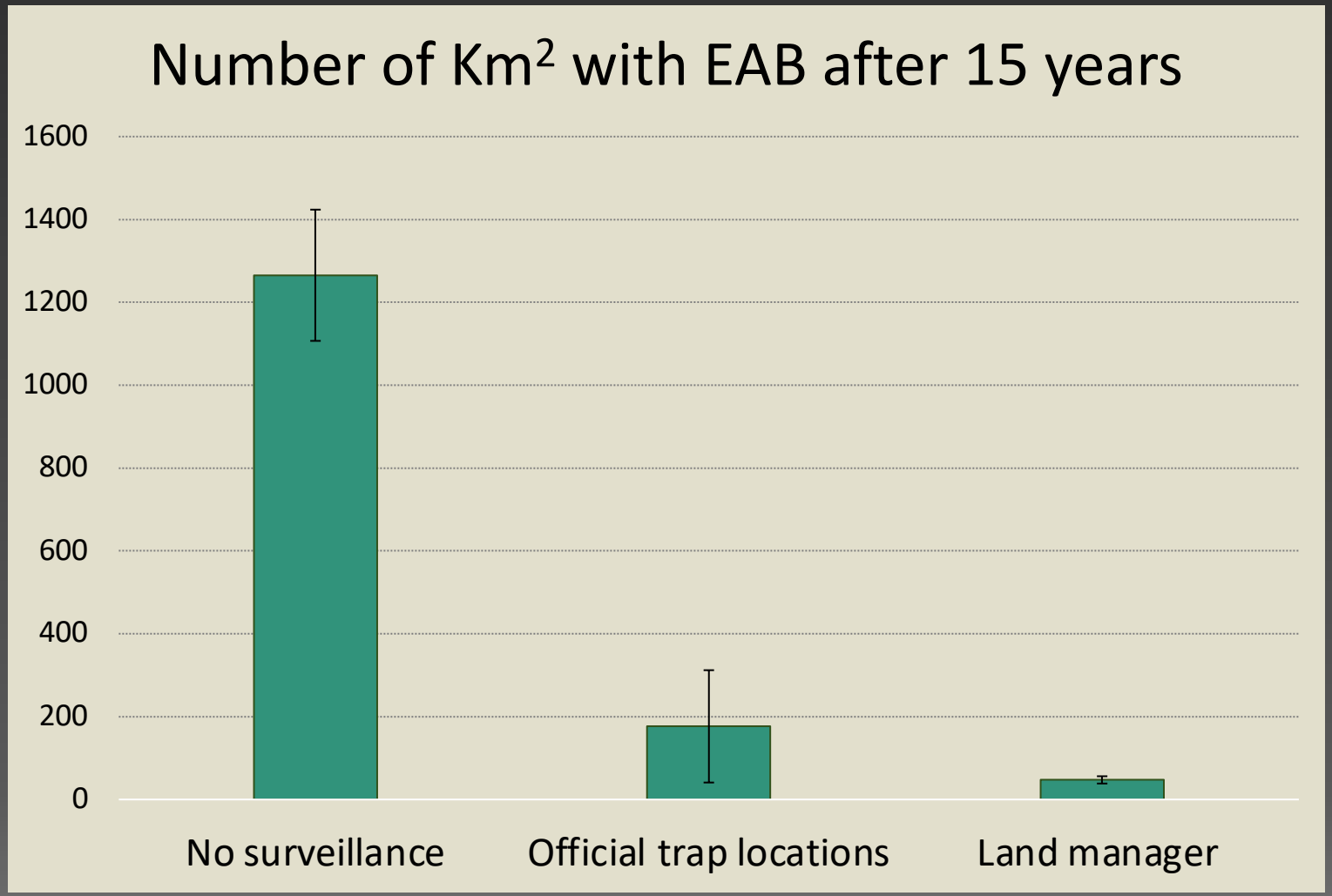


Results

Deploying traps to high-risk locations substantially slows spread

Incentivising land managers to adopt surveillance further slows the spread

In our stochastic simulations only in very very few instances did we stop the spread altogether



Conclusion

- Formal surveillance deployed according to entry hazard or optimised to maximise detection will substantially improve chances of detecting the pest before significant damage is done
- If land managers adopt surveillance and management then the spread of EAB can be slowed further
- Land managers generally expect support to deploy trapping – without this take up is likely to be minimal
- Interaction with ADB has positive and negative effects on the socio-epidemic system
- Health and Safety is a key concern of many groups and tree checks will aid detection, but this form of detection is not timely
- It is unlikely that the pest will be eradicated – but it's spread can be slowed

Thank you

- Acknowledgments to the team

Rothamsted epidemiological modellers: Vasthi Alonso Chávez, Nathan Brown
University of Warwick epidemiological modellers: Stephen Parnell, Frank van den Bosch, Matt Combes
SEI –University of York Social scientists: Alison Dyke, Joanne Morris,
Forest research social scientists: Mariella Marzano, Liz O'Brien, Clare Hall, Berglind Karlsdottir,
Forest research tree health experts and modellers: Dave Williams, Nathan Brown

And the funders