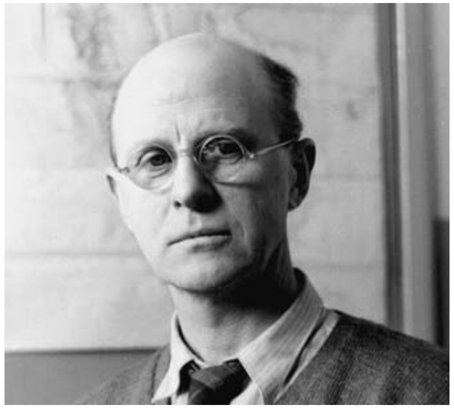
Early detection of forest invaders in New Zealand: optimising surveillance effort based on spatially-explicit modelling of high-risk pathways

Nicolas Meurisse (Scion), Steven Mascaro (BI),
John Kean (AgResearch), Paul Stevens (MPI)
Lindsay Bulman (Scion)

IPRRG 11, Ottawa, August-Sept. 2017

(New Zealand Forest Research Institute)

New Zealand – an invasion 'hotspot'



Charles S. Elton (1958)

"No place in the world has received for such a long time such a steady stream of aggressive invaders"

Pacific rat
(1200s)

Goat
(1770s)

Honeybee
(1839)

Possum
(1858)

Brown trout
(1860s)

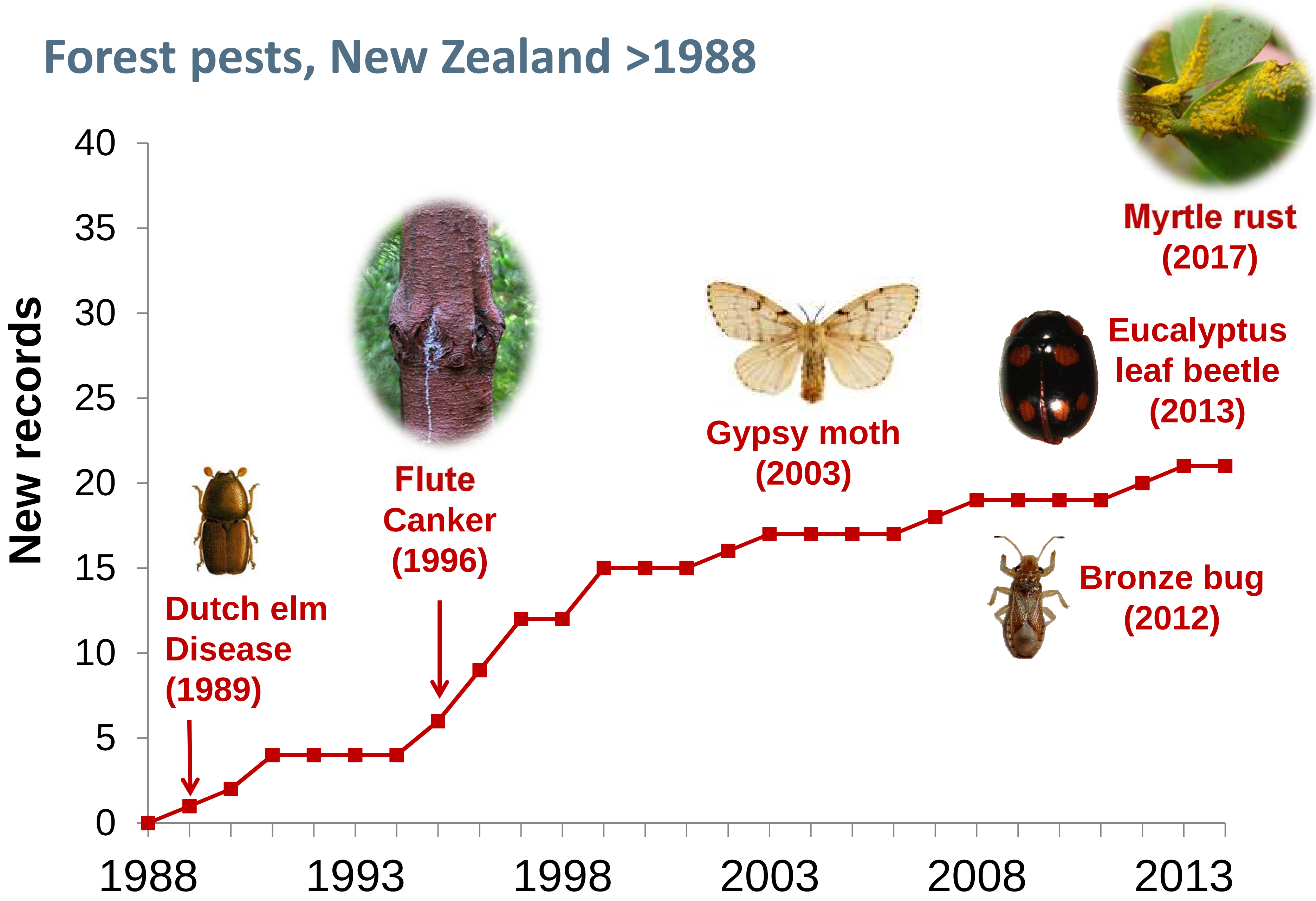
Ferret
(1880s)

Woodwasp
(1900's)

Eucalyptus
tortoise beetle
(1916)

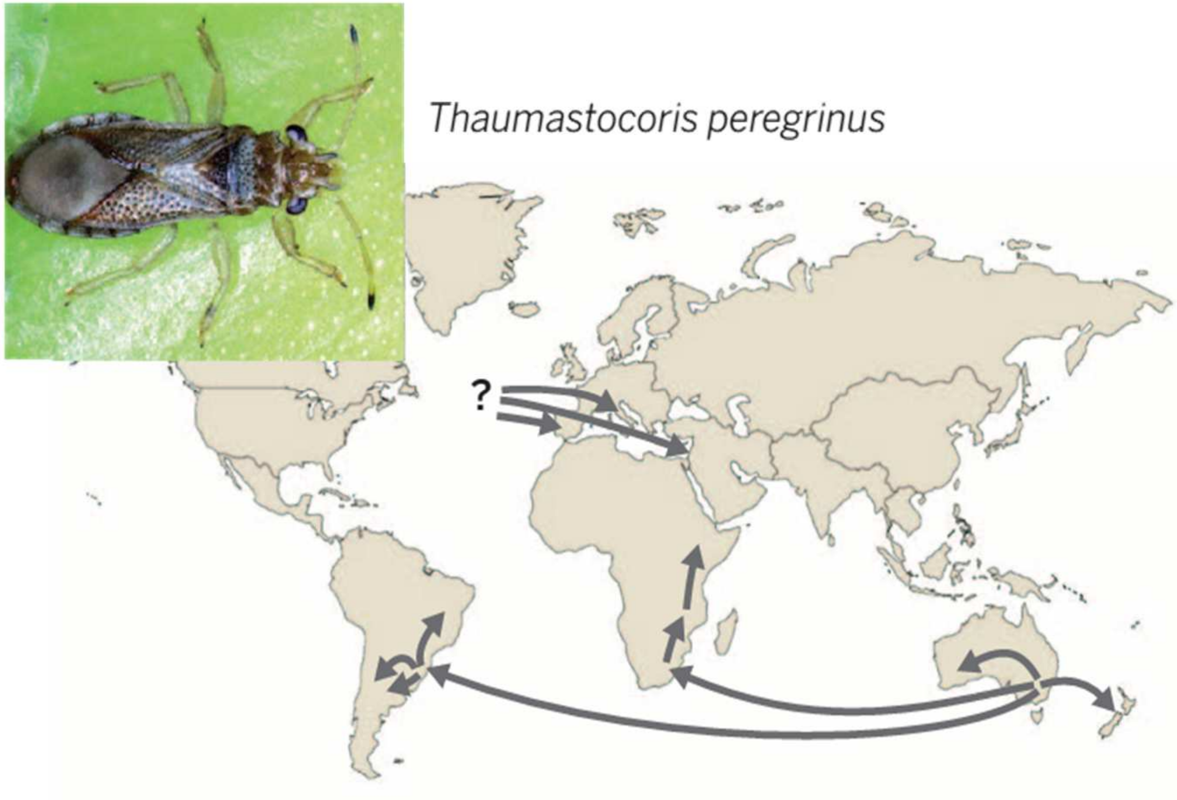
German wasp
(1940s)

Forest pests, New Zealand >1988



Biosecurity

Need to protect plants and animals from foreign, invasive pests & diseases

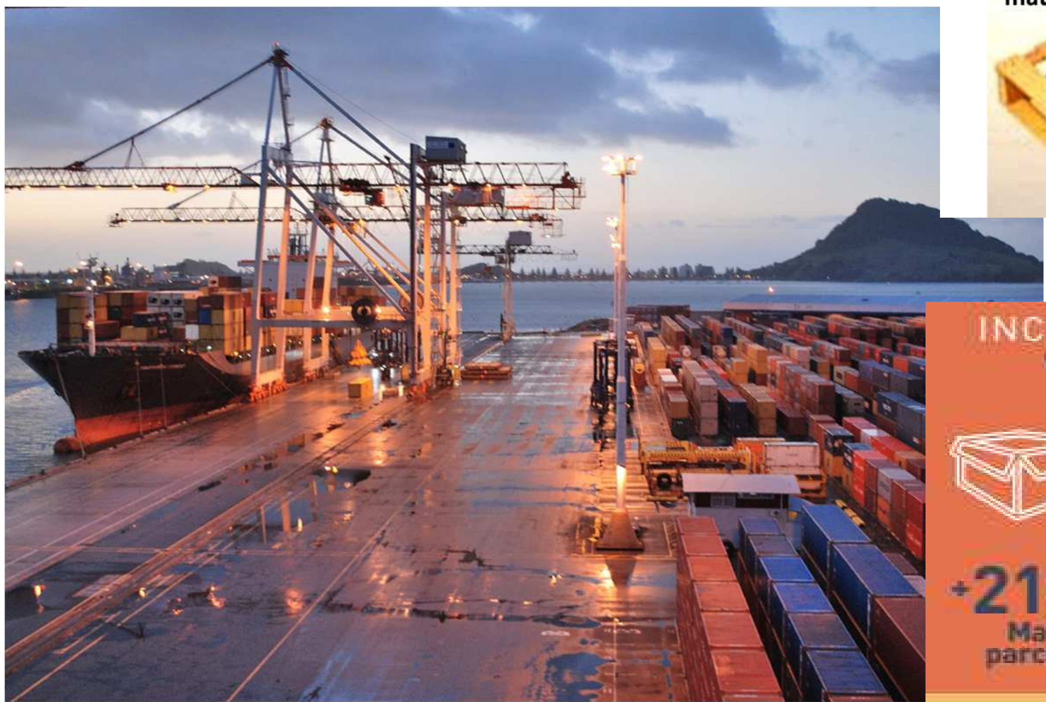


M. J. Wingfield *et al.*
Science **349**, 832 (2015)

Biosecurity

NZ govt expenditure (animal and plant)- $ 251 million

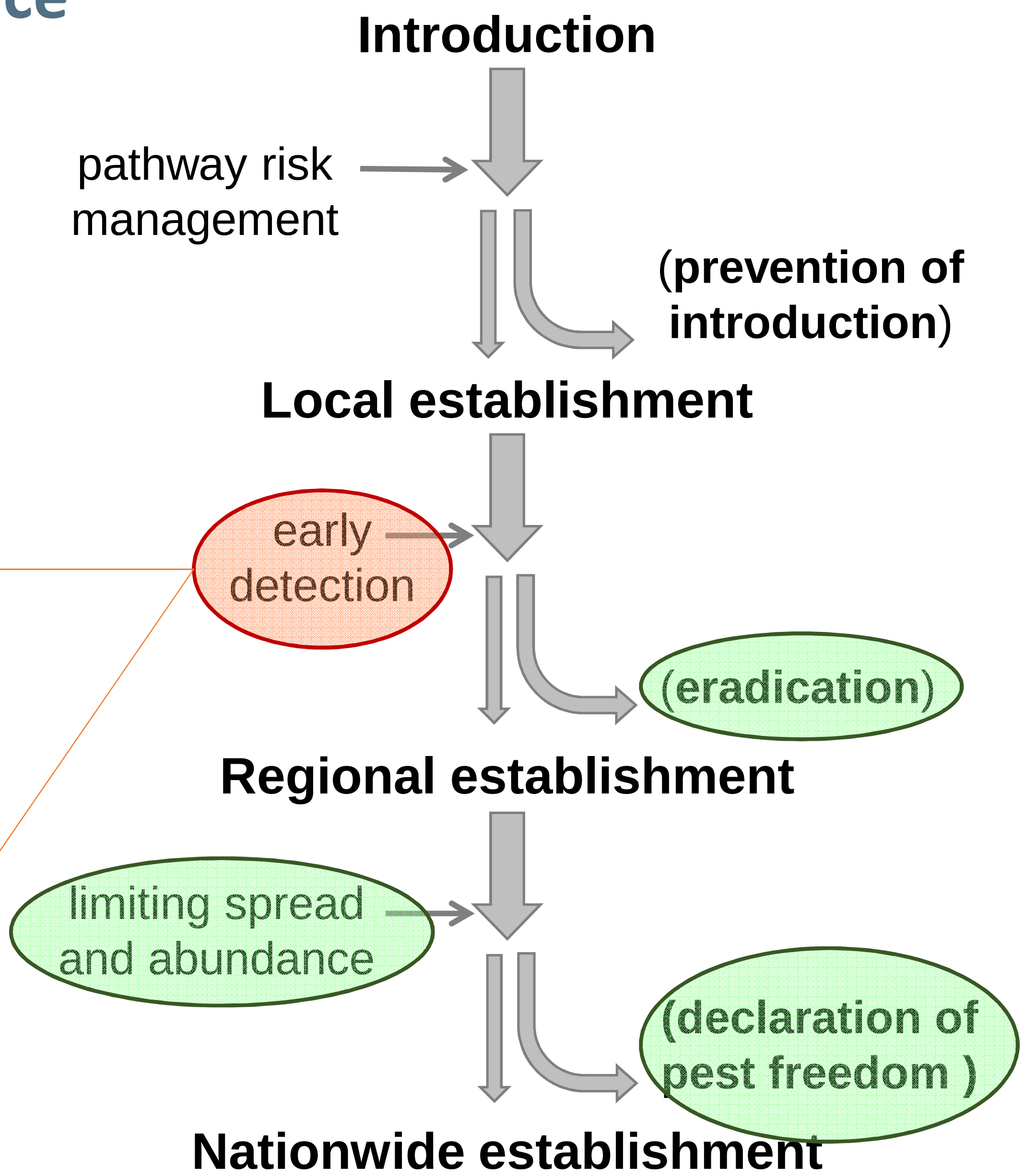
1. Border ($190 million)
2. Surveillance ($26 million)
3. Response ($35 million)



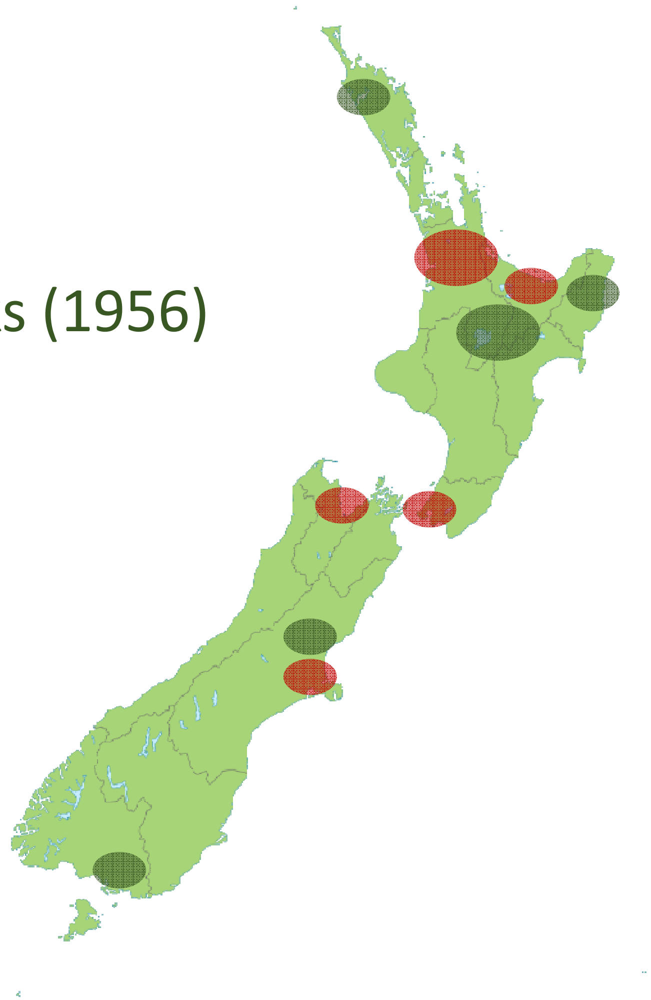
Forest pests – surveillance

Early detection

= more options



Forest pests – surveillance



Surveillance

- forests, prompted by insect outbreaks (1956)
- high risk sites (1990’s/ 2000’s)

Different survey types

- aerial surveys
- forest drive-through surveys
- forest plots
- walk transects

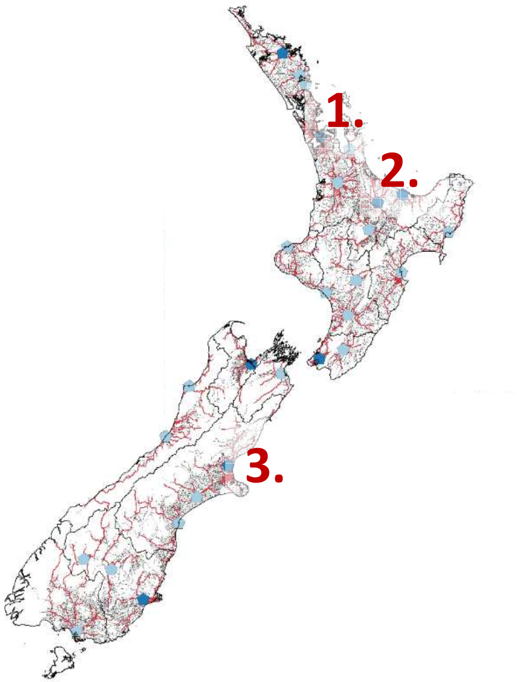
Need to optimize pest detection at points of first establishment

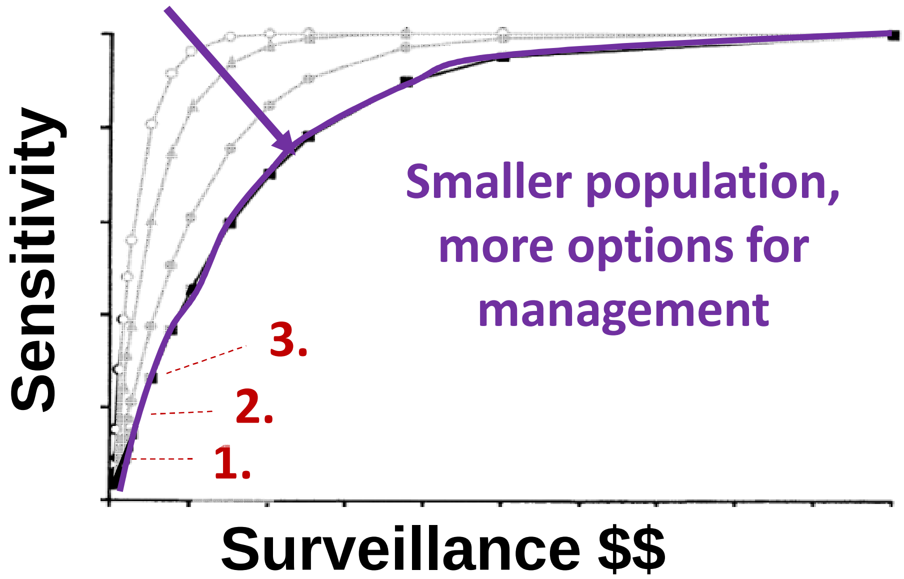
→ new **F**orest **B**iosecurity **S**urveillance system (**FBS**)

(started 2014)

New Forest Biosecurity Surveillance system – why?

- First investment in surveillance = biggest gain
  - law of diminishing return
- Want to maximise overall system sensitivity
  - i.e. maximise probability to detect pest/disease if established population





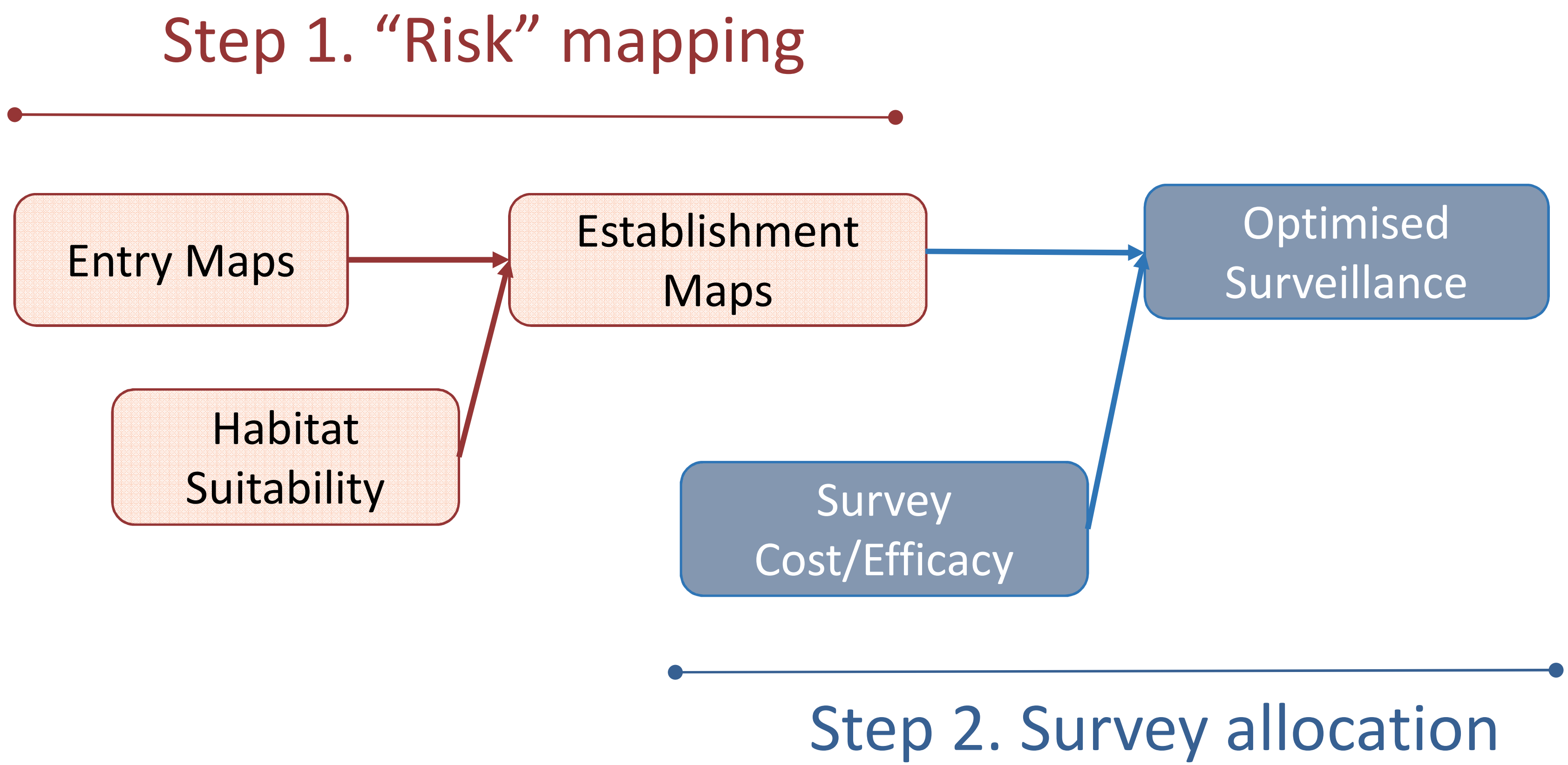
New Forest Biosecurity Surveillance system – how?

Allocation of surveillance effort based on risk and benefit

1. Capture risk from likelihood of "escapes" of pests associated to specific introduction pathways
   - track pests on commodities, vehicles or persons (BN models)
     → introduction maps
   - environmental suitability (host-plants and climate)
     → establishment maps

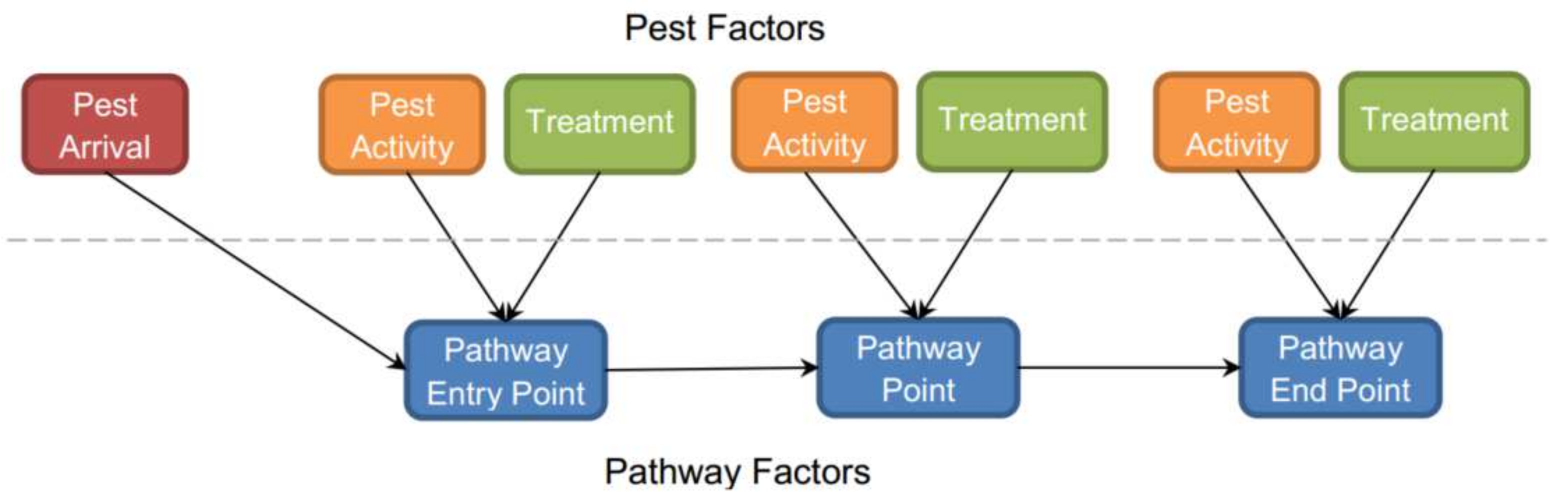
2. Allocation of surveillance effort based on risk maps (considers risk, survey efficacy and survey costs)
   - "impact" weights for # pests/diseases (expert-driven)
   - optimisation to allocate survey effort
   - covers all of New Zealand, "area units" (port, suburb, forest,…)

New Forest Biosecurity Surveillance system – how?



1. “Risk” maps

Modules = Bayesian networks



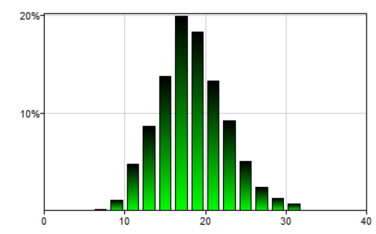
Pathway factors

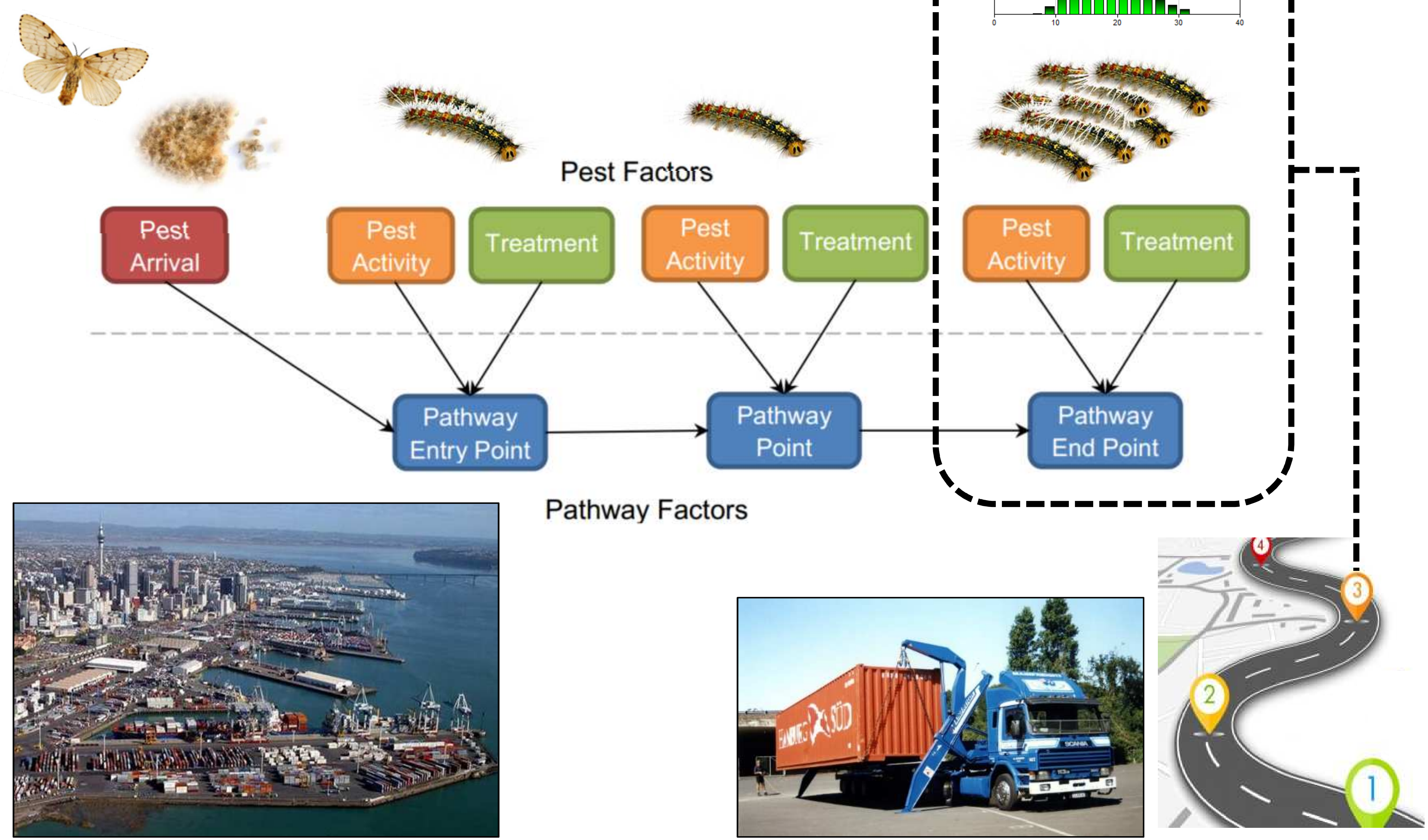
- Known pathways points where pests and diseases escape
- Quantification and tracking of items on pathway points

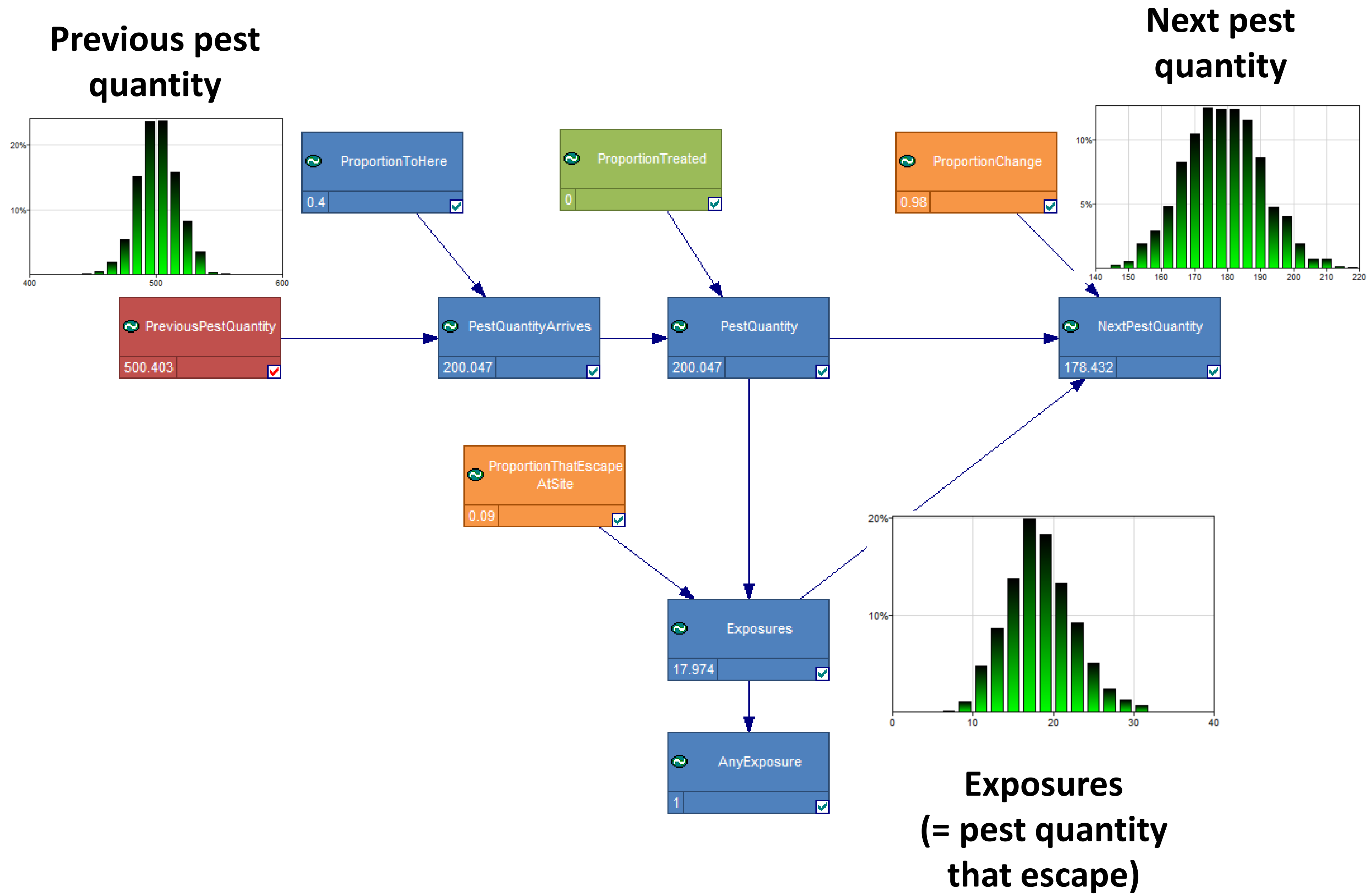
Pest factors

- Quantification of the number of propagules associated to items
- Quantification of their escape rate

1. “Risk” maps

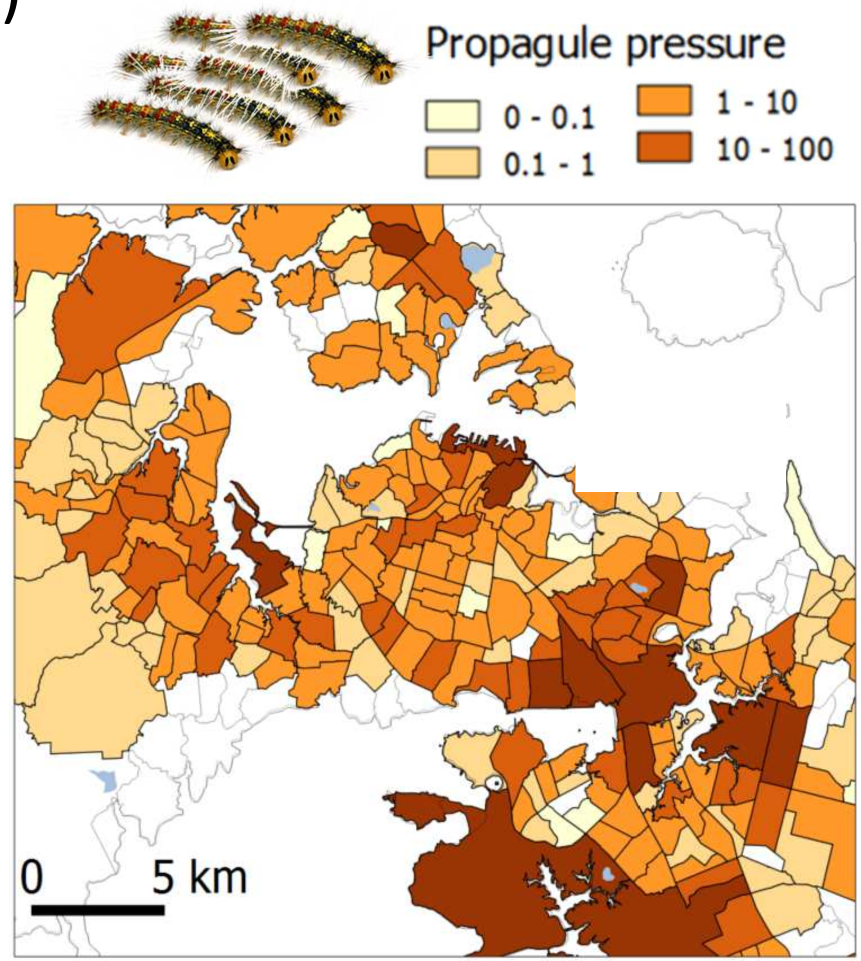

20%
10%
0
10
20
30
40


Pest Factors
Pest Arrival
Pest Activity
Treatment
Pest Activity
Treatment
Pest Activity
Treatment
Pathway Entry Point
Pathway Point
Pathway End Point
Pathway Factors
1
2
3
4


Previous pest quantity
Next pest quantity
ProportionToHere
0.4
ProportionTreated
0
ProportionChange
0.98
PreviousPestQuantity
500.403
PestQuantityArrives
200.047
PestQuantity
200.047
NextPestQuantity
178.432
ProportionThatEscape AtSite
0.09
Exposures
17.974
AnyExposure
1
Exposures
(= pest quantity that escape)

1. “Risk” maps

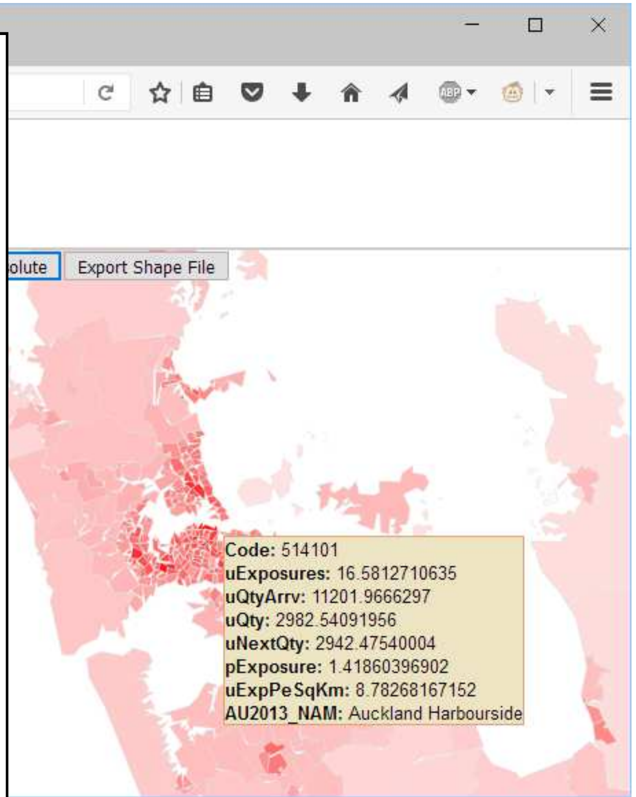
Final entry maps = expected number of escapes in each “area unit” (propagule pressure)



1. “Risk” maps

Spear: **S**patial **P**est **E**ntry **A**nalysis **R**unner

Software for running BN models and managing the results

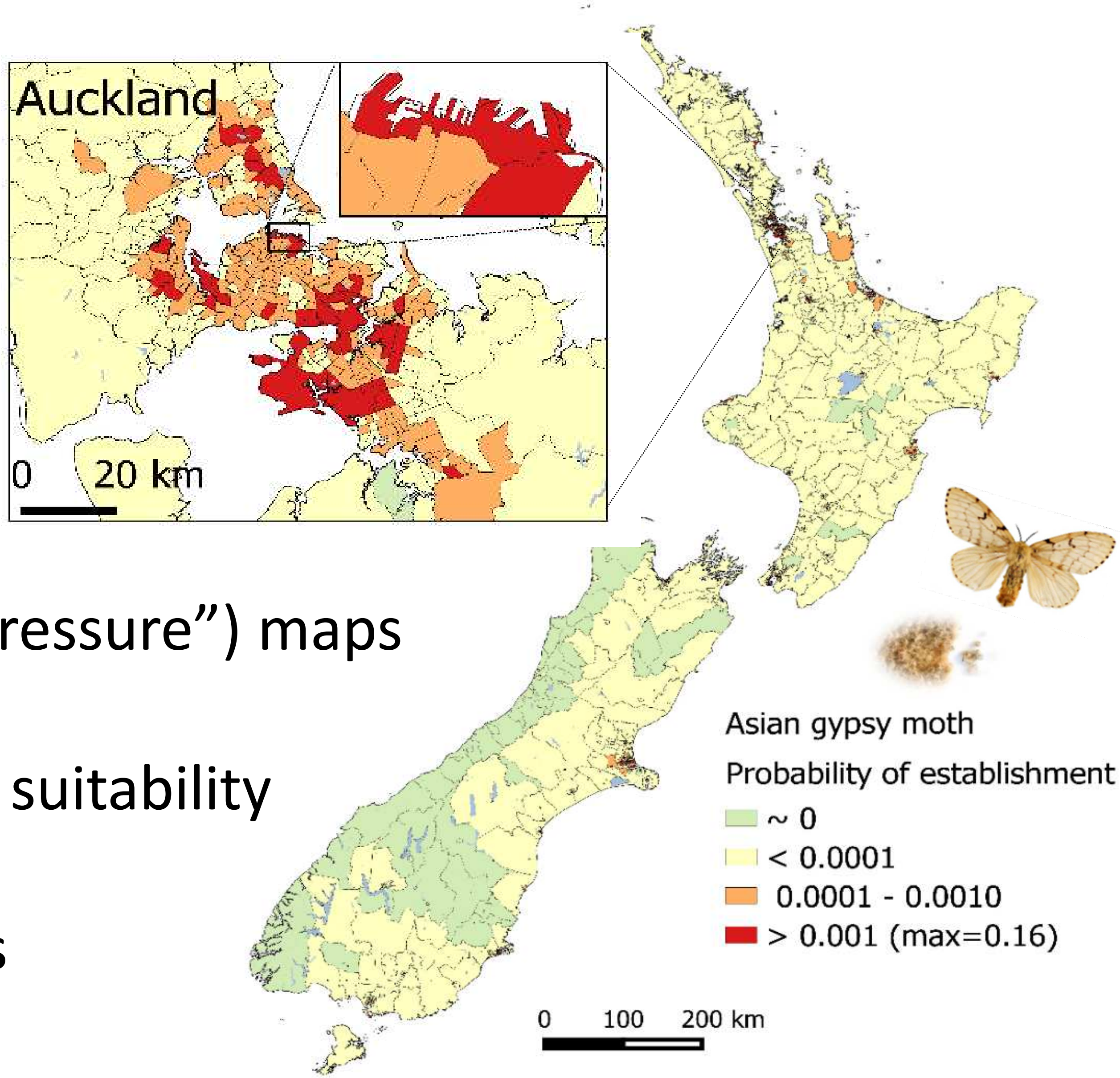


Multiple pests, — X — Multiple pathways

Asian gypsy moth
Asian longhorn beetle
Pine shoot moth
Sudden oak death
Pine pitch canker
…

Sea containers
Wooden furniture
Used vehicles
Used machinery
Overseas visitors
Returning residents
…

1. “Risk” maps



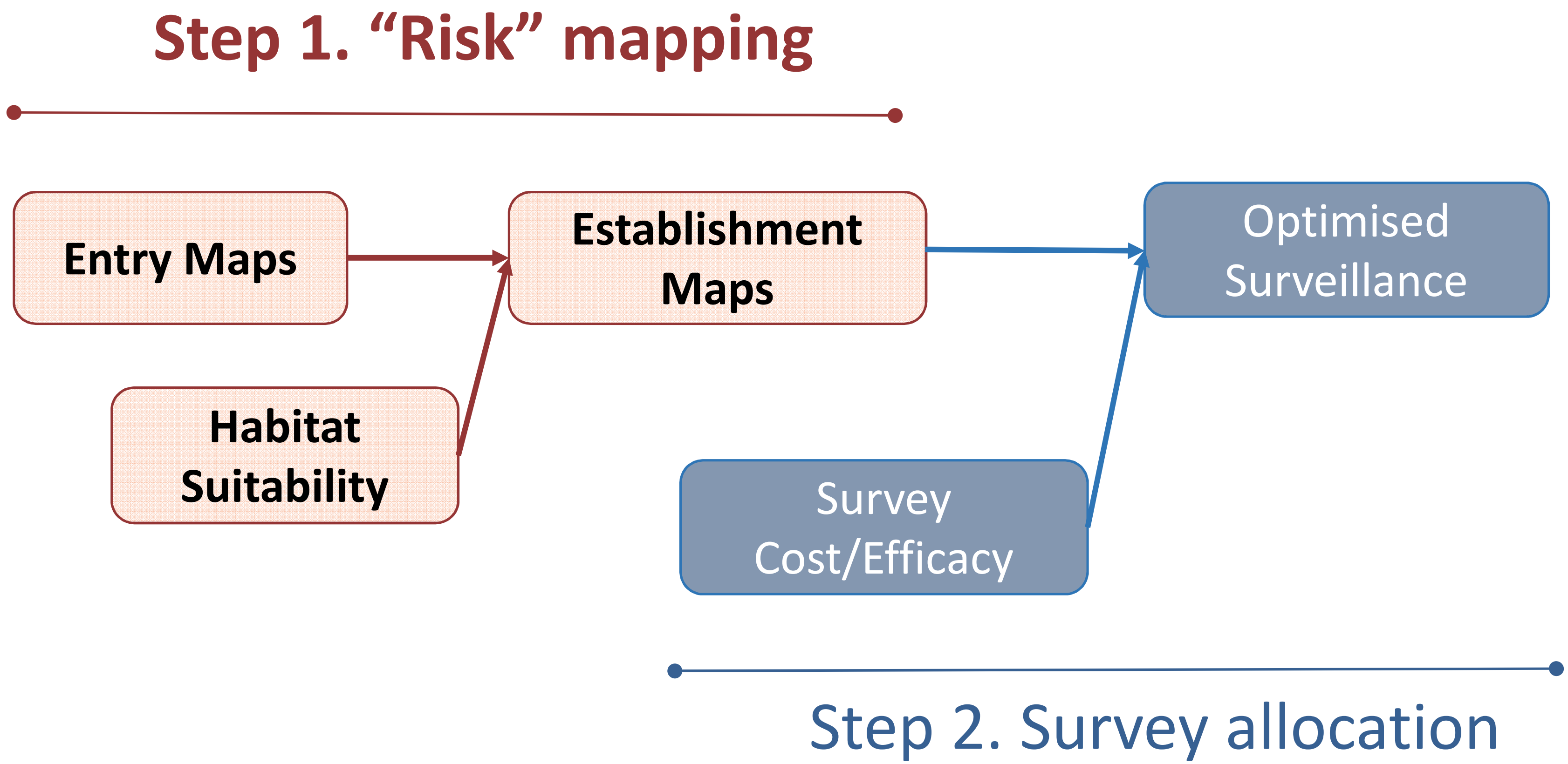
Entry (“propagule pressure”) maps

+

Habitat and climate suitability

=

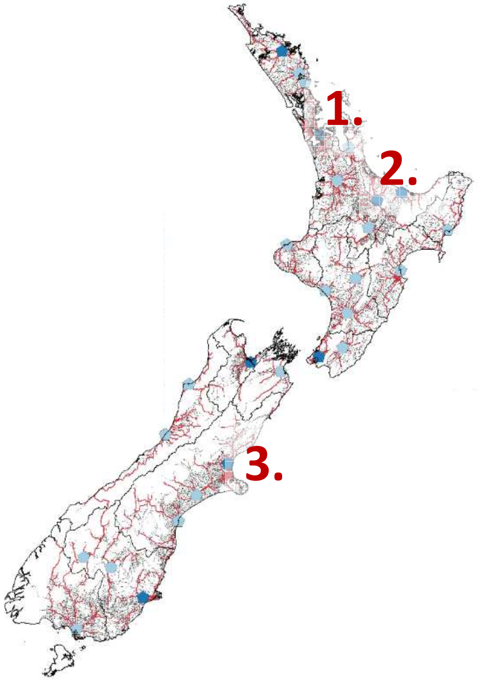
Establishment maps

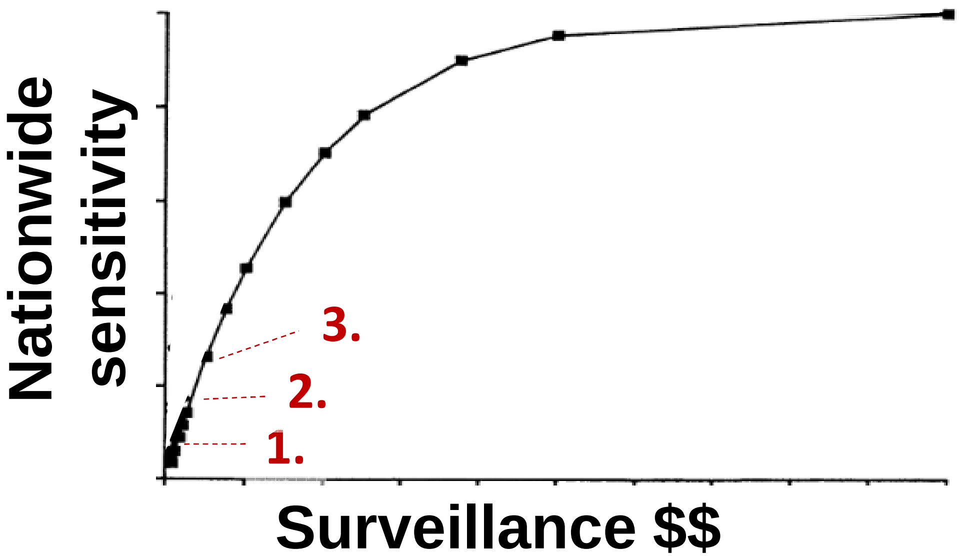


Step 1. "Risk" mapping
Entry Maps
Habitat Suitability
Establishment Maps
Optimised Surveillance
Survey Cost/Efficacy
Step 2. Survey allocation

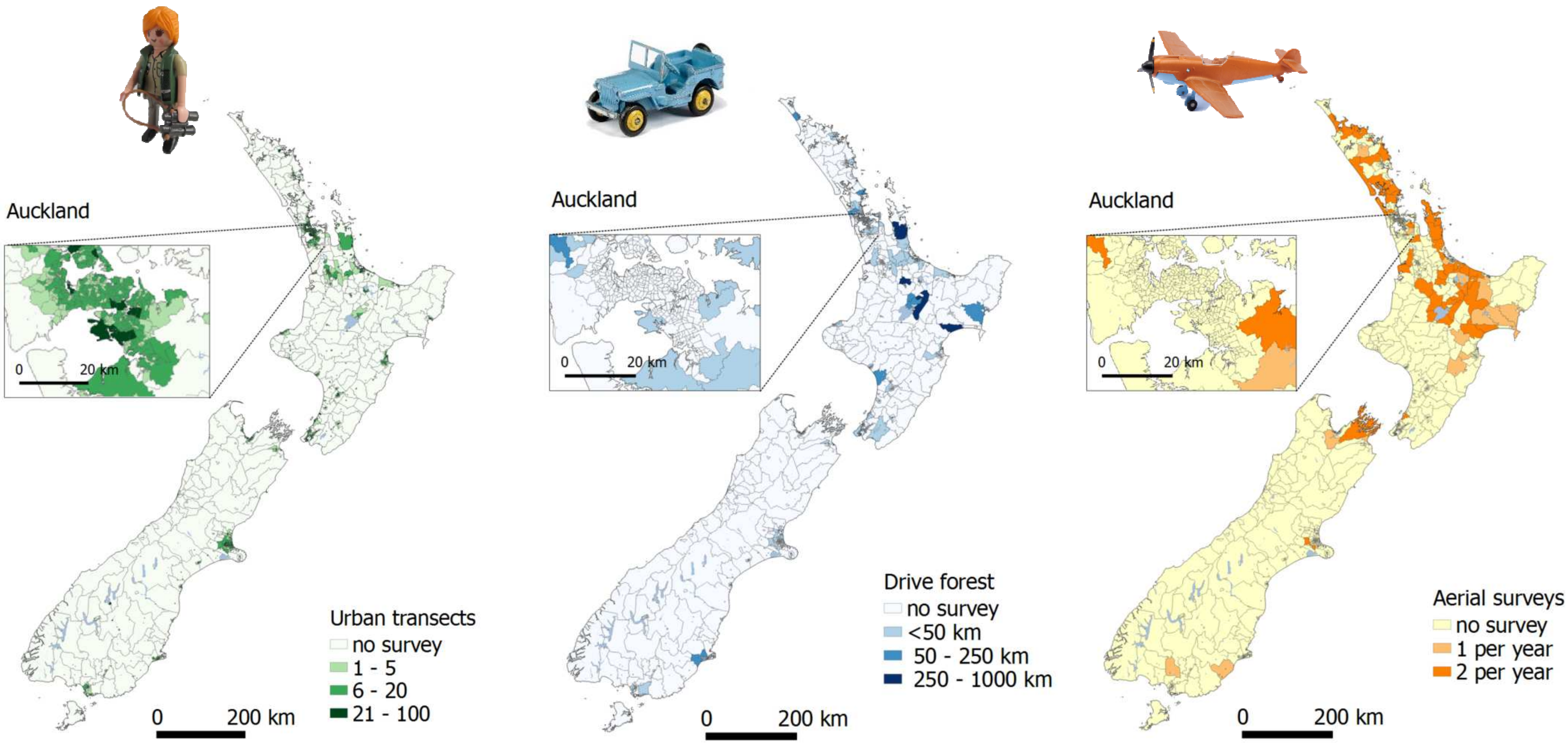
2. Survey allocation

- Want to maximise overall system sensitivity
  - i.e. maximise probability to detect pest/disease if established population
- Allocation on a cent by cent method
  - target population size ("eradicable")
  - iterative process, allocates $$ to location and survey type that provides the best ratio "probability of detection/cost"





2. Survey allocation



Implications and future work

Implementation

- operational surveys in Auckland (urban) and Taupo (rural) in 2017

Value of approach

- merge with “generic risk assessment model”
- address larger number of pests and pathways (incl. BMSB)

Improve the entry models

- identifying gaps in what is being measured
- moving to monthly resolution, incorporating seasonality

Improve risk mapping

- include climate and habitat suitability in BN models
- consider impact and rate of spread

Improve survey allocation

- better understanding of costs and efficacy

Project team

- Government: Ministry for Primary Industries
- Industry: New Zealand Forest Owner Association
- Researchers: Crown Research Institutes Scion and AgResearch
- Co-opted international experts: CEBRA, Bayesian Intelligence

Thank you!

Nicolas Meurisse
Entomologist, Forest Protection, Scion
nicolas.meurisse@scionresearch.com

Date:30/08/2017

Abstract

Early detection of forest invaders in New Zealand: optimising surveillance effort based on spatially-explicit modelling of high-risk pathways
Nicolas Meurisse, Steven Mascaro, John Kean, Paul Stevens, Lindsay Bulman

New Zealand is currently reviewing its system for early-detection of invasive forest pests and diseases. Probabilistic models have been developed to estimate the risk of unintentional introduction of potentially harmful organisms associated with seven import pathways (sea vessels, used vehicles, used machinery, sea containers, wood packaging, wooden furniture, live plants), international passengers (returning residents and visitors) and wind currents (natural introduction). The model estimates propagule pressure associated with each pathway, not only at the entry points (sea and airports) but also at each of 1912 "area units" covering any location in New Zealand. The modelling approach that was used, Bayesian networks, allows it to capture uncertainties in all model variables.
Maps of expected propagule pressure have been produced for four potential insect invaders (Asian gypsy moth, pine shoot moth, Asian and citrus longhorn beetles) and two potential diseases (pine pitch canker and sudden oak death). These aim to represent invaders associated with different modes of introduction and biological characteristics. Specific propagule pressure maps have been weighted by climatic suitability and host-plant availability to produce establishment risk maps. An optimisation model then estimates what allocation of surveillance effort (type and intensity of survey within each area unit) maximises the overall probability of detection of an establishment for any defined budget. The model indicates that the probability of early establishment of forest invaders is particularly high in populated areas and around pathway–specific facilities such as ports, car yards or container cleaning depots. These are priority areas to be surveyed.