BIOECONOMIC APPROCHES TO INVASIVE SPECIES CONTROL

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AARES Symposium

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Some important questions

- Eradicate, contain or do nothing?
- When to stop searching?
- Rapid delimitation of invasions.
- Allocation of search and control resources.
- Tradeoffs between preparedness (pre-discovery) and response (post-discovery).
- Design of efficient search strategies.

Tools and approaches

Analytical mathematical models

Simple numerical models (examples 1 & 2)

Detailed simulation models (example 3)

our focus

Derive rules of thumb

Produce tailored models for expensive invasions
(evolves as program progresses)

Outline

- Essential features of biological invasions.
- Bioeconomic modelling examples:
  - 1: eradicate, contain or do nothing?
  - 2: search theory and population dynamics;
  - 3: spatially-explicit approaches.
- An application to RIFA.
- Concluding comments.

Essential information to describe a biological invader

- rates of spread and growth;
- habitat suitability;
- vulnerability to control techniques;
- severity of damages caused.

Essential information to describe a control program

- the types and amounts of resources available;
- the effectiveness and costs of surveillance and control options;
- constraints imposed by legislation and the environment.

Example 1: eradicate, contain or do nothing?

State-based approach: optimal action depends on state of the system (stochastic dynamic programming)

Minimise:

Total cost of the invasion (present value) { Damage cost; Control cost }

- Damage cost
- Control cost

Subject to:

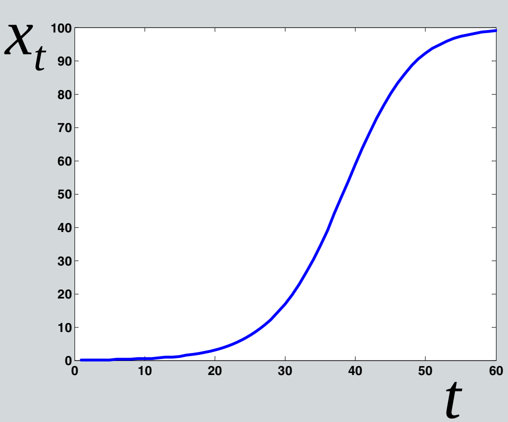
- rate of spread of the invasion
- effectiveness of control options

The model

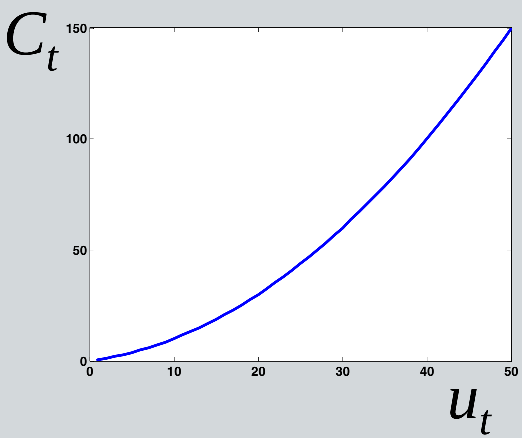
Cacho (2006)

Requires six parameters to describe:

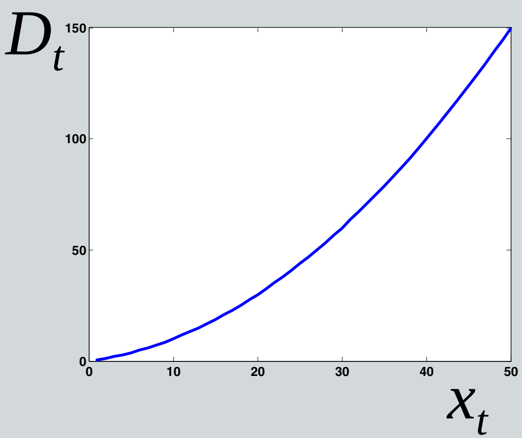
state transition



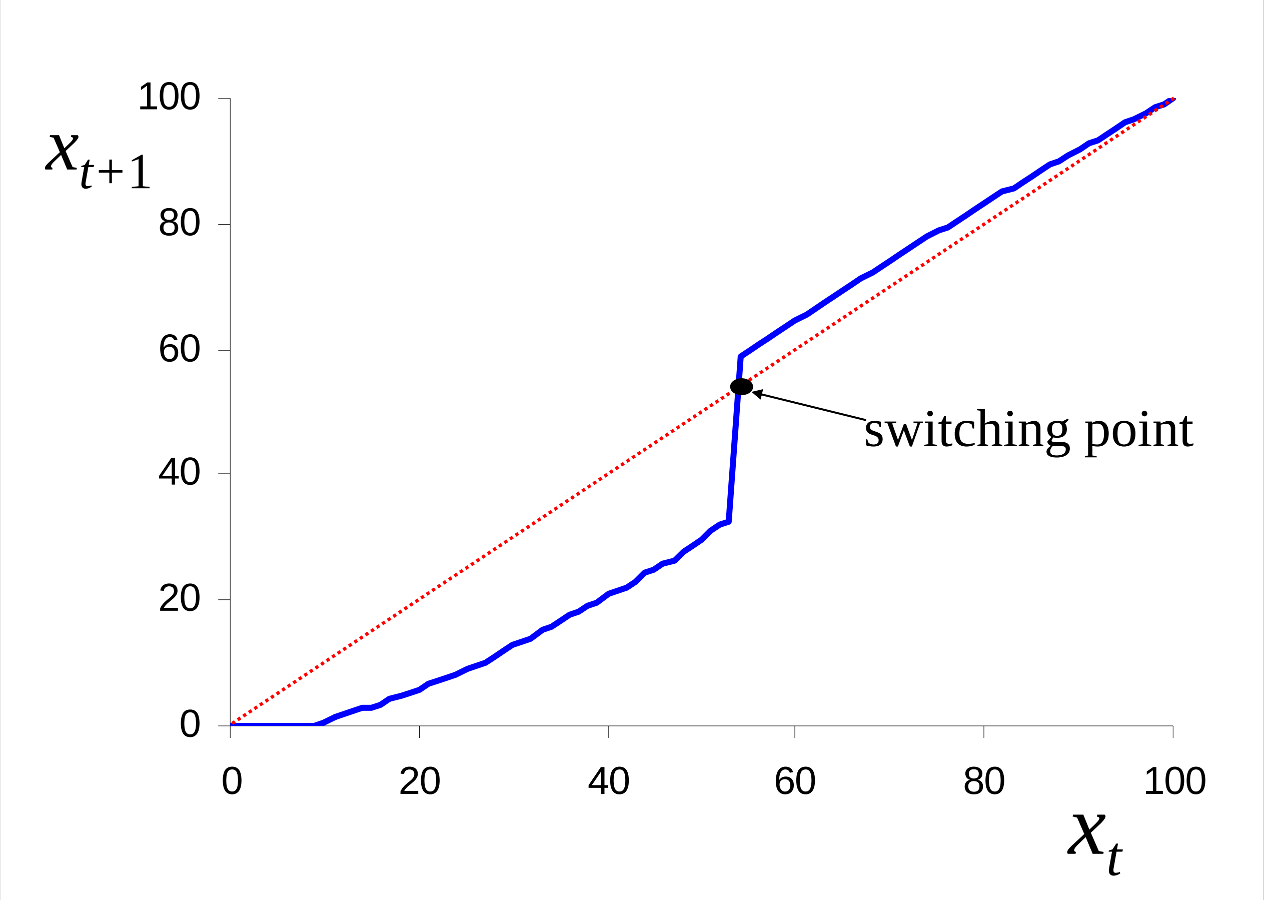
control cost



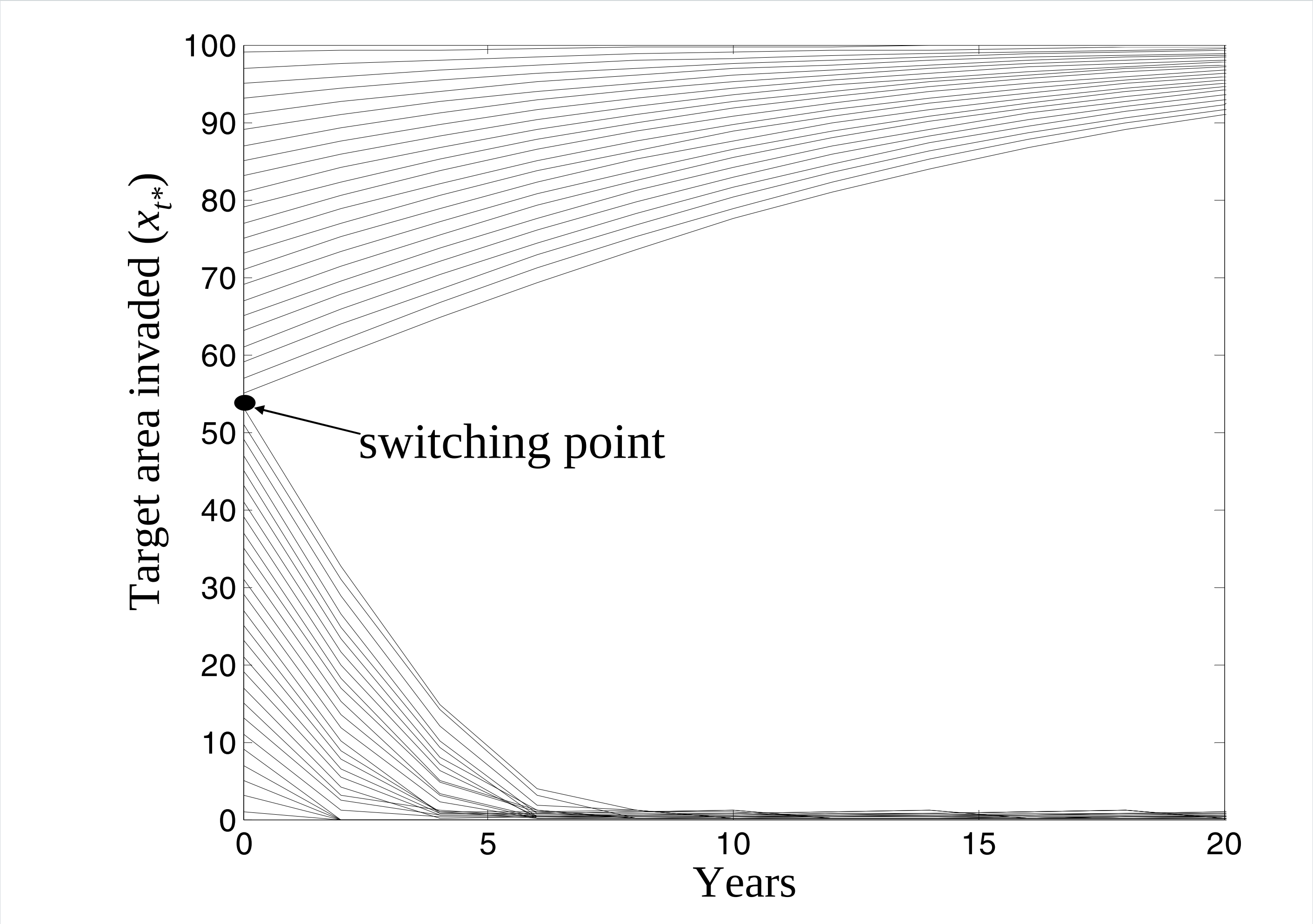
damage



Optimal state transition



Optimal state path



Optimal decision rule

Damage ($/ha)	Control cost ($/ha)					eradicate?
	160	180	200	220	240	
5	0	0	0	0	0	never
7.5	57	44	0	0	0	
10	83	71	61	54	44	depends
15	100	100	100	92	83	
20	100	100	100	100	100	always

Example 2:
search theory and population dynamics

To eliminate a weed invasion we need to:

- find and treat all plants;
- kill plants before they set seed.

Probability of detection depends on :

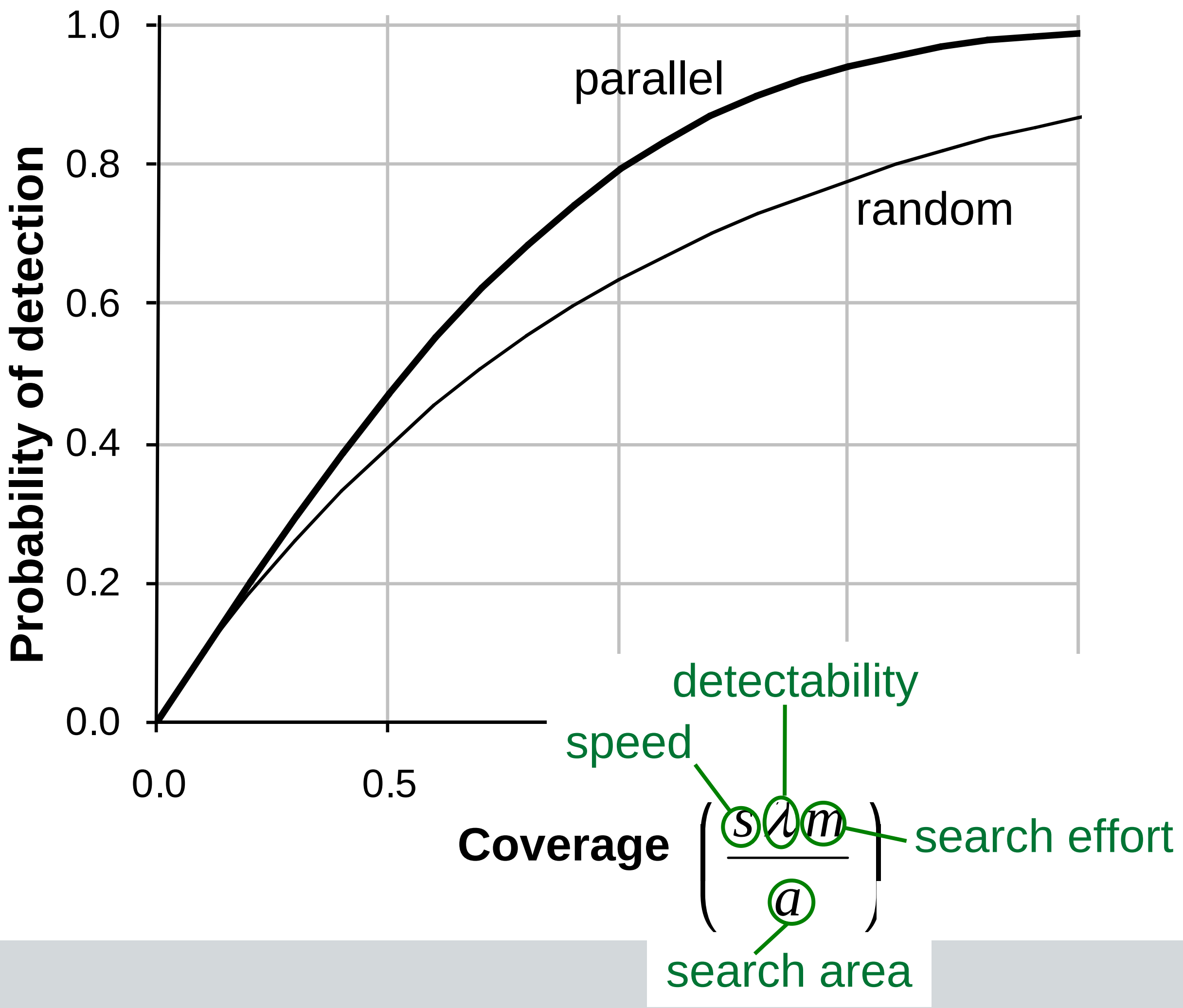
- detectability of the plant;
- search effort;
- environment;
- logistic factors (speed, accessibility).

The model

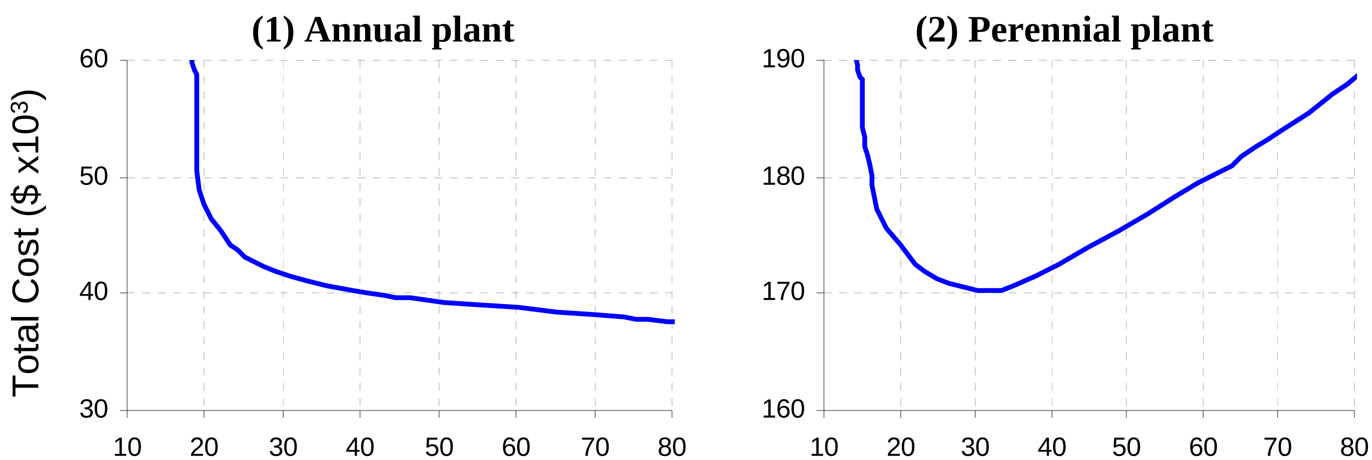
Oscar Cacho, Susan Hester, Daniel Spring, Paul Pheloung

- **Search theory:** relates surveillance effort to probability of detection.
- **Matrix model:** captures life stages and population dynamics.
- **Considers plant features:**
  - seed longevity;
  - plant longevity;
  - time to maturity;
  - fecundity.
- **Considers costs** of labour and chemicals.

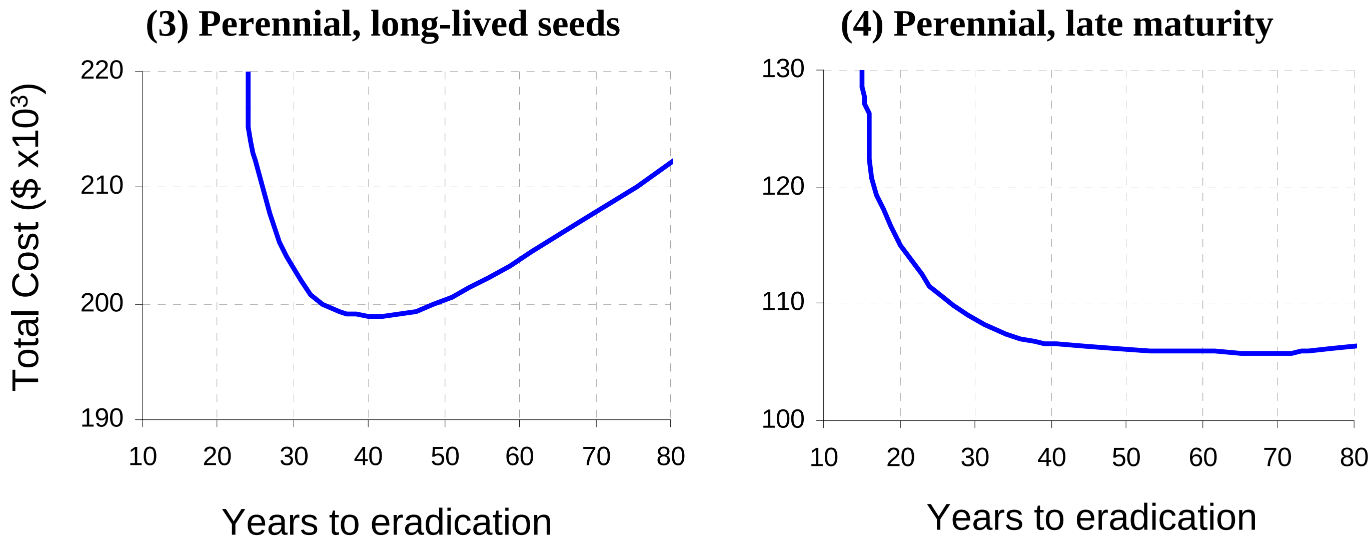
Detection curve



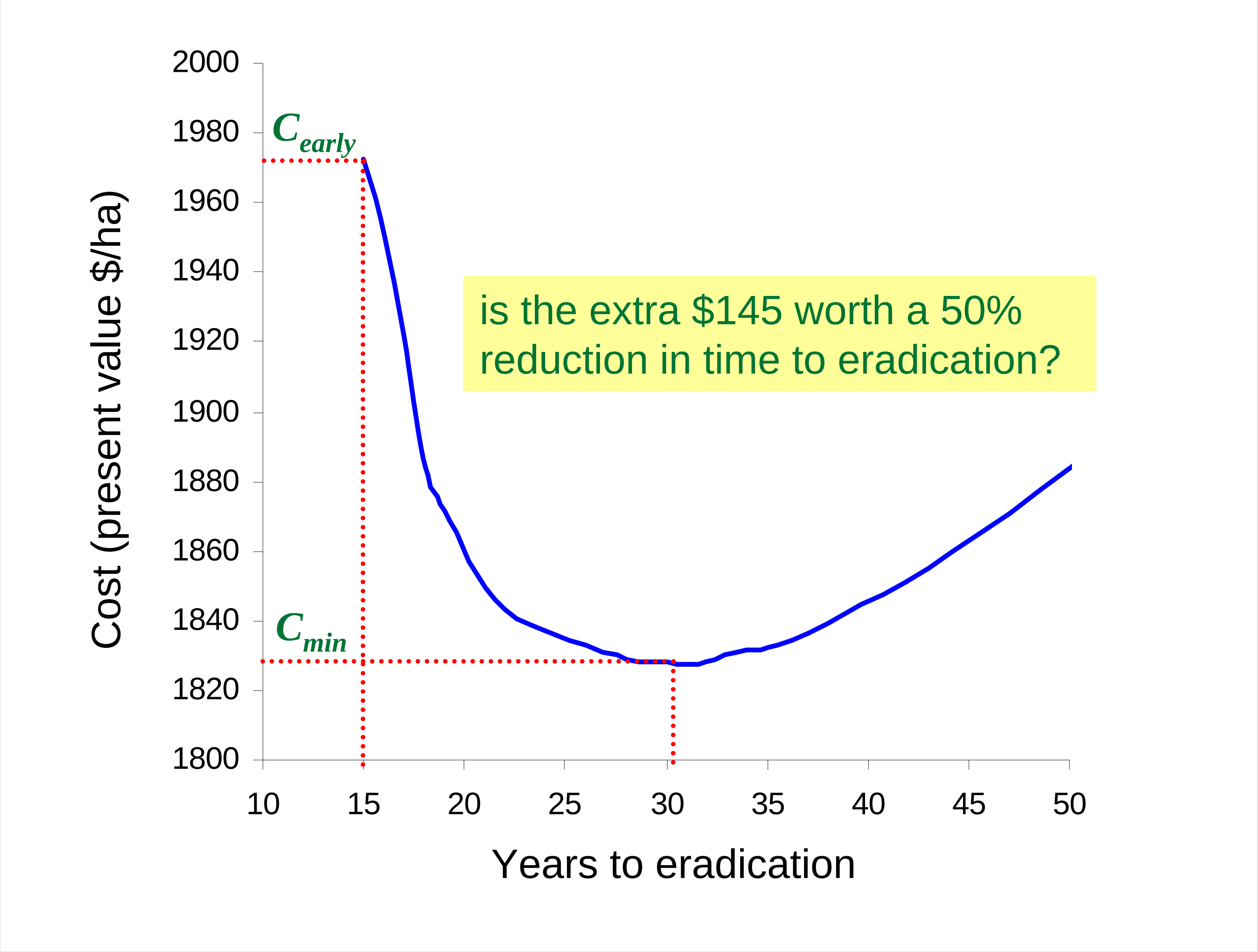
Minimising eradication cost



years to eradication are controlled through search effort



Should we attempt early eradication?



Example 3:
A spatial model

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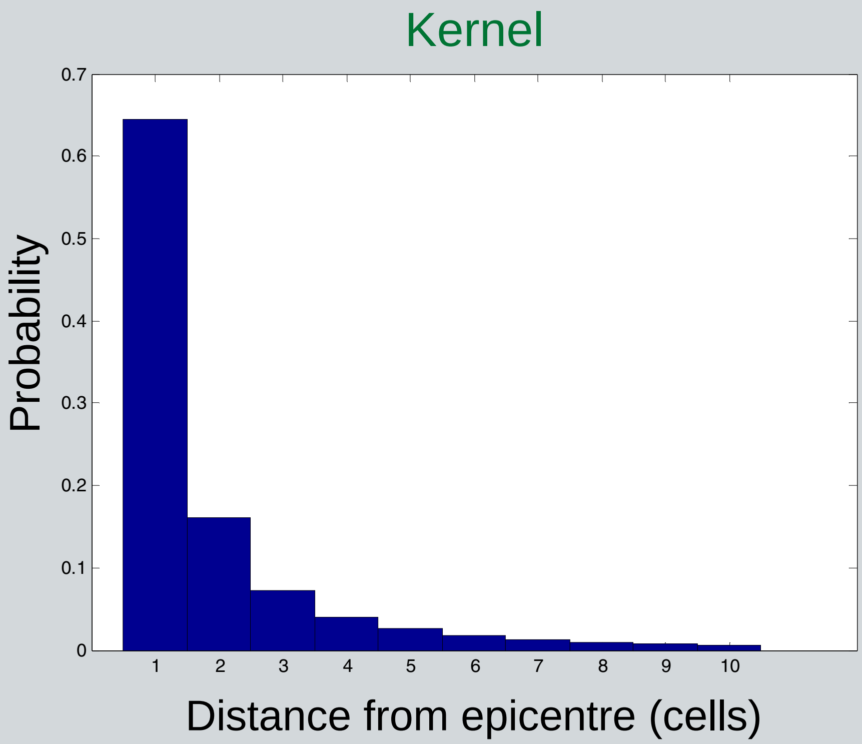
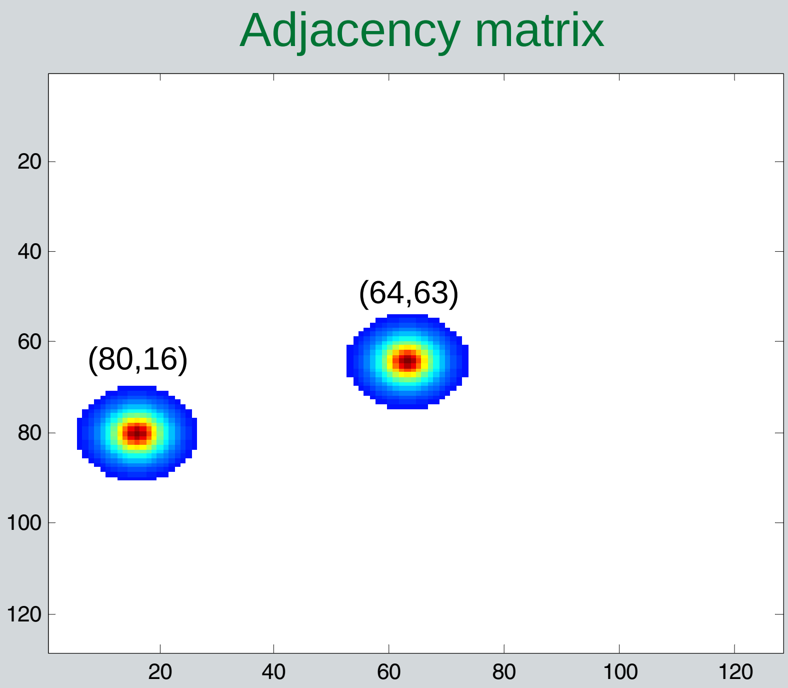
Features:

- **Detectability** of the invader
- **Logistic factors** (search effort, speed and pattern)
- **Population dynamics** (dispersal, growth)
- **Environmental factors** (habitat suitability)
- **Geographical factors** (urban/rural, private/public)
- **Passive surveillance**
- **Active search**

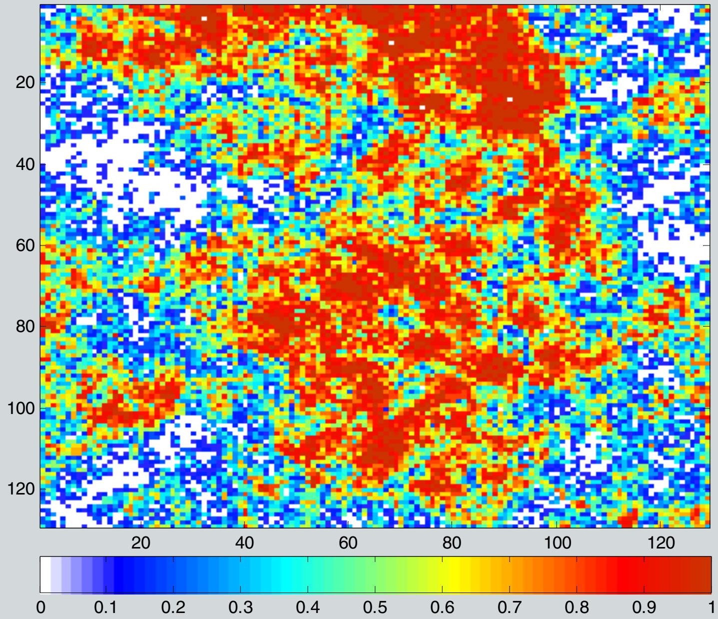
Dispersal kernel and adjacency matrix



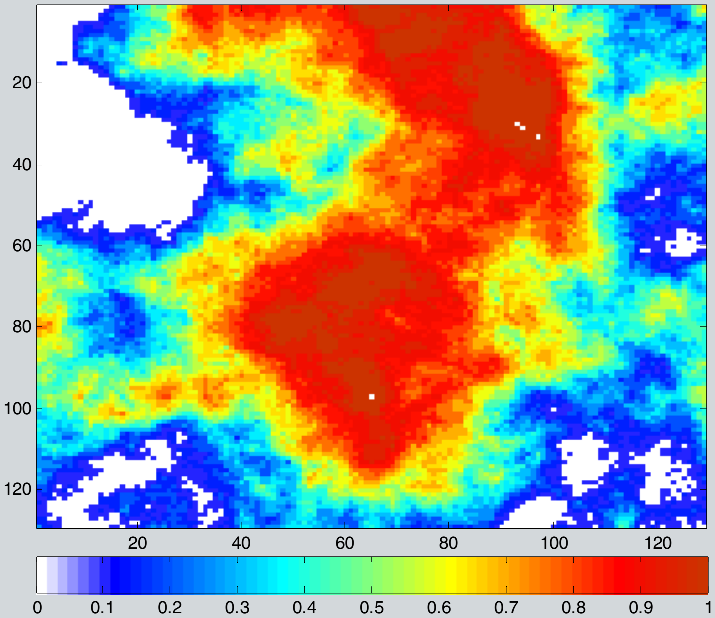


Habitat suitability

H=0.2



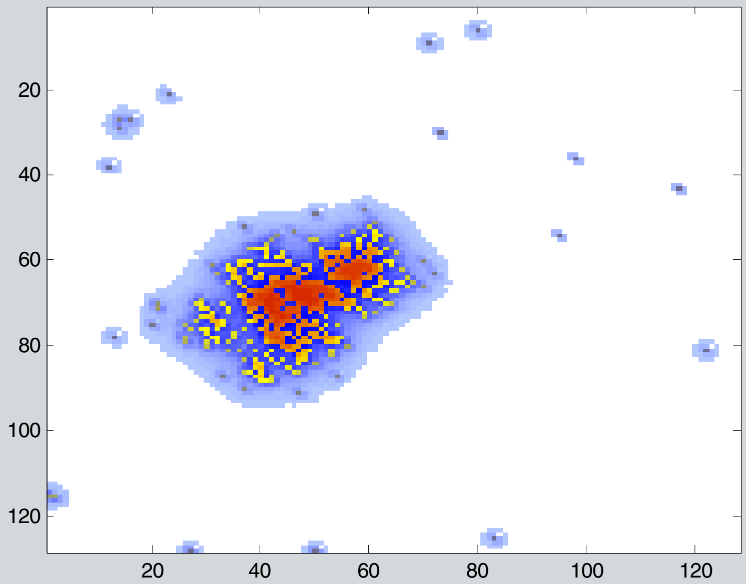
H=0.8



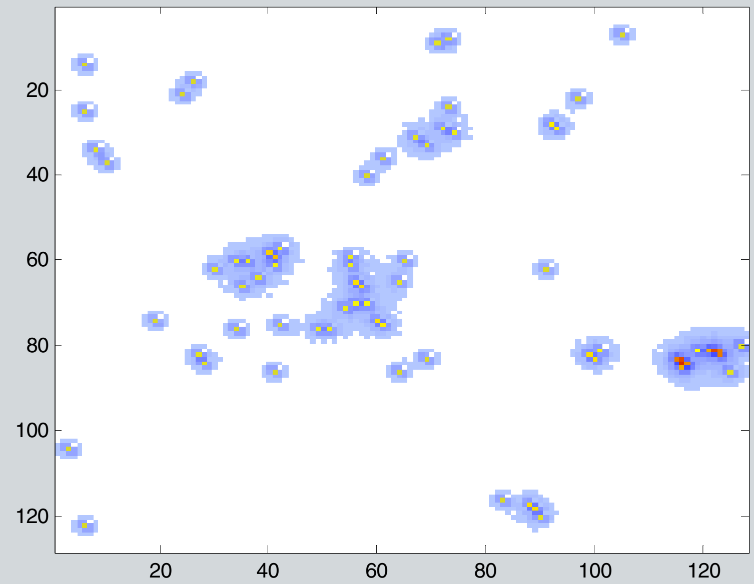
fractal worlds can be created or actual maps can be used when available

Probability maps (pest presence)

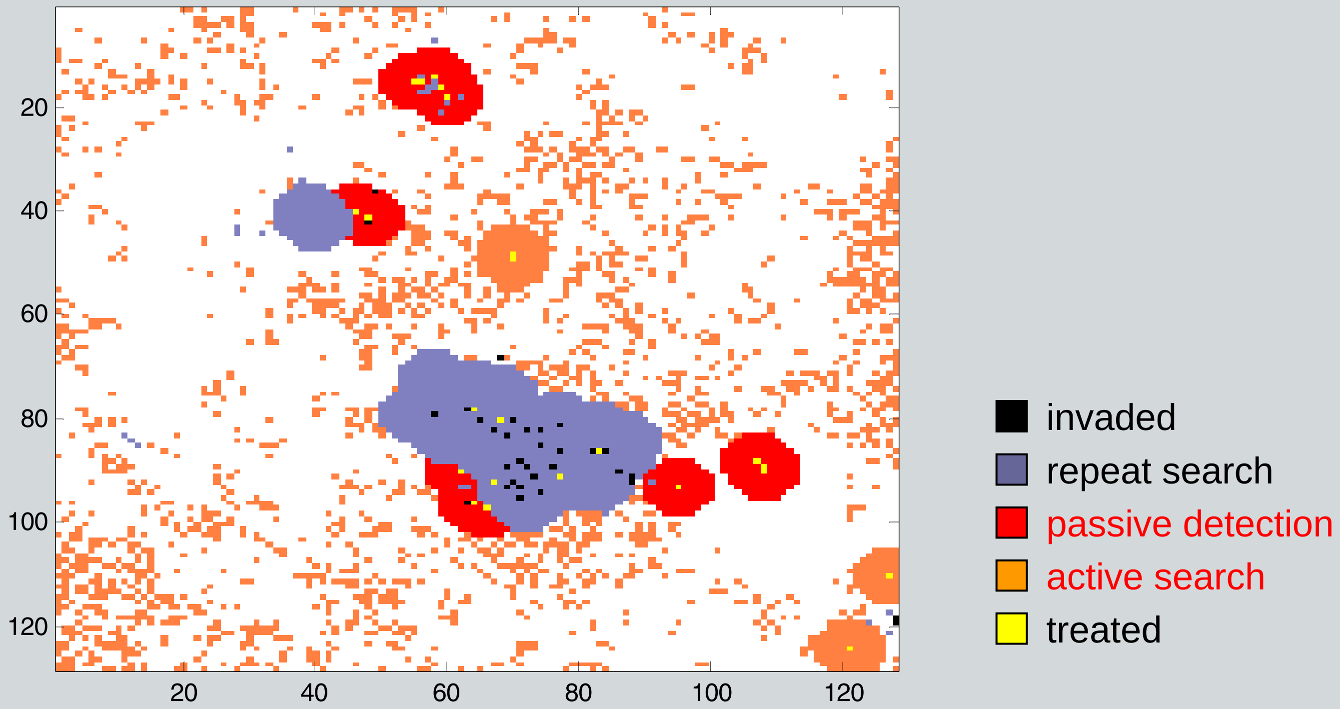
Before



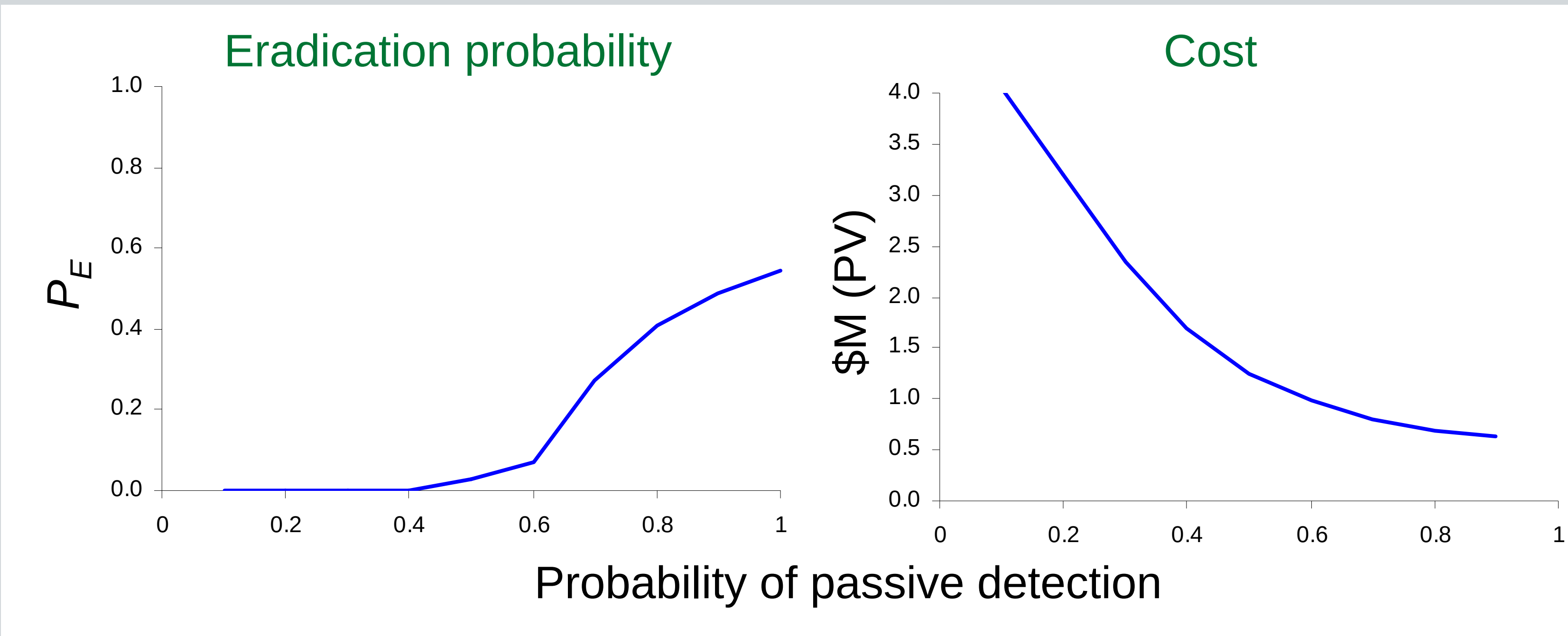
After



Search and treatment



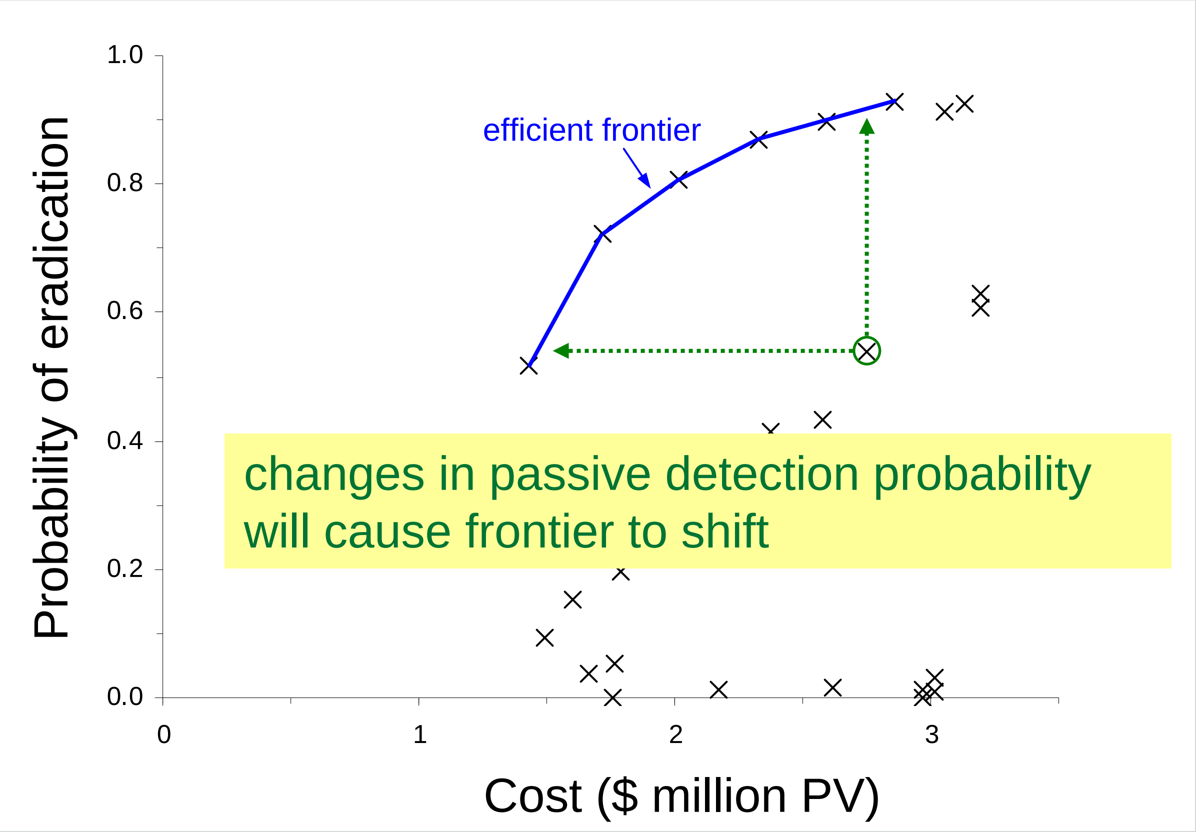
Eradication probability and cost



T = 15 years

Eradication-probability frontier

Points differ in terms of
total effort, effort per ha



Monetary effects of parameter changes

Based on elasticity estimates derived from the model

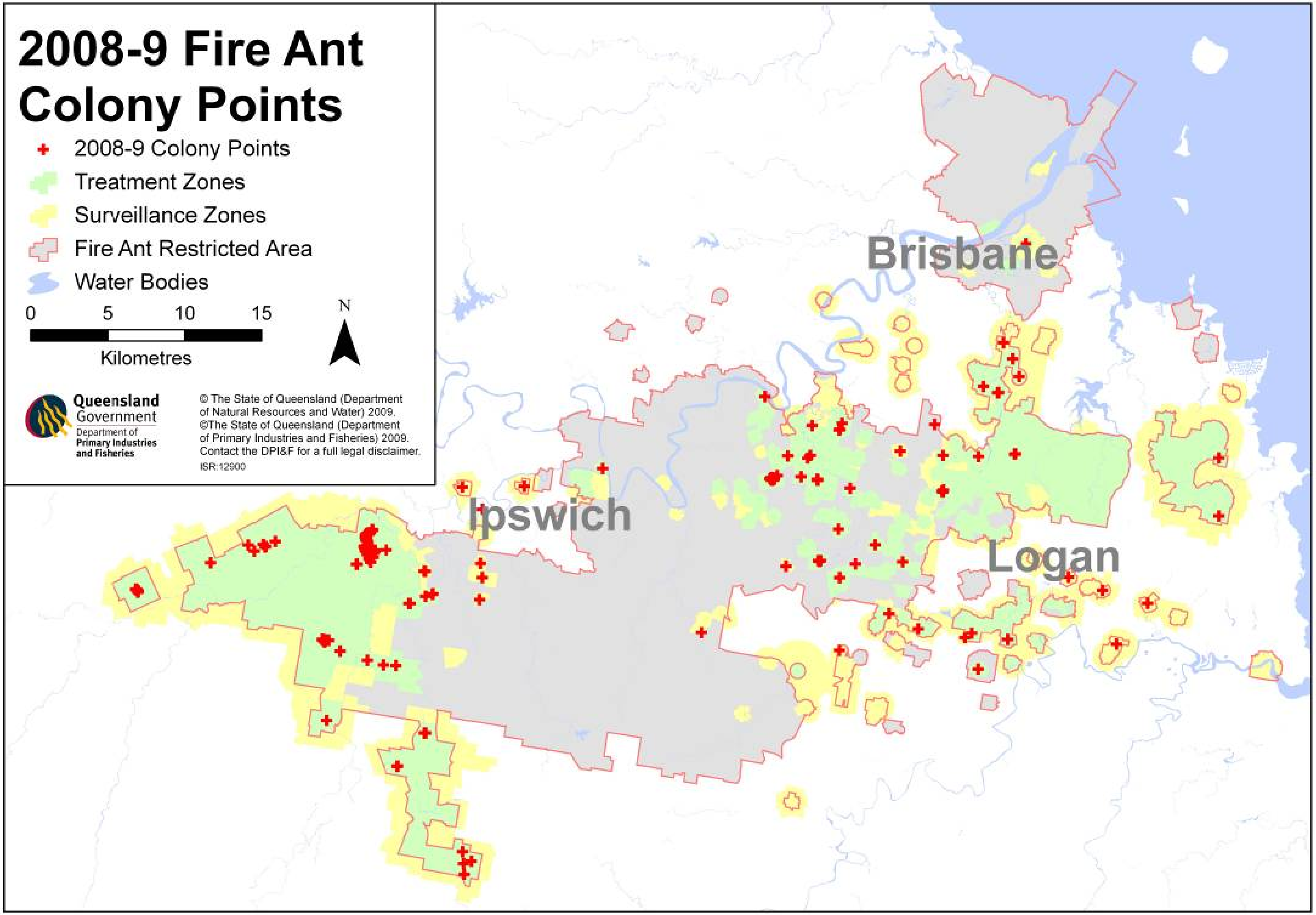
Parameter	Parameter change	Cost of change ($)
Propagule pressure (*w*)	from 100 to 101	60,157
Detectability (λ)	from 5m to 6m	-710,180
Treatment effectiveness (p_k)	98% to 99%	-60,530
Prob. of long distance jump (p_L)	from 2% to 3%	538,688
Time to discovery (t_D)	from 5y to 6y	927,955

An application: fire ants

Daniel Spring, Oscar Cacho, Daniel Schmidt

Background

- Number of nests removed has declined from >65,000 to 90 known infested properties.
- Most detections resulted from accidental encounters with private citizens rather than active searching.
- April-June 2008 bounty scheme ($500 reward) for reports by private citizens of new infestations; public reports increased 940% compared to previous year.
- About 2/3 of suspect ant locations have been on the reporting person's residence; the majority of the remainder have been on public land.



2008-9 Fire Ant Colony Points
2008-9 Colony Points
Treatment Zones
Surveillance Zones
Fire Ant Restricted Area
Water Bodies
0
5
10
15
Kilometres
N
Queensland Government
Department of Primary Industries and Fisheries
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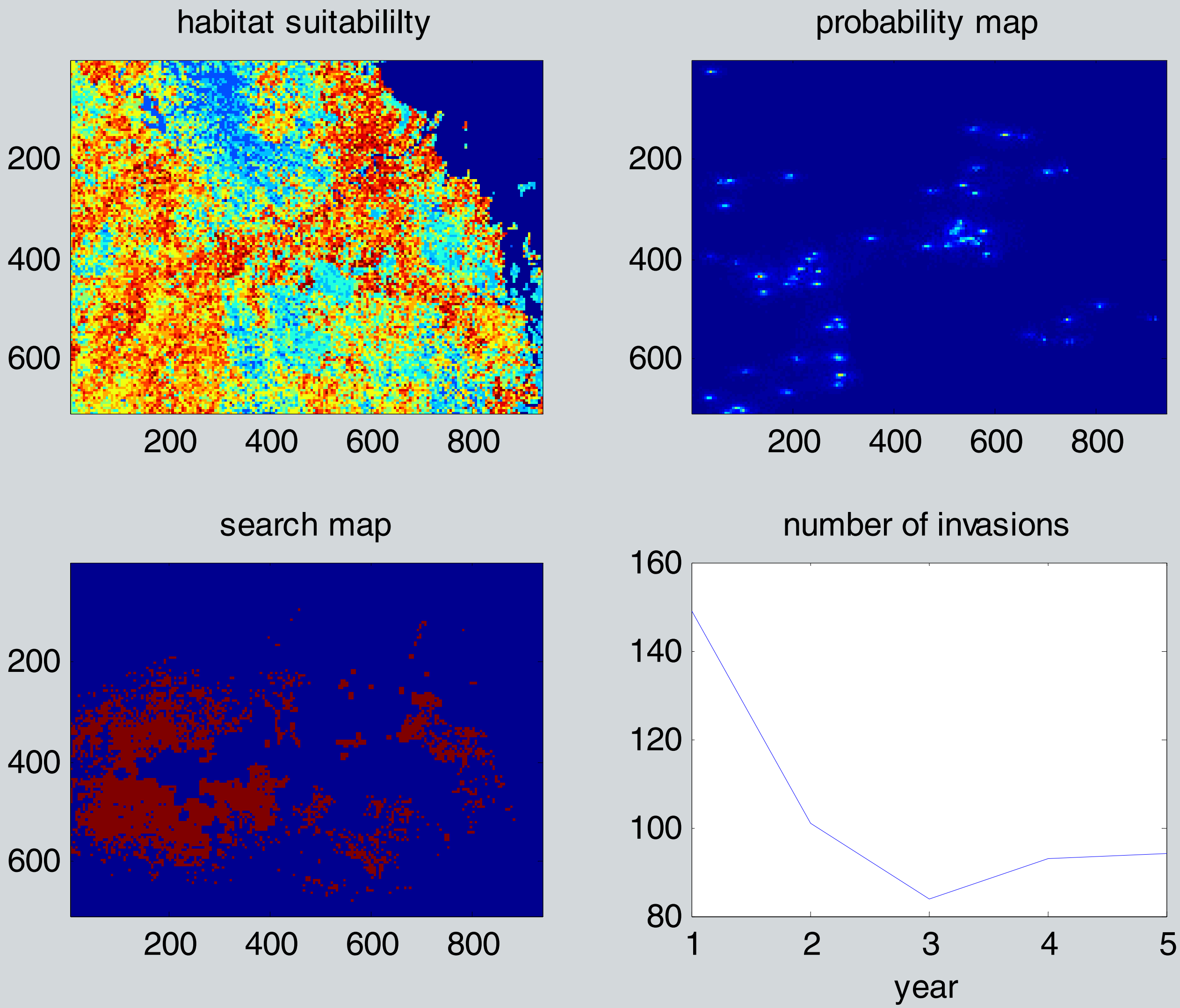
Contact the DPI&F for a full legal disclaimer.
ISR:12900
Brisbane
Ipswich
Logan

Source: BQCC

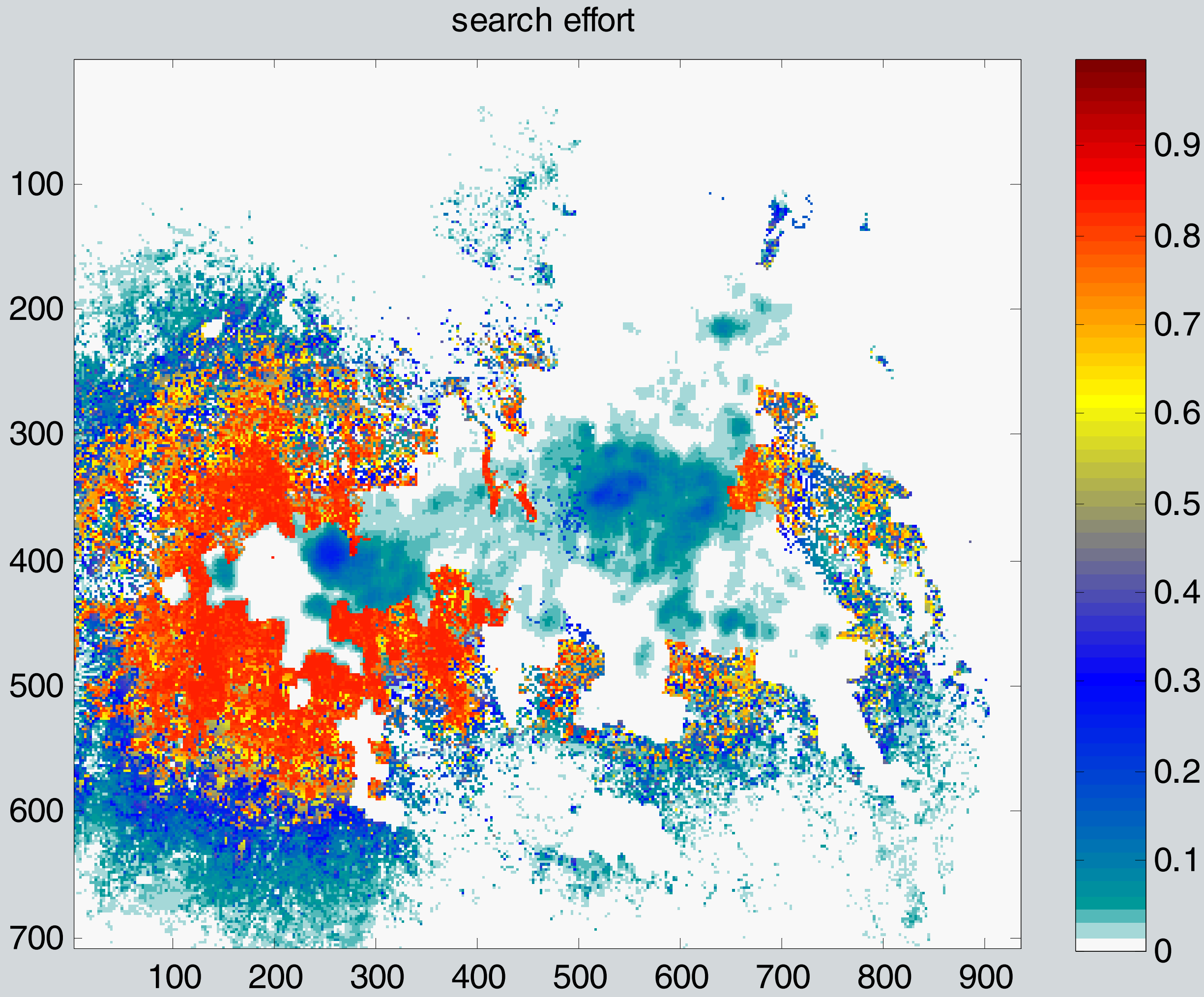
The model

- The map is a 707×935 ha grid.
- Growth and spread equations were estimated from 7 years of GIS data collected by BQCC.
- The **'Government'** generates probability map based on **known** colonies.
- The **model** generates probability map based on **all** colonies (drives spread of invasion).
- Search is based on BQCC protocols supplemented by probability map.

The model


habitat suitabililty
probability map
search map
number of invasions
200
400
600
800
80
100
120
140
160
1
2
3
4
5
year

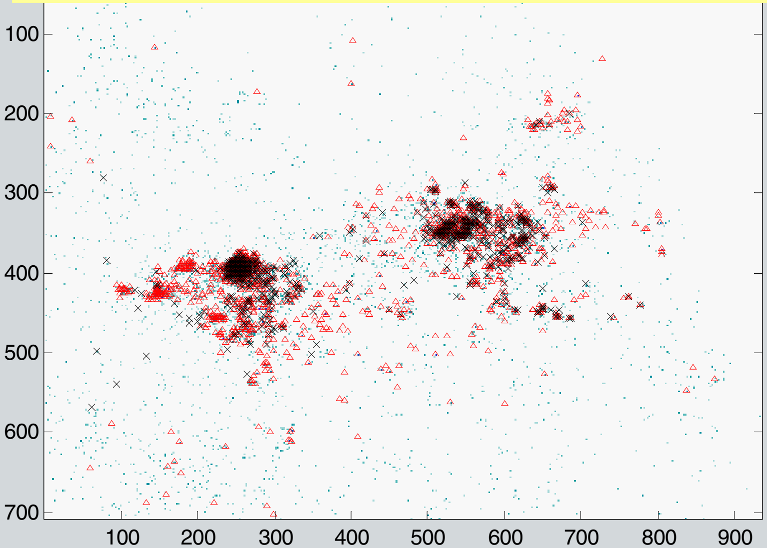
Distribution of search effort



The model does not predict the location of invasions,
it estimates where invasions are more likely to occur

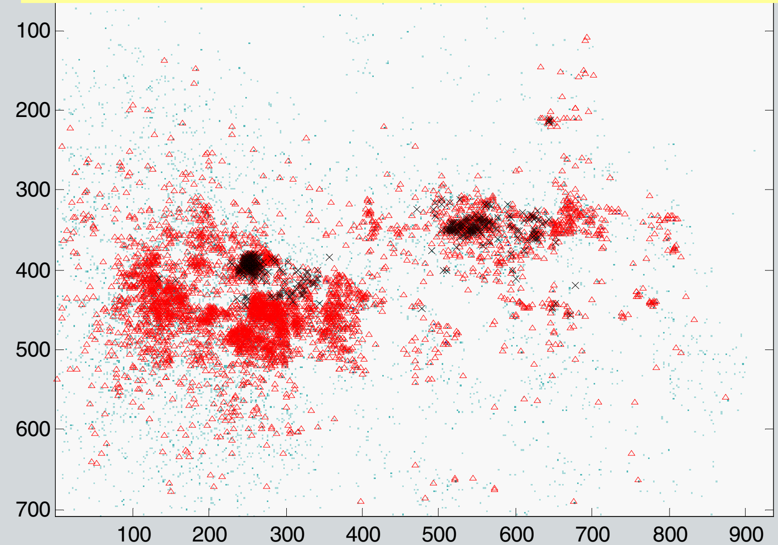
High budget

3.6 invasions within 1 km of edge



Low budget

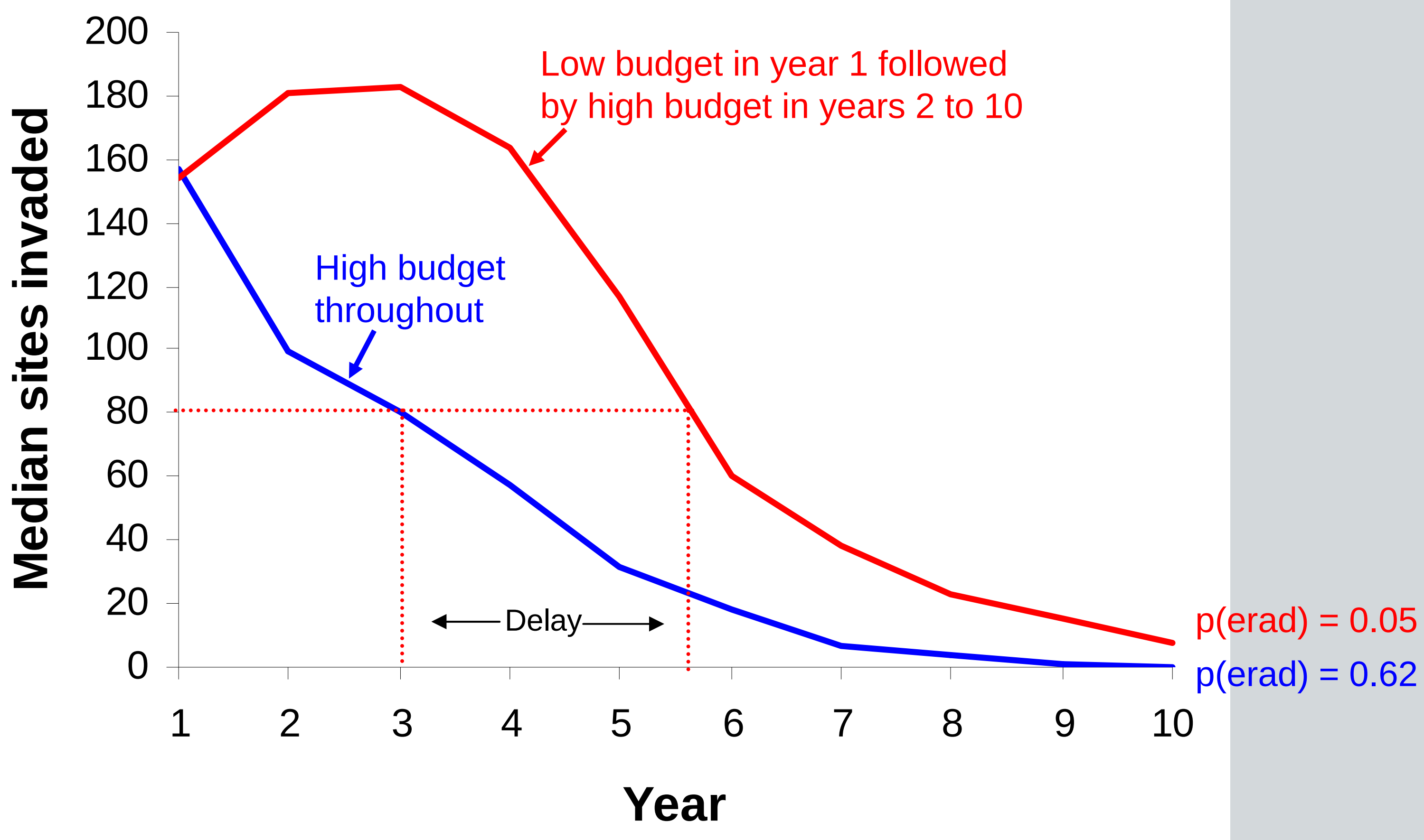
13.7 invasions within 1 km of edge



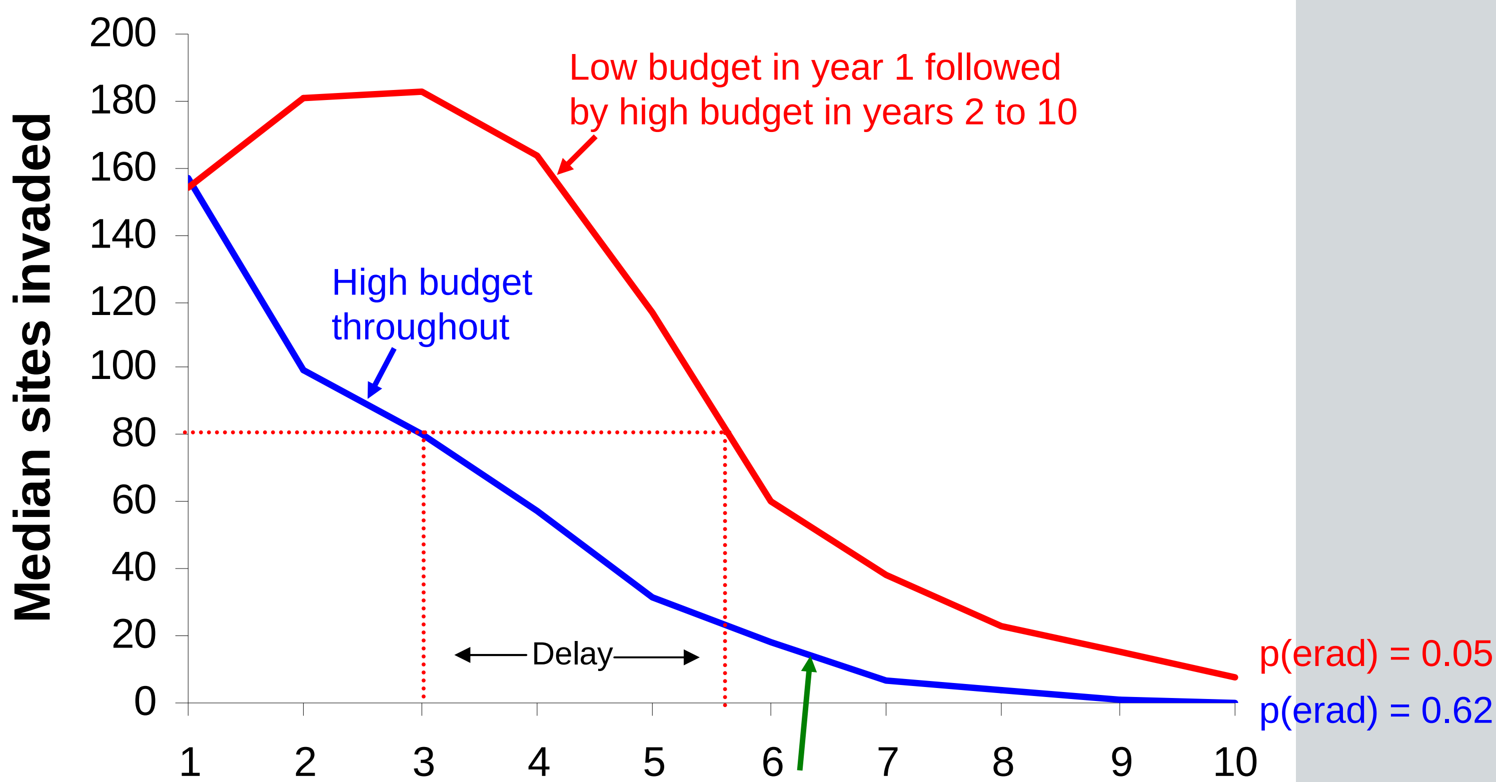
▲ Colony locations in 95% of simulations

x Detections in 95% of simulations

Effect of budget delays



Effect of budget delays



We should be able to improve on this as we find more effective search and treatment strategies and apply new techniques (dogs, better traps, new chemicals)

Concluding comments

- Biological invasions are complex dynamic systems but they have common features that make them amenable to modelling.
- Models integrate information on economics, biology, logistic factors and the search environment.
- Bioeconomic models can contribute significantly to planning, evaluation and execution of control programs.
- A broad range of problems can be tackled through bioeconomic modelling.

With thanks to

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Dane Panetta, Paul Pheloung

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