INVENTORY AND REVIEW OF QUANTITATIVE MODELS FOR SPREAD OF PLANT PESTS FOR USE IN PEST RISK ASSESSMENT FOR THE EU TERRITORY

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EFSA PROJECT OC/EFSA/PLH/2012/01

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Background to the project

- EFSA Panel on Plant Health (PLH) performs risk assessments for plant pests
- Can quantitative spread and dispersal models assist risk assessment?
- Entry, establishment, spread and risk mitigation

Plant diseases

Invertebrate herbivores and vectors

Parasitic plants

Invasive plants and weeds

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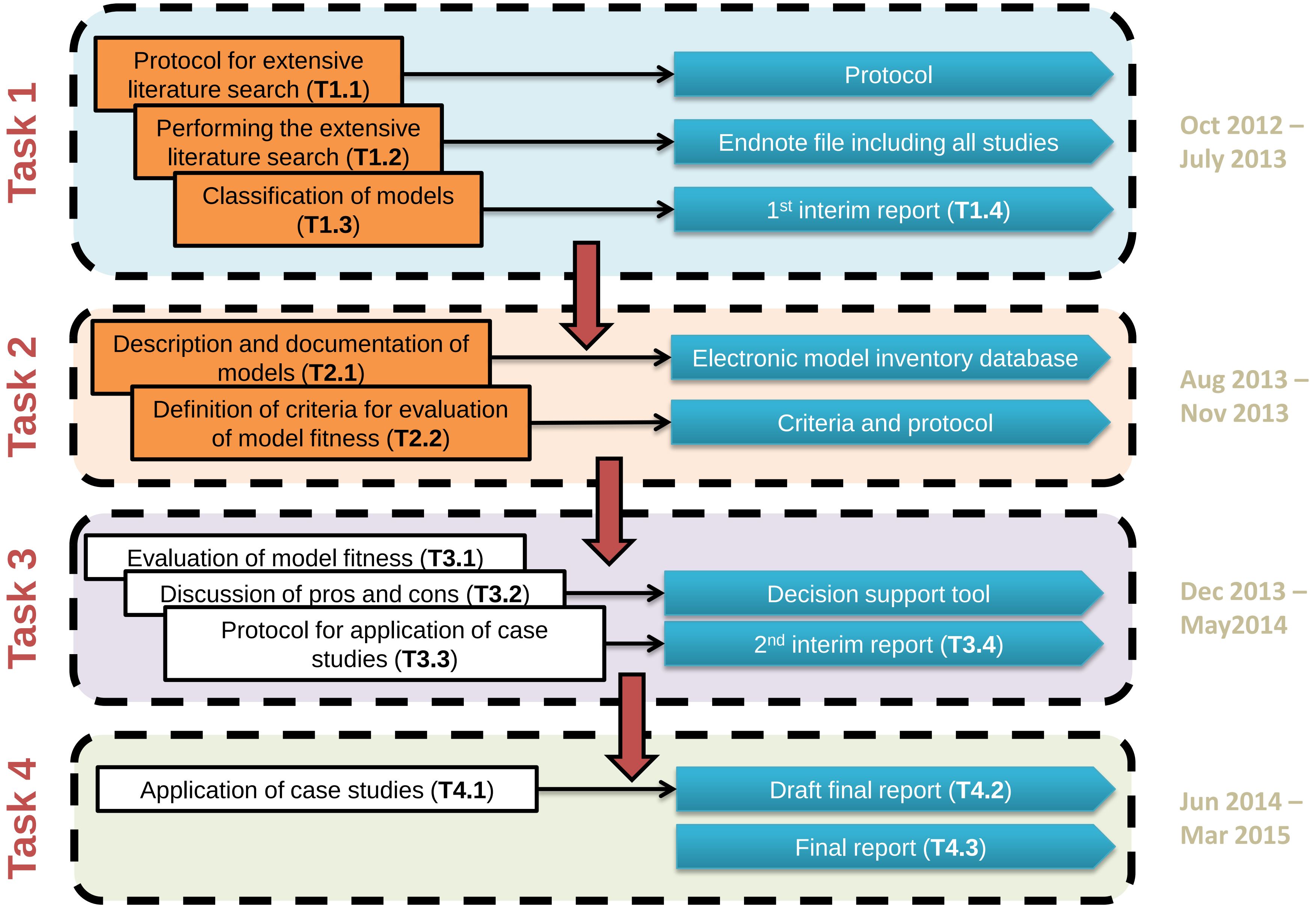
Project aims

- Review and document literature on pest spread and dispersal models
- Identify general modelling strategies
- Evaluate fitness of the strategies for risk assessment
- Design a decision support tool
- Develop case studies for use of modelling in risk assessment

Overview of project tasks



Talk structure

- Results of Task 1:
  - Literature review
  - Cluster analysis of literature review results to identify modelling strategies.
  - Examples of the strategies
- Results of Task 2:
  - Model inventory
  - Fitness criteria
- Current status of Task 3:
  - Proposal for evaluating fitness of the strategies for EFSA risk assessment
  - Use of the criteria in a decision support scheme

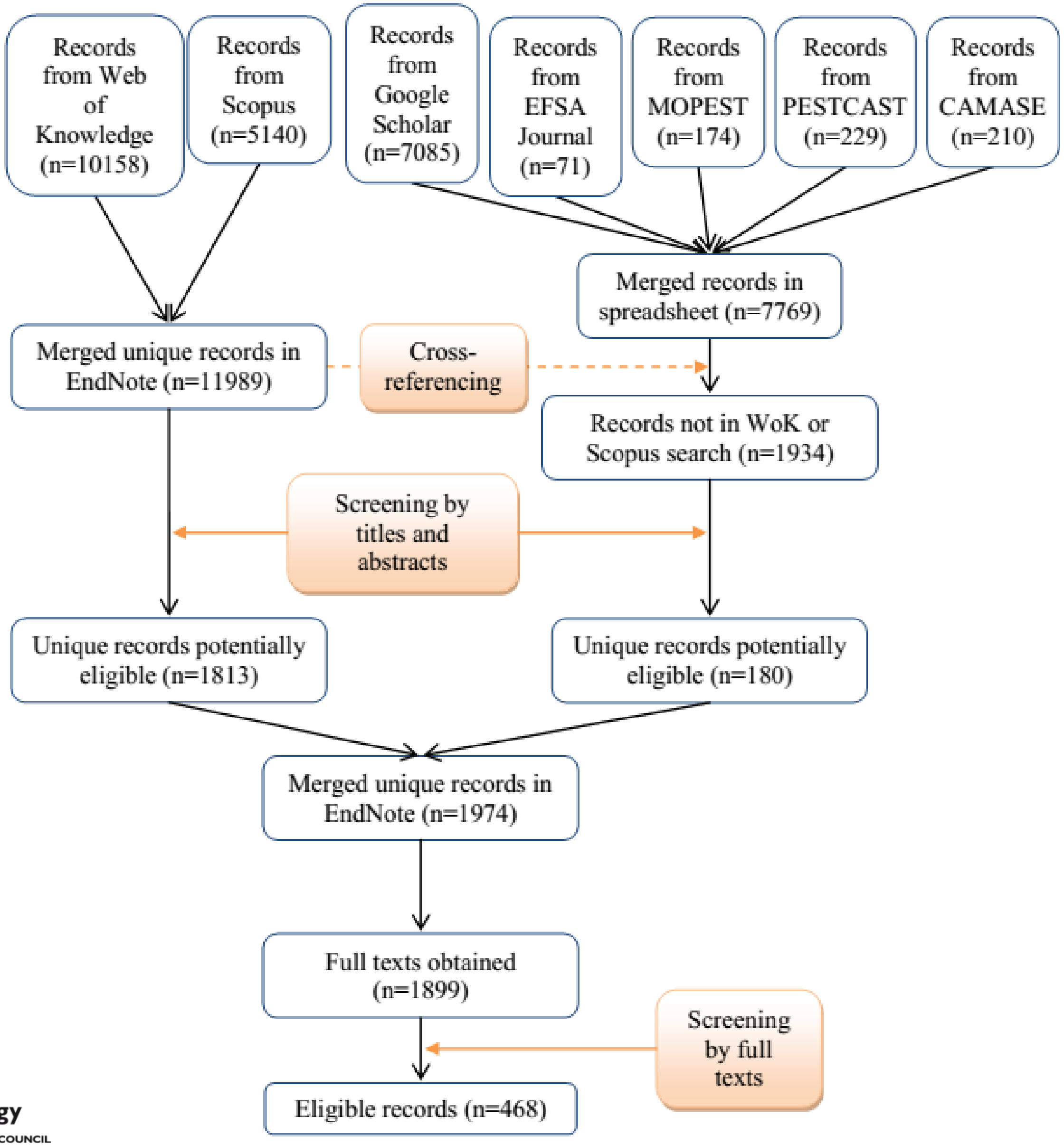
Extensive literature review

- Survey scientific literature on pest spread and dispersal models
- Based on systematic reviewing and mapping
- Created an extensive search string with Boolean operators
- Initial scoping to ensure feasibility and quality
- Searches of Web of Knowledge, Scopus, Google Scholar, EFSA Journal, MOPEST, PESTCAST and CAMASE
- Screening to find relevant studies
- Reference management with EndNote X5 (Deliverable)

EFSA (2010) Application of systematic review methodology to food and feed safety assessments to support decision making. ***EFSA Journal****, 8, 90.*

Bates, S., Clapton, J. & Coren, E. (2007) Systematic maps to support the evidence base in social care. ***Evidence & Policy: A Journal of Research, Debate and Practice****, 3, 539-551.*

Extensive literature review results



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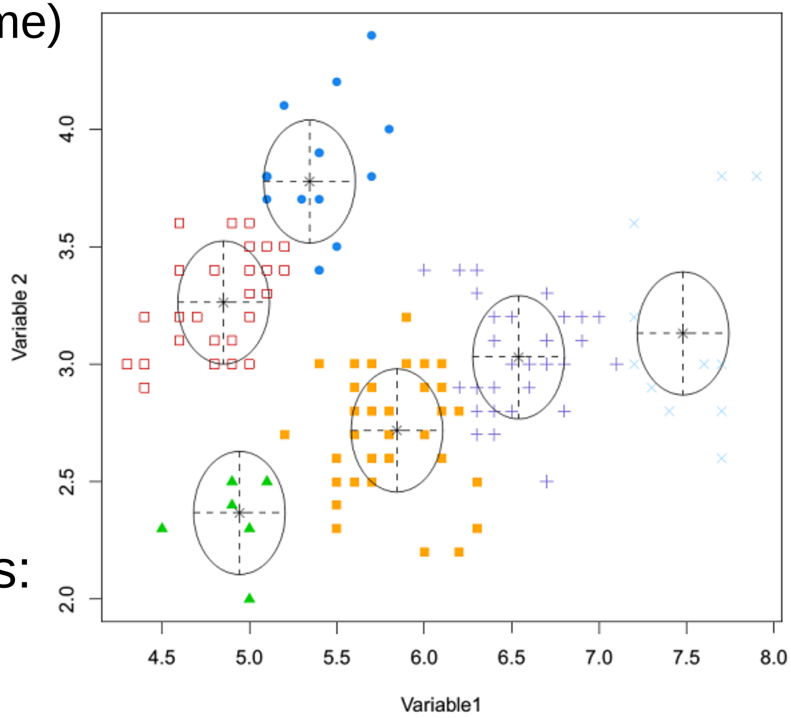
Identification of model strategies

- Data on model formulation:
  - General model structure (space and time)
  - Pest population and dispersal
  - Host plant
- Unsupervised clustering :
  - Model-based clustering
  - 8 clusters best supported by the data
- Data on model use to interpret clusters:
  - Which pests and hosts?
  - What economic sector?
  - How is model parameterised and analysed?



*Fraley C, Raftery AE (2002) Model-based clustering, discriminant analysis, and density estimation. **Journal of the American Statistical Association**, 97, 611-631.*

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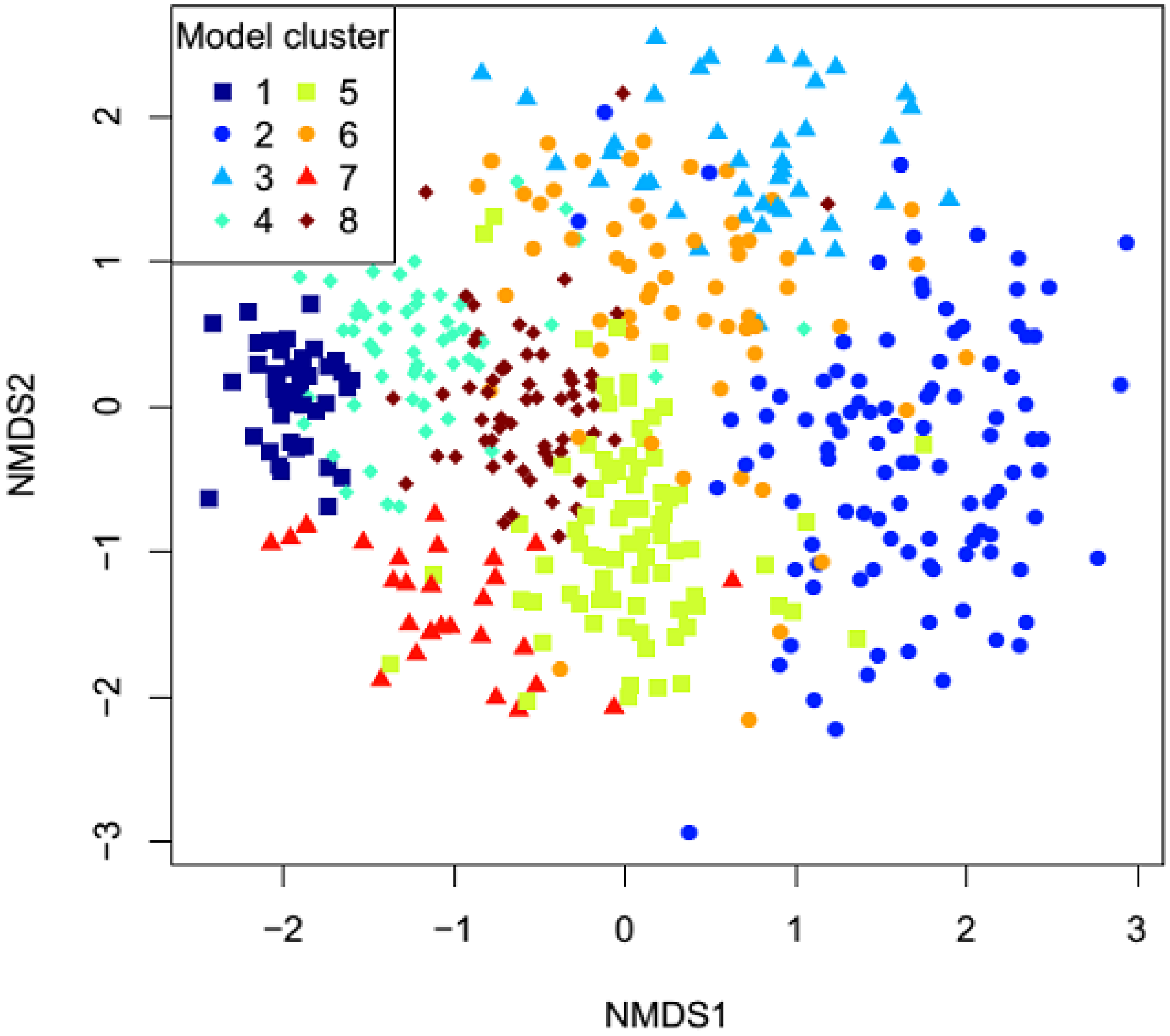
Cluster visualisation



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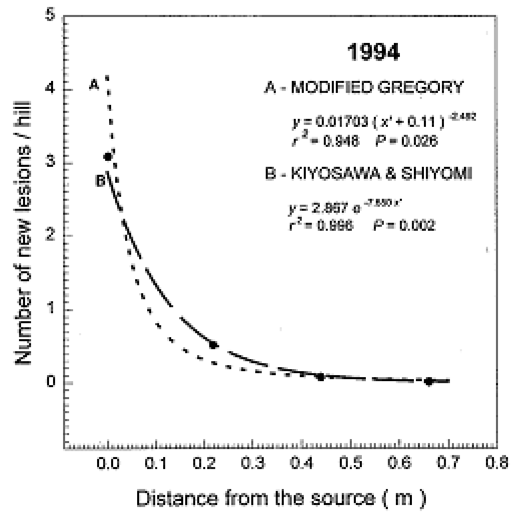
Strategy 1 - Single pest dispersal event

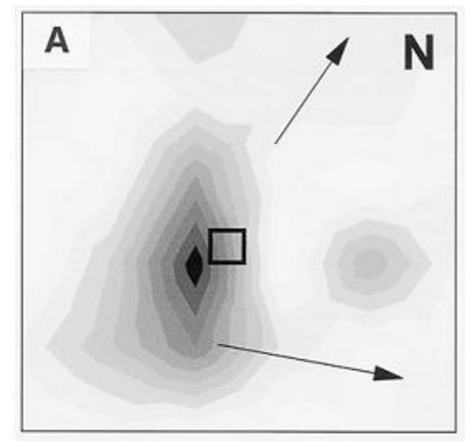
Dispersal kernel and disease gradient models

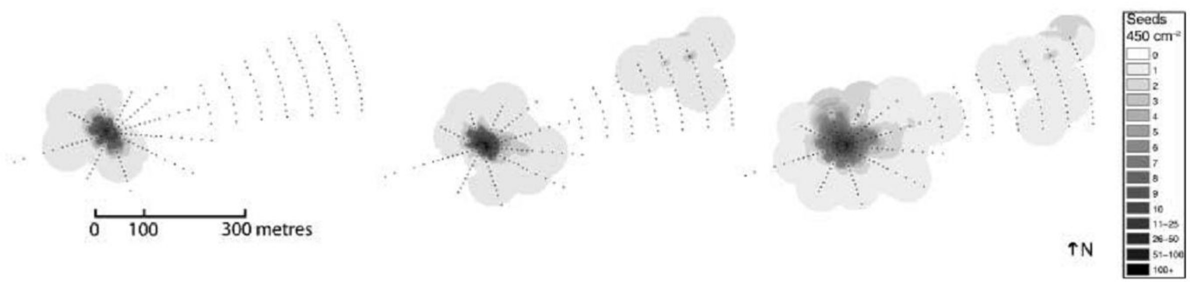
No temporal dynamics

Typically small spatial scale

Often used for crop diseases and seed dispersal







Mundt CC, Ahmed HU, Finckh MR, Nieva LP, Alfonso RF (1999) Primary disease gradients of bacterial blight of rice. ***Phytopathology****, 89, 64-67.*

Paulitz TC, Dutilleul P, Yamasaki SH, Fernando WGD, Seaman WL (1999) A generalized two-dimensional Gaussian model of disease foci of head blight of wheat caused by Gibberella zeae. ***Phytopathology****, 89, 74-83.*

Dauer JT, Mortensen DA, Vangessel MJ (2007) Temporal and spatial dynamics of long-distance Conyza canadensis seed dispersal. ***Journal of Applied Ecology****, 44, 105-114.*

Strategy 2 – Simulation of specific pest and host dynamics

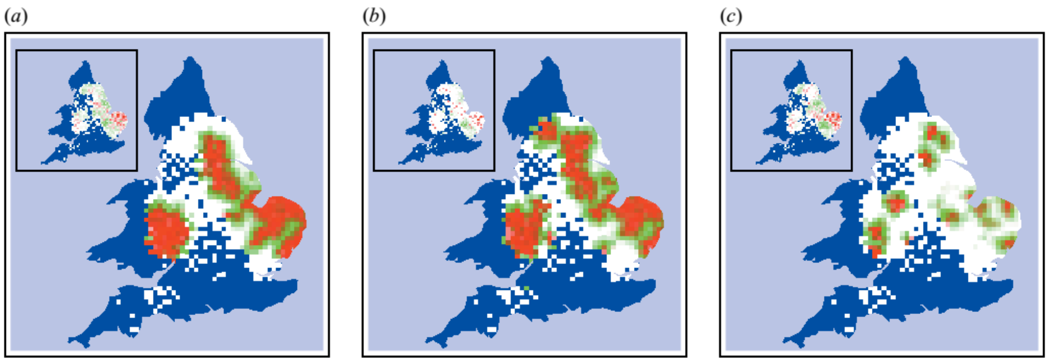
Complex simulations with lots of realistic detail

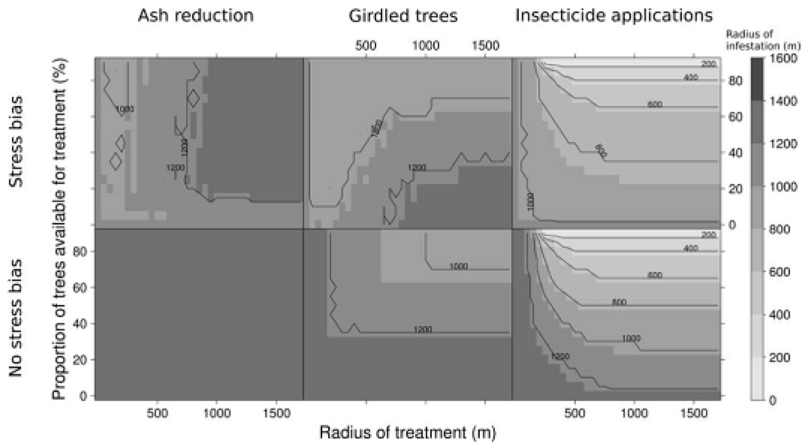
Dynamics and dispersal

Landscape heterogeneity

Multiple entry

Used to experiment with risk mitigation





Gilligan CA, Truscott JE, Stacey AJ (2007) Impact of scale on the effectiveness of disease control strategies for epidemics with cryptic infection in a dynamical landscape: an example for a crop disease. ***Journal of the Royal Society Interface****, 4, 925-934.*

Mercader RJ, Siegert NW, Liebhold AM, Mccullough DG (2011) Simulating the effectiveness of three potential management options to slow the spread of emerald ash borer (Agrilus planipennis) populations in localized outlier sites. ***Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere****, 41, 254-264.*

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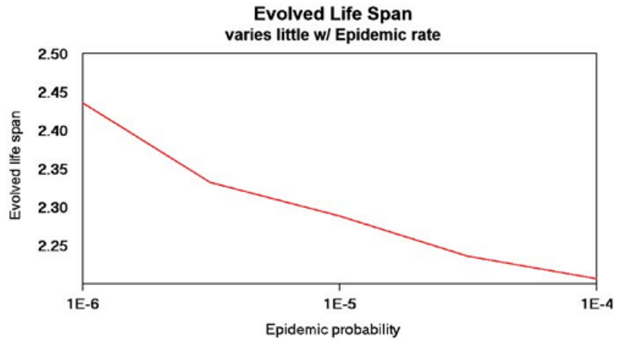
Strategy 3 – Simulation of generic pest and host dynamics

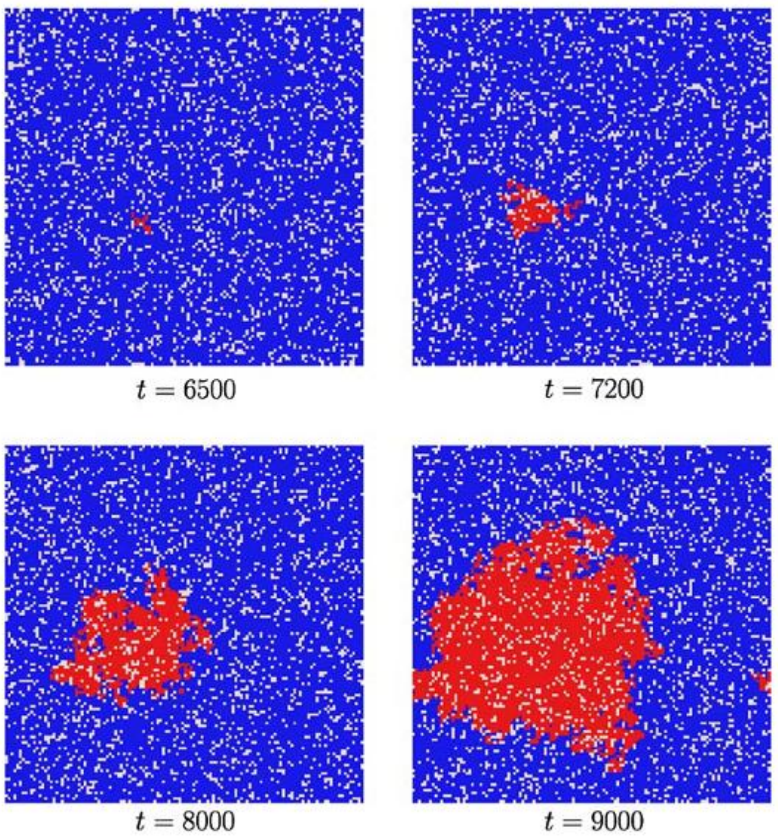
Maths and simulations for generic organisms

Stochastic dynamics and dispersal

Uniform landscape

Used to develop theory, including interactions and evolution





Korniss G, Caraco T (2005) Spatial dynamics of invasion: the geometry of introduced species. ***Journal of Theoretical Biology****, 233, 137-150.*

Mitteldorf J, Pepper J (2009) Senescence as an adaptation to limit the spread of disease. ***Journal of Theoretical Biology****, 260, 186-195.*

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Strategy 4 – Pest spread or dispersal in continuous space and time

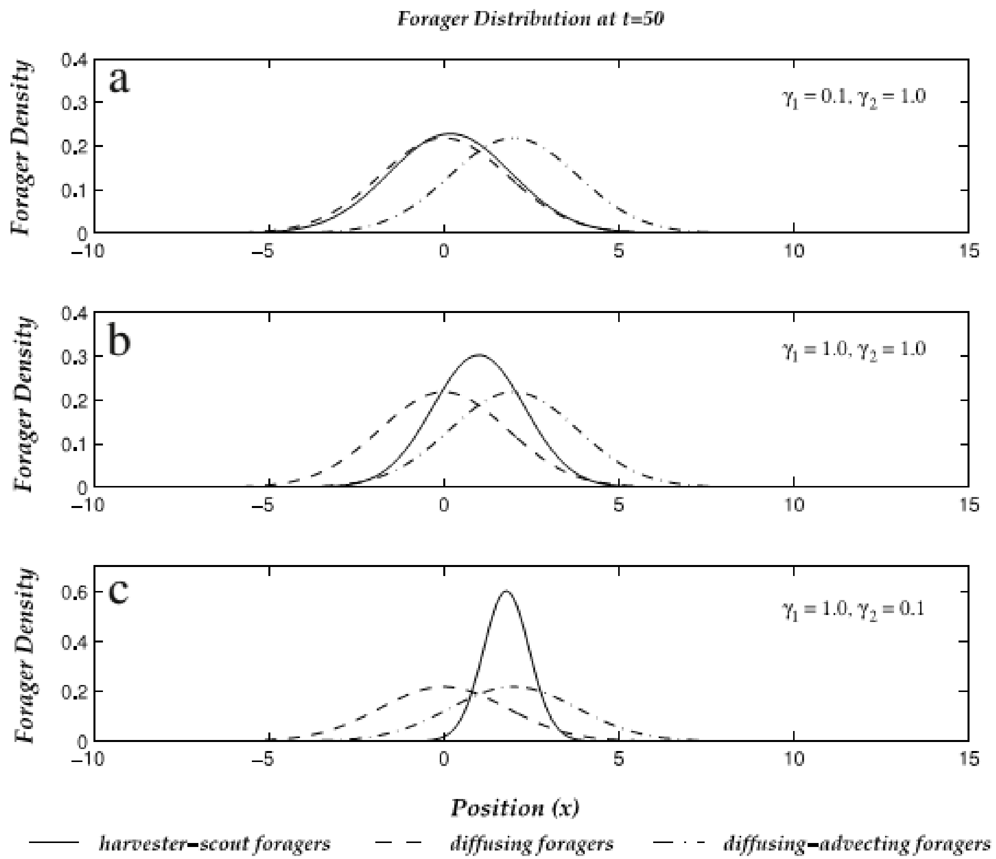
Diffusion and reaction-diffusion

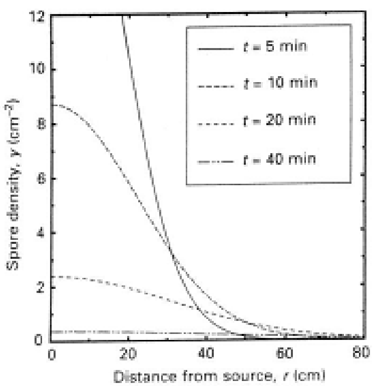
Deterministic spread or dispersal

Generic pests

Uniform landscape

Spread from a single entry point





*Tyson RC, Wilson JB, Lane WD (2011) Beyond diffusion: Modelling local and long-distance dispersal for organisms exhibiting intensive and extensive search modes. Theoretical **Population Biology**, 79, 70-81.*

*Yang XS, Madden LV, Brazee RD (1991) Application of the diffusion equation for modeling splash dispersal of point-source pathogens. **New Phytologist**, 118, 295-301.*

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Strategy 5 – Large-scale simulation of specific pest spread

Stochastic pest spread simulation models

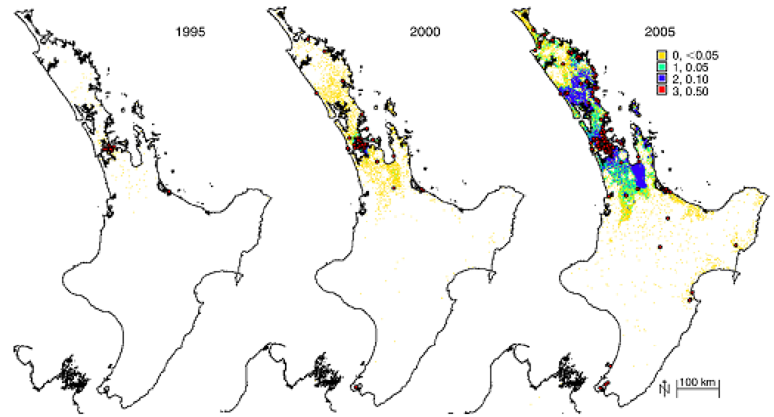
No host plant dynamics

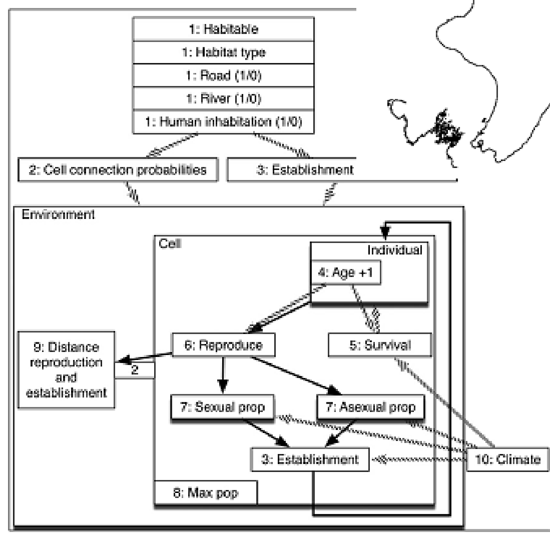
Heterogeneous landscapes

Multiple entry

Used for invasive plants and insects

Risk mitigation often modelled





Pitt JPW, Worner SP, Suarez AV (2009) Predicting Argentine ant spread over the heterogeneous landscape using a spatially explicit stochastic model. ***Ecological Applications****, 19, 1176-1186.*

Fennell M, Murphy JE, Armstrong C, Gallagher T, Osborne B (2012) Plant Spread Simulator: A model for simulating large-scale directed dispersal processes across heterogeneous environments. ***Ecological Modelling****, 230, 1-10.*

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Strategy 6 – Iterative colonisation of hosts over a single growing season

Epidemic models

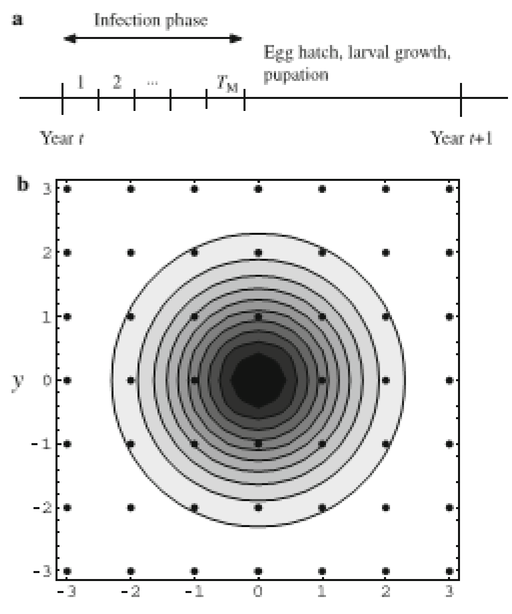
Hosts are individual plants, with no dynamics

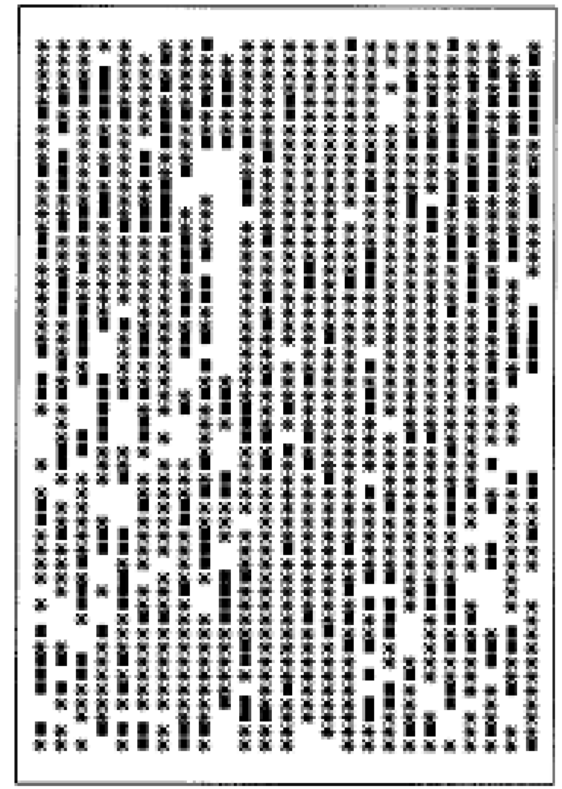
Pests are presence/absence per host

Small spatial scales

Spatially and temporally uniform landscape

Applied to crop diseases





*Pethybridge SJ, Madden LV (2003) Analysis of spatiotemporal dynamics of virus spread in an Australian hop garden by stochastic modeling. **Plant Disease**, 87, 56-62.*

*Takasu F (2009) Individual-based modeling of the spread of pine wilt disease: vector beetle dispersal and the Allee effect. **Population Ecology**, 51, 399-409.*

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Strategy 7 – Large-scale simulation of the pest dispersal process

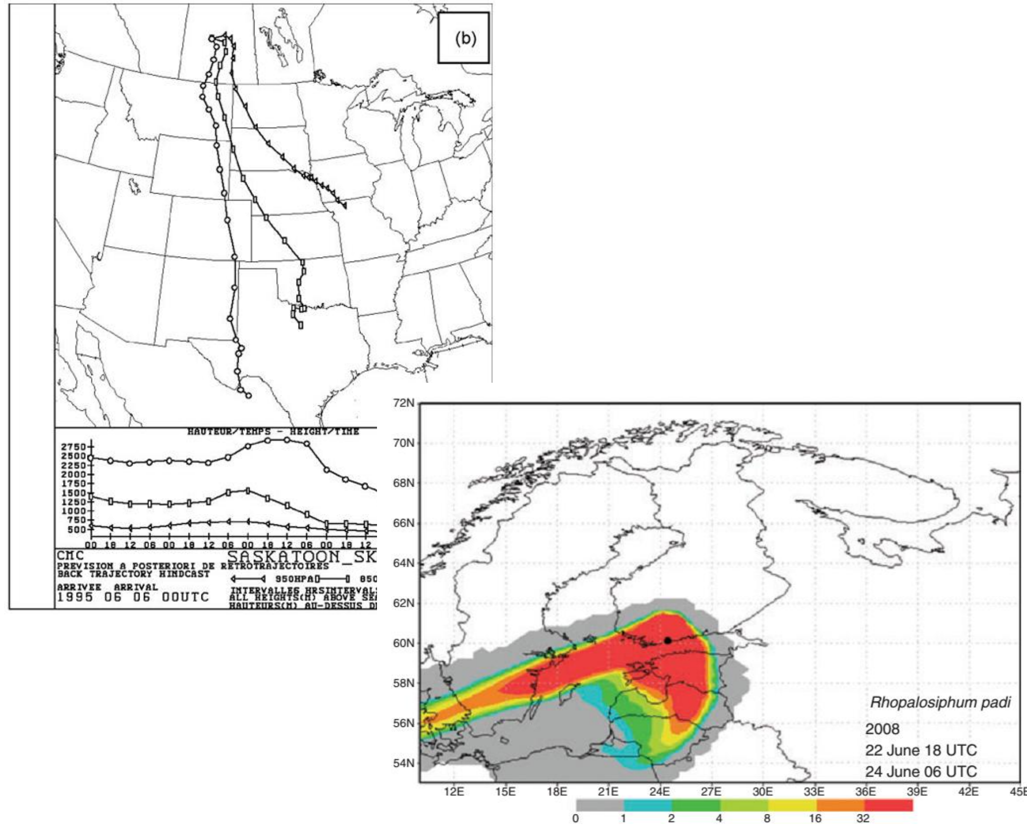
Lagrangian dispersion models

3-dimensional models of wind dispersal trajectories

Individual pests

Temporal forcing by meteorology

Mainly insects and diseases



Hopkinson RF, Soroka JJ (2010) Air trajectory model applied to an in-depth diagnosis of potential diamondback moth infestations on the Canadian Prairies. ***Agricultural and Forest Meteorology****, 150, 1-11.*

Leskinen M, Markkula I, Koistinen J et al. (2011) Pest insect immigration warning by an atmospheric dispersion model, weather radars and traps. ***Journal of Applied Entomology****, 135, 55-67.*

Strategy 8 – Continuous-space pest spread in discrete time

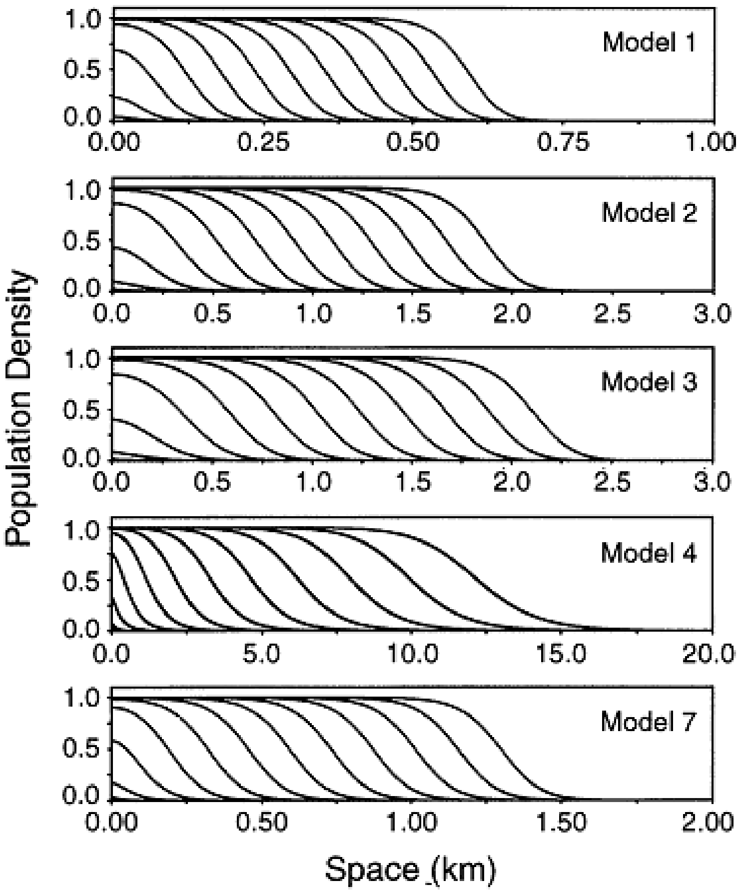
Integrodifference wavespeed models

Highly mathematical

1-dimensional

Spatially homogeneous

Mainly invasive plants and insects



*Kot M, Lewis MA, Van Den Driessche P (1996) Dispersal data and the spread of invading organisms. Ecology, **77**, 2027-2042.*

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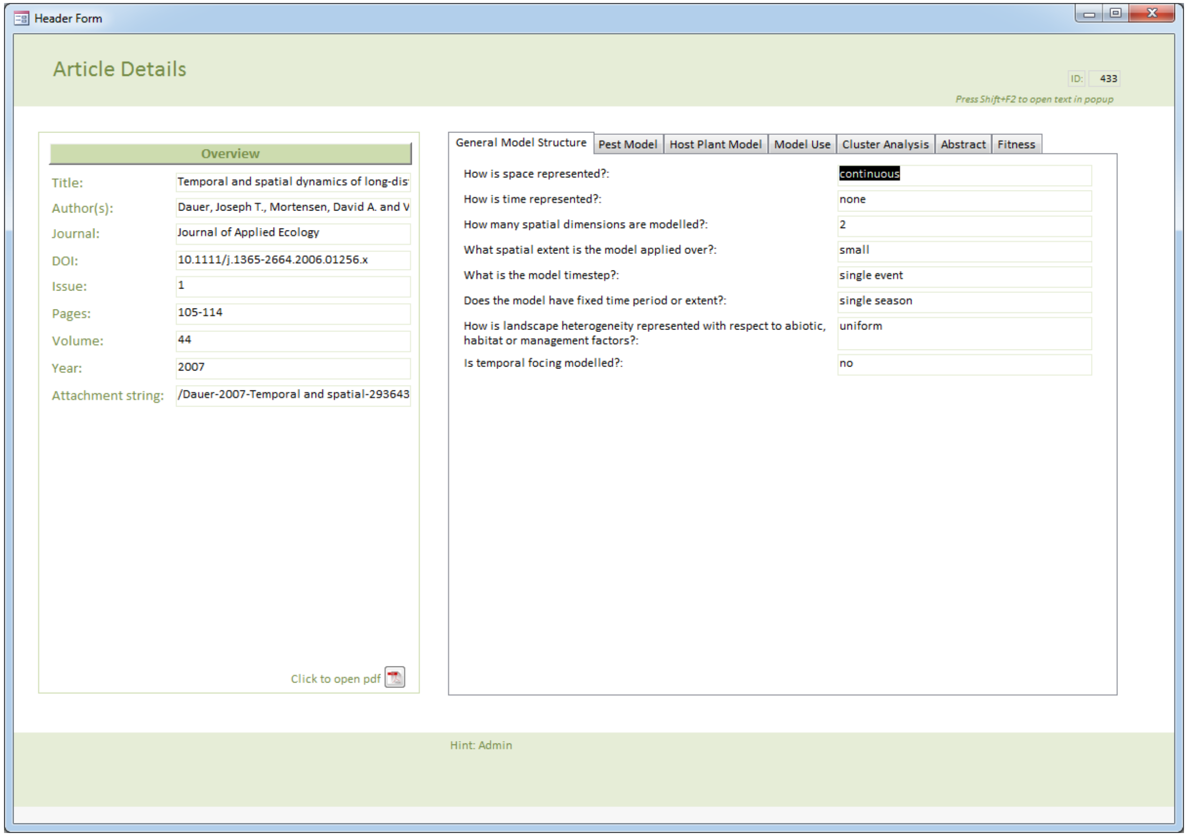
Electronic inventory

- All information collected is held in an Microsoft Access database
- The database is fully searchable
- Each record contains a clickable link to the published model (PDF)



Evaluation of strategy fitness

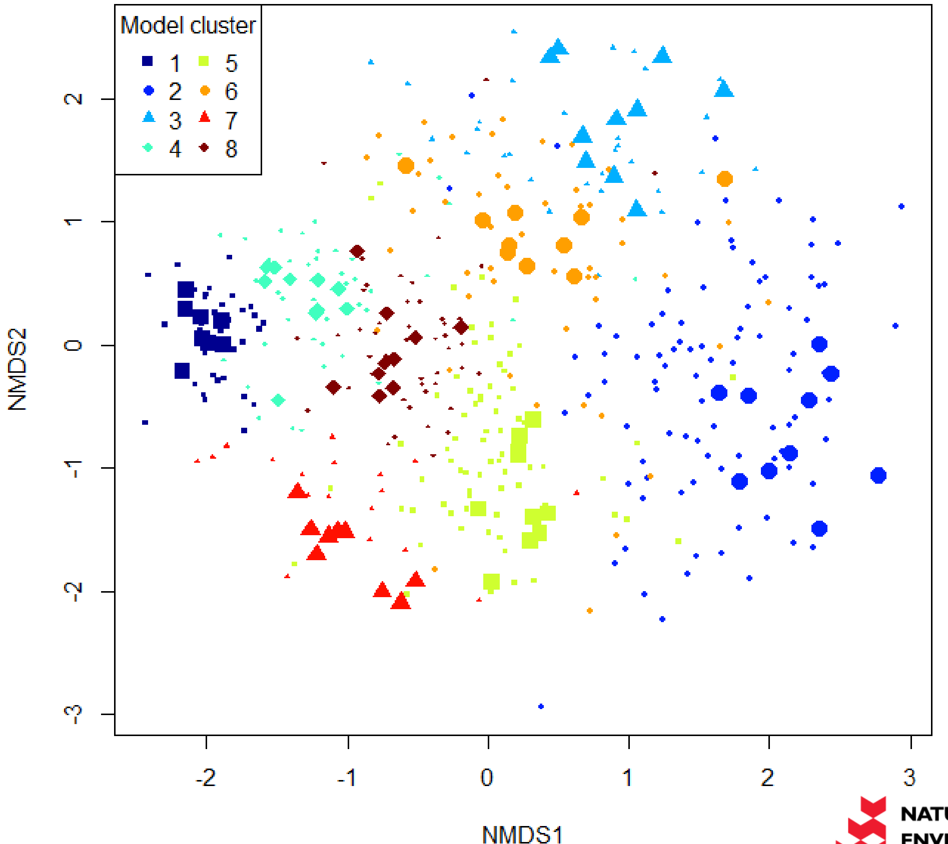
- **AIM:** What parts of EFSA risk assessment can spread or dispersal modelling help with?
- Quantitative answers to risk assessment questions (Appendix C Stage 2B - Assessment of the probability of introduction and spread and of potential consequences):
  - Entry*
  - Establishment*
  - Spread
  - Impact*

**** Literature review only includes models with these + spread***

EFSA Panel on Plant Health (2010) Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA. ***EFSA Journal****, 8, 1495.*

The 10 representative models

- Mainly based on model application, but also potential:
  - Data from literature review
  - Re-examine 10 representative models per cluster...



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Fitness criteria

Does the strategy predict:

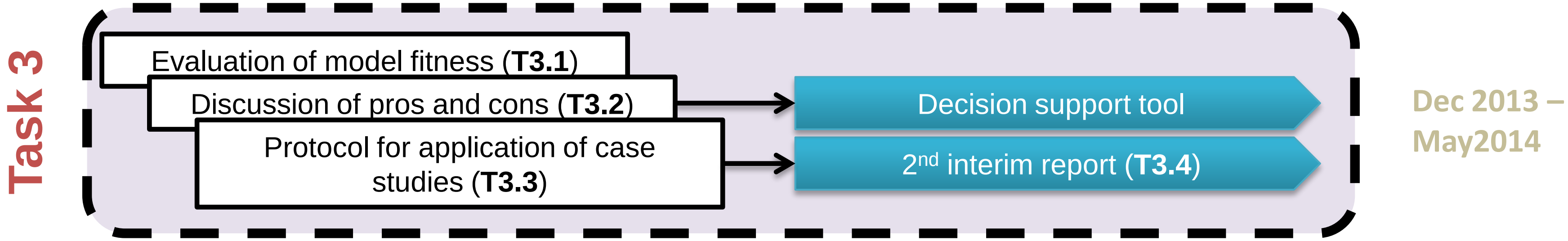
1. Effects of phytosanitary measures?
2. Where host plants permit establishment and spread?
3. Where the environment permits establishment and spread?
4. Whether competition or natural enemies limit establishment and spread?
5. Effectiveness of risk mitigation measures?
6. Key biological characteristics facilitating pest spread?
7. Spread rates through ‘natural’ dispersal mechanisms?
8. Spread rates through human dispersal?
9. Spread rates through multiple dispersal mechanisms?
10. Spread over the whole risk assessment area (and beyond)?
11. Impact on crop yield or quality?

Is the strategy:

12. Independent of pest demography or population dynamic data?
13. Independent of pest distribution data?
14. Independent of pest dispersal data?
15. Used for multiple taxonomic groups?
16. Used for multiple functional groups?
17. Used for multiple host plant functional groups?
18. Used across multiple economic sectors?

Reporting the fitness evaluation

- Score each criteria for the strategies
- Fitness is scored high=3, medium=2, low=1
- Decision support tool



The Decision Support Scheme

Must consider the strategy properties, risk assessment tasks and data constraints.

Multi-criteria assessment table

Risk assessor selects relevant fitness criteria

Risk assessment needs	Fitness score per strategy							
	S1	S2	S3	S4	S5	S6	S7	S8
Need to predict effect of phytosanitary measures	0	1	1	0	0	1	1	0
Need to predict spread at large spatial scales	0	0	0	1	1	1	1	0
Need to represent climate effects on the pest	0	0	1	1	0	1	0	1
Need to predict impact of the pest on host yield	0	1	1	0	0	1	1	0
Fitness Sum	1	2	10	6	3	12	11	4

Risk assessor selects relevant constraints

Potential constraints	S1	S2	S3	S4	S5	S6	S7	S8
Need data on pest distribution	0	1	0	1	1	1	0	0
Need data on pest dispersal	1	1	0	0	0	1	1	1
Constraints sum	1	2	0	1	1	2	1	1

Choice of strategy
(High fitness & low constraints)

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Summary

- We reviewed the scientific literature and documented 468 papers with models of pest spread or dispersal.
- Cluster analysis identified 8 generic modelling strategies.
- We are currently evaluating criteria to evaluate their relative fitness for EFSA risk assessment and feeding this into a decision support tool.

Thank you for your attention.

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