ALLOCATING BIOSECURITY RESOURCES IN SPACE AND TIME

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Outline

- Background
- Spatially-explicit model
- The role of passive and active surveillance
- State transitions
- What next?

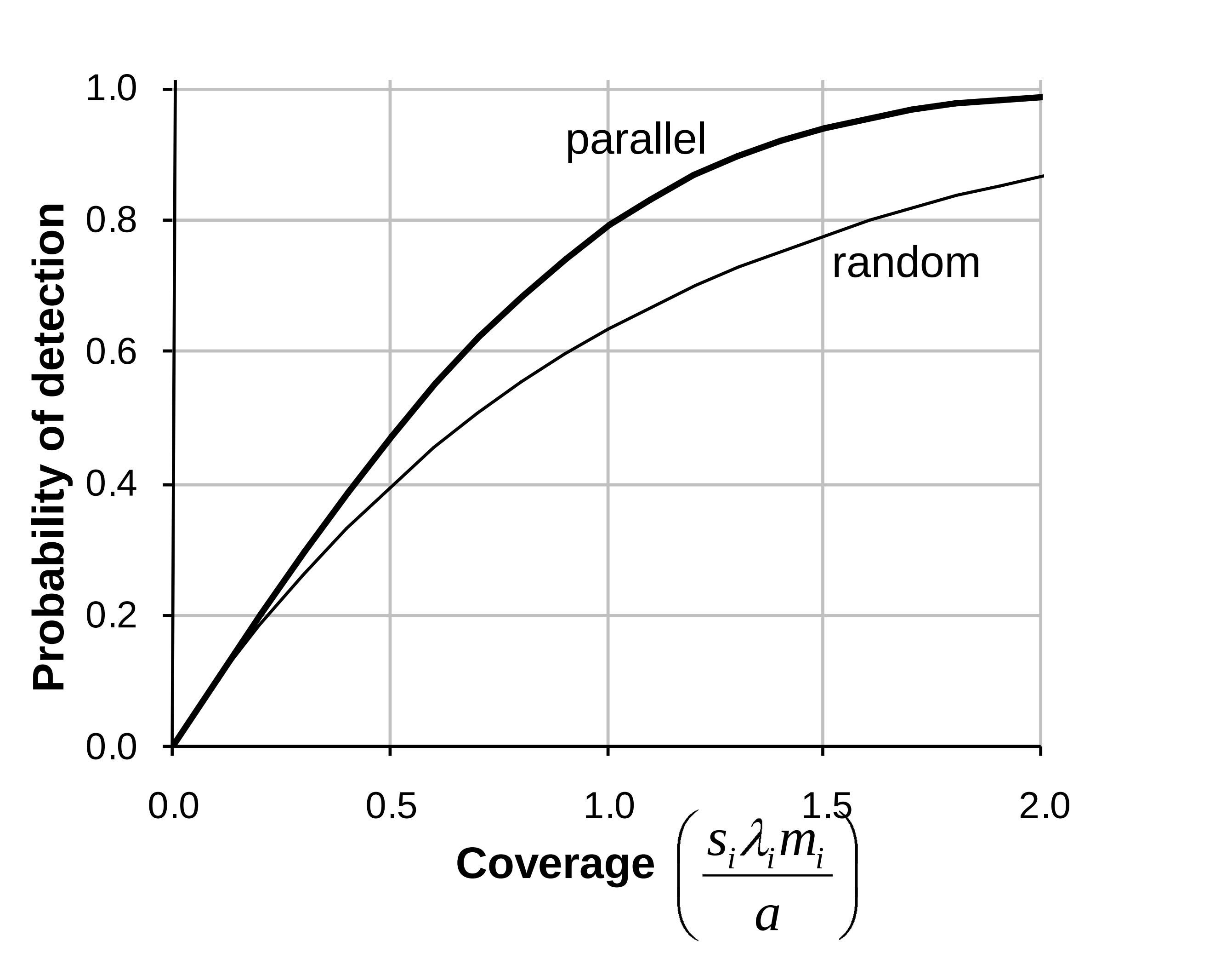
Background

- Invasive species can cause significant damage to natural environments, agricultural systems, human populations and the economy as a whole.
- The main constraint to eliminating invaders is generally finding them rather than killing them.
- Once an invasion is found it can usually be successfully treated and destroyed.
- Search theory can be applied within a spatially-explicit model to identify efficient strategies to manage invasions.

Model features

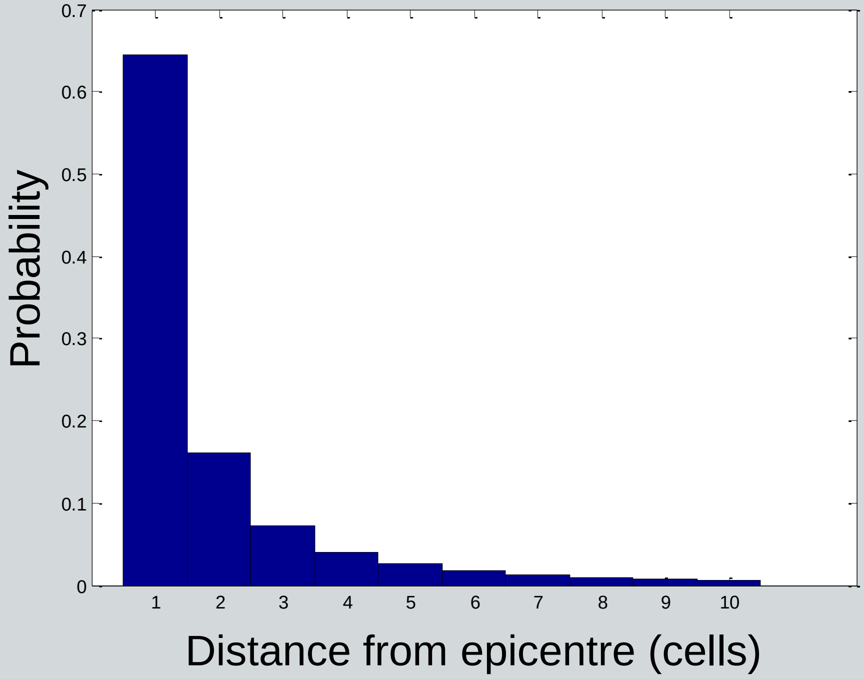
- **Detectability** of the invader
- **Logistic factors** (search effort, speed and pattern)
- **Population dynamics** (dispersal, growth)
- **Environmental factors** (habitat suitability)
- **Geographical factors** (urban/rural, private/public)
- **Passive surveillance**
- **Active search**

Detection curve

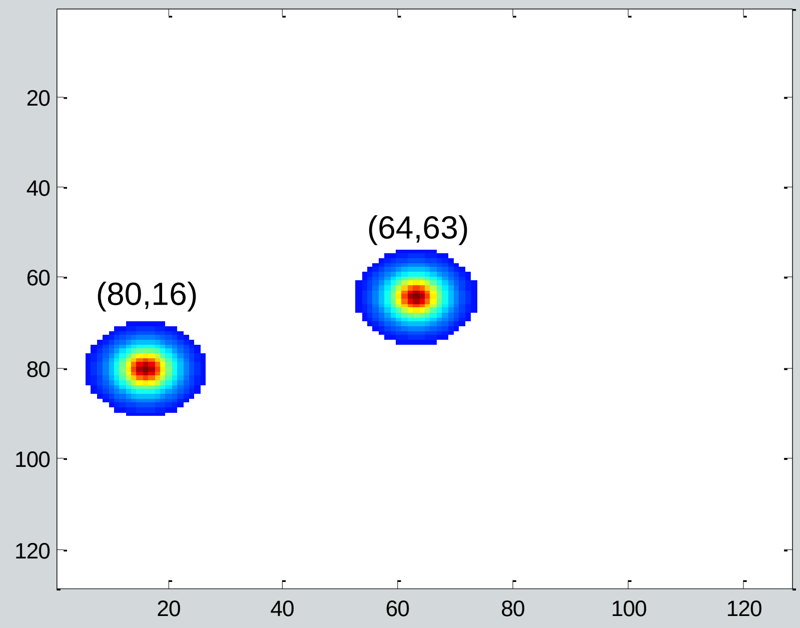


Dispersal kernel and adjacency matrix

Kernel



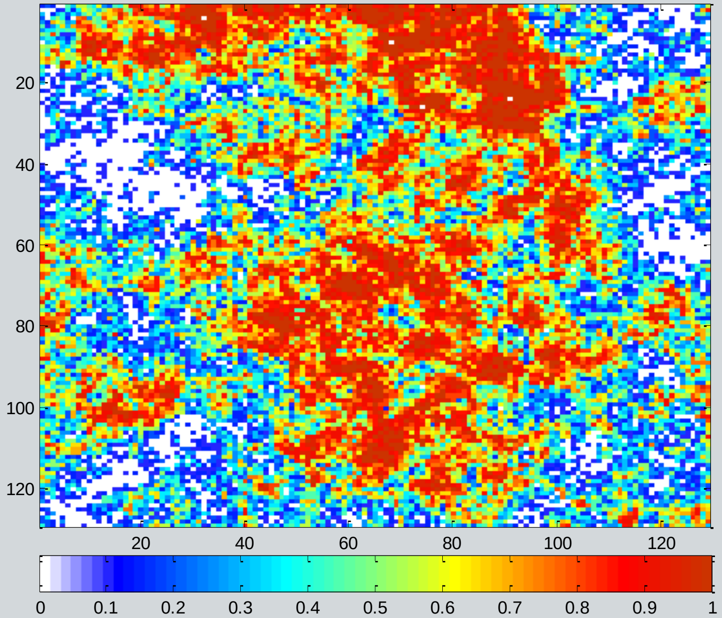
Adjacency matrix



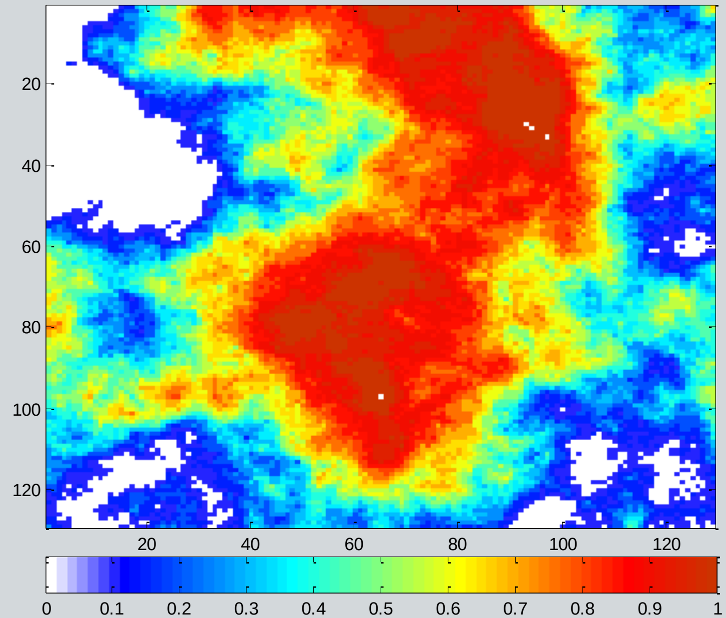
Habitat Suitability

Fractal Worlds

H=0.2

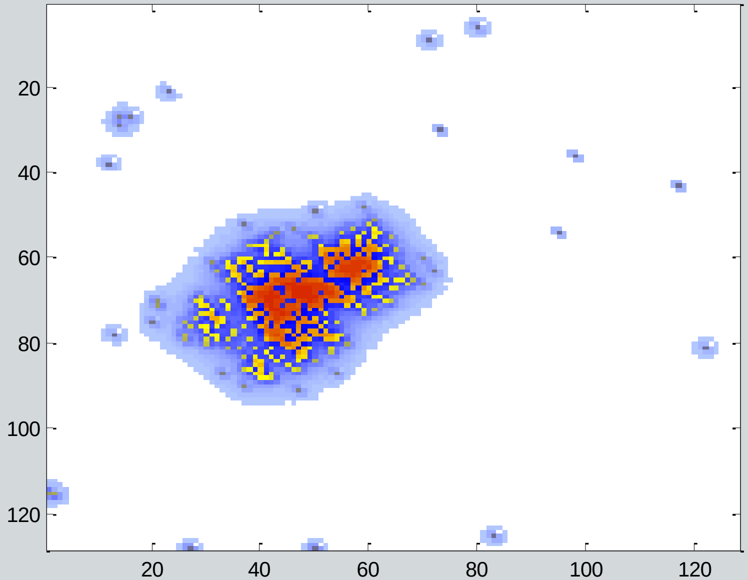


H=0.8

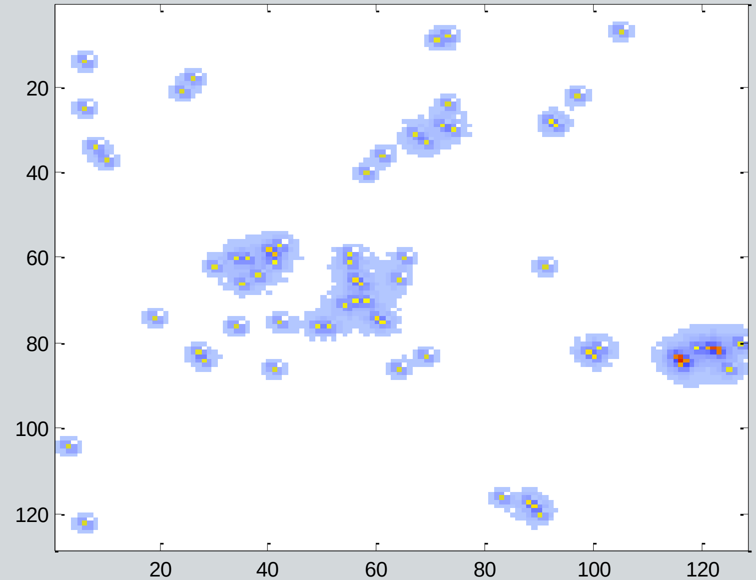


Probability maps (pest presence)

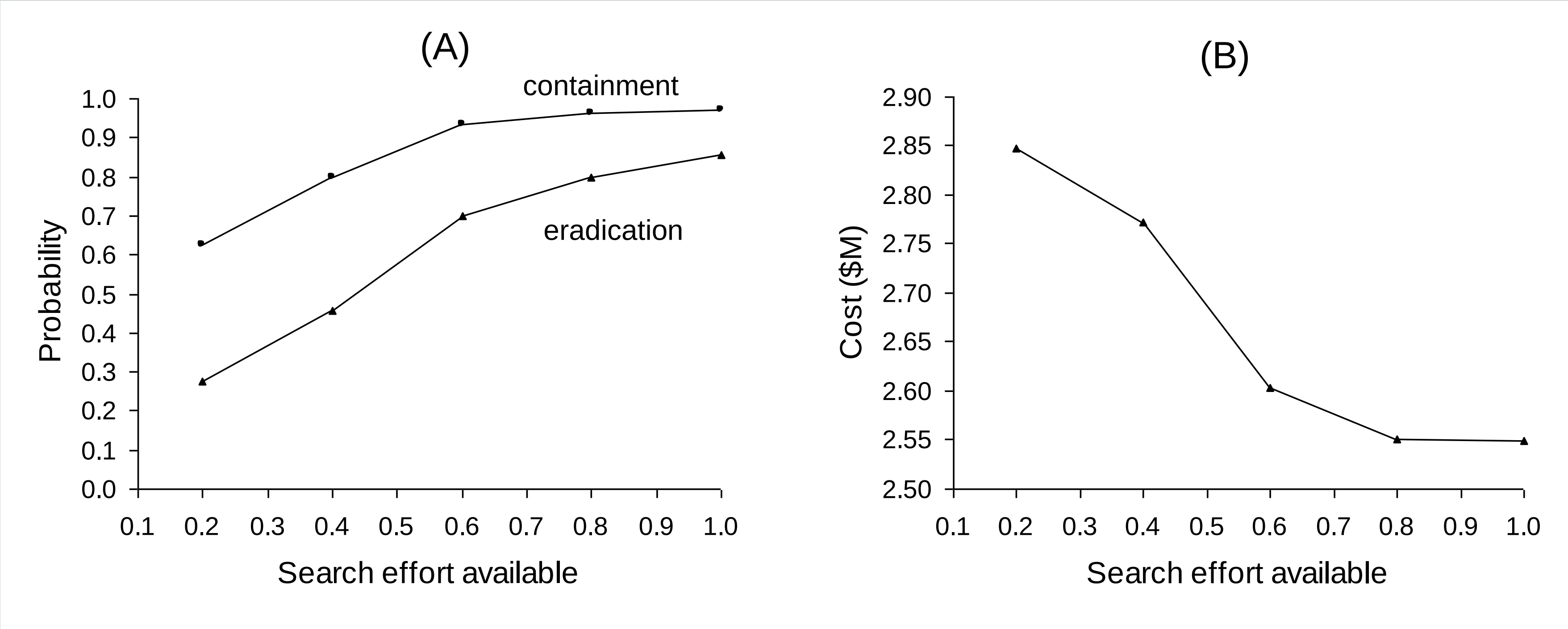
Before



After

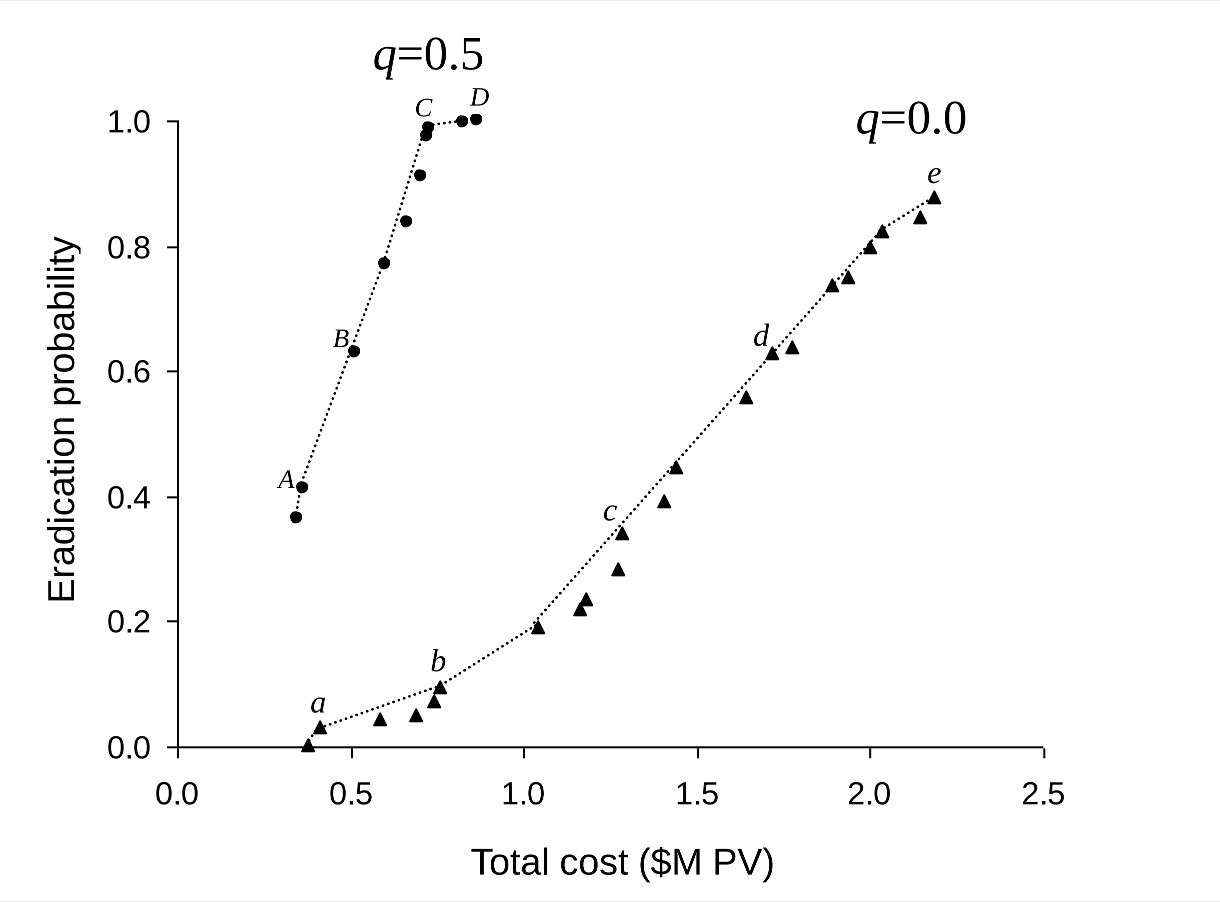


Probability of success



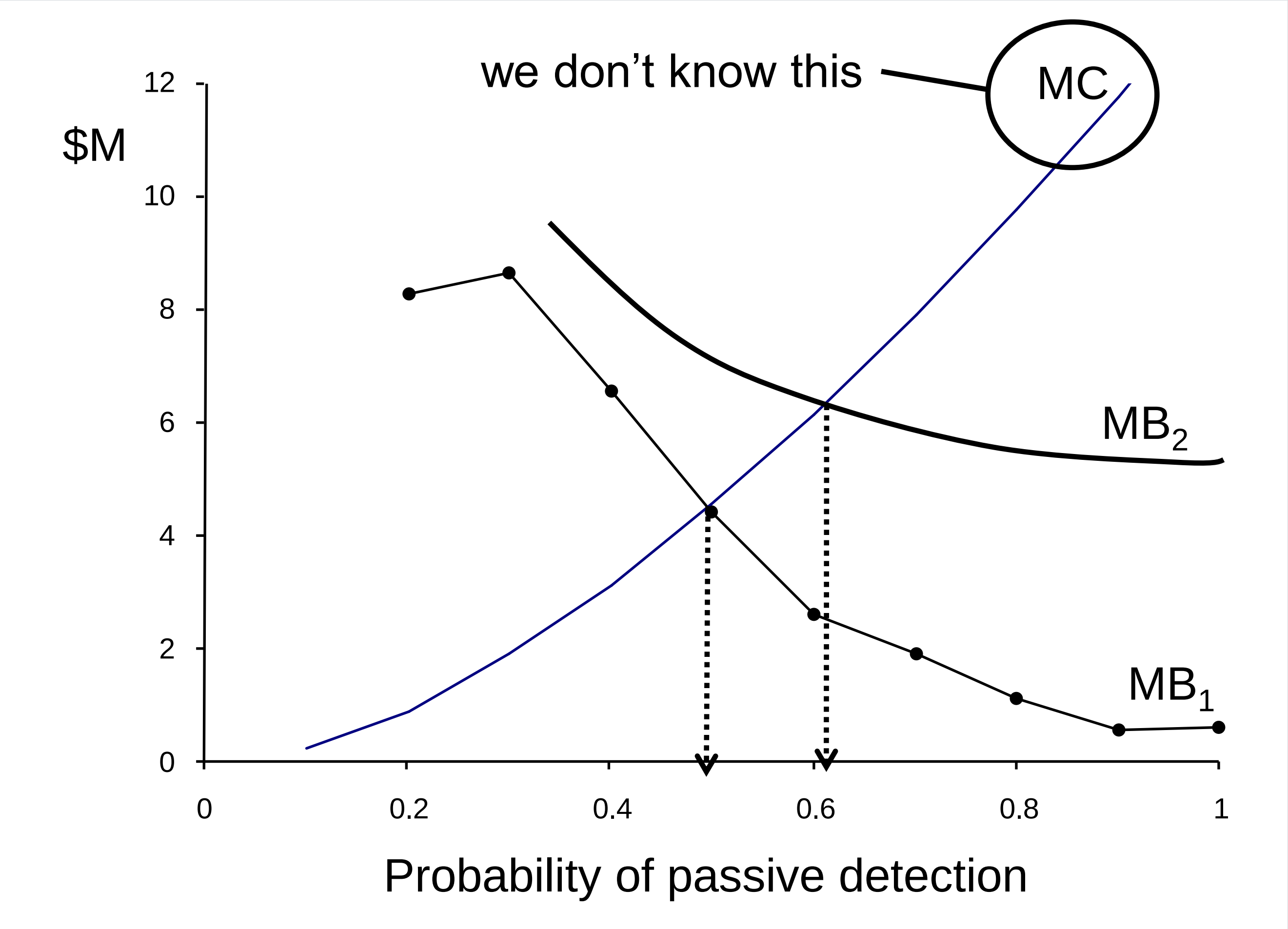
Cacho and Hester (2011)

Efficient frontiers



Cacho and Hester (2011)

Optimal passive surveillance



The cost function

$$C_t = \sum_t \left[\left(N_{Pt} C_B + N_{At} m\, C_m + A_{Tt} C_T \right) + \sum_{\tau = t - S_R}^{t-1} N_{A\tau} m C_m \right] \left(1 + \delta \right)^{-t}$$

N_{Pt} = n passive detections
N_{At} = area searched
A_{Tt} = area treated

$\Big\}\ f\,(M, m, r_m, S_{R,}, q)$

C = total cost
C_B = bounty cost
C_M = search cost
C_T = treatment cost
δ = discount rate

M = budget
m = search h/ha
r_m = search radius
S_R = repeat searches
q = passive detection probability

The fitted cost function

$$C_t = f\left(t, M, m, r_m, S_R, q \mid p_E, \delta\right)$$

M = budget
m = search h/ha
r_m = search radius
S_R = repeat searches
q = passive detection probability

p_E = eradication probability

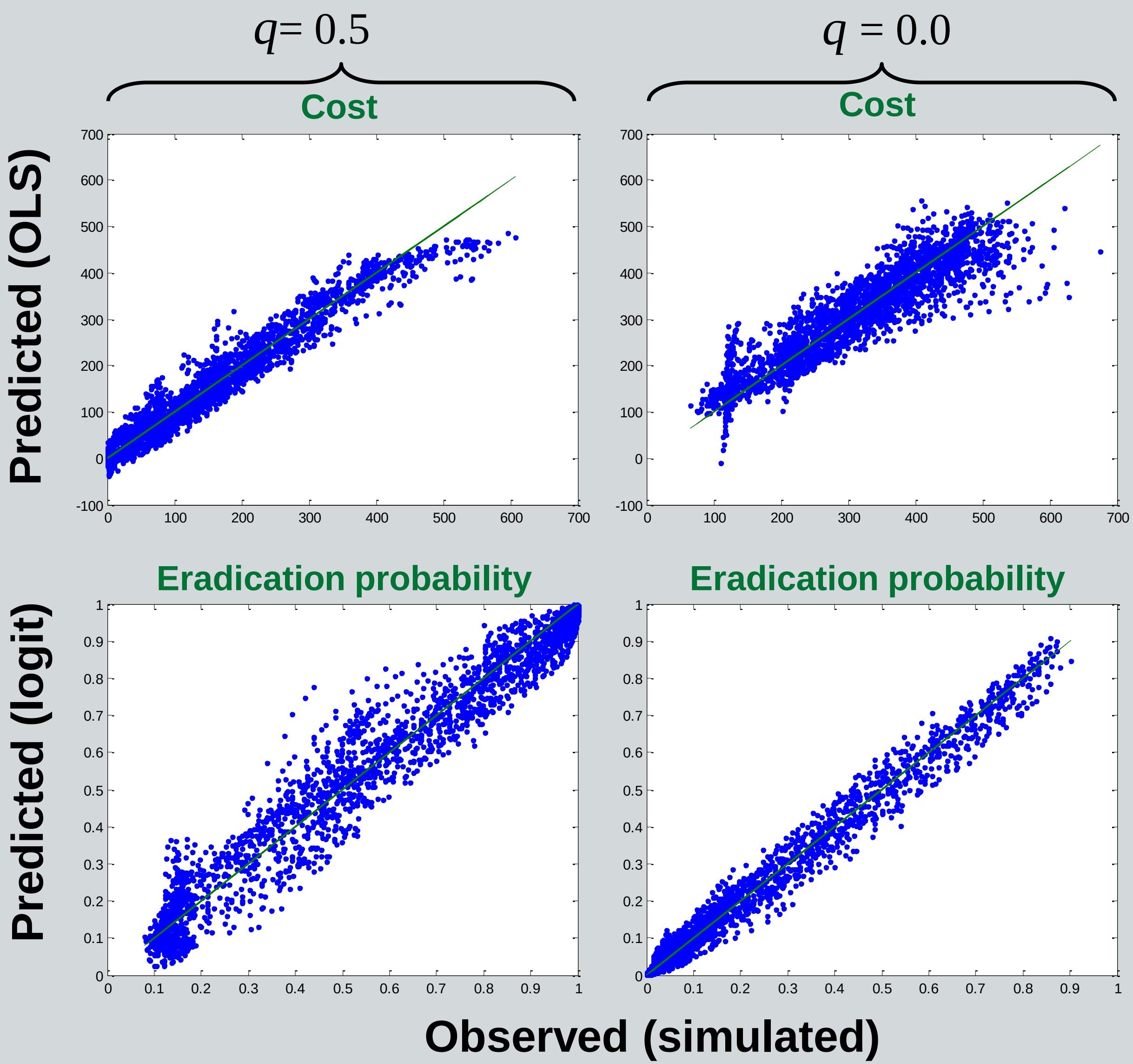
Probability of eradication

$$p_E = \frac{e^{\mathbf{U\beta}}}{1+e^{\mathbf{U\beta}}}$$

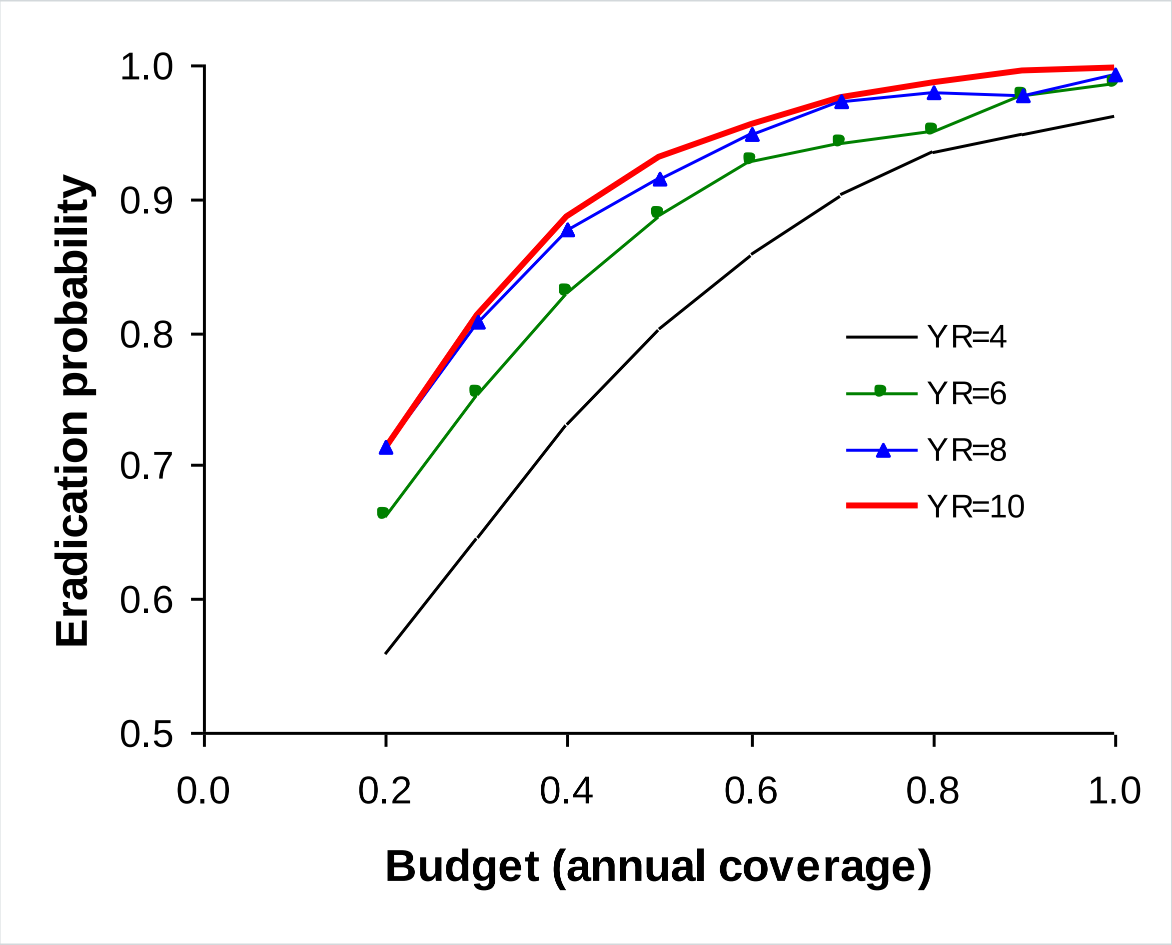
$$U_j = (1, u_{1j}, u_{2j}, \ldots, u_{nj}, \ldots, u_{1j}u_{1,j}, u_{1j}u_{2j}, \ldots, u_{nj}u_{nj})$$

$$u_1 = t$$
$$u_2 = M$$
$$u_3 = m$$
$$u_4 = r_m$$
$$u_5 = S_R$$

Metamodelling results



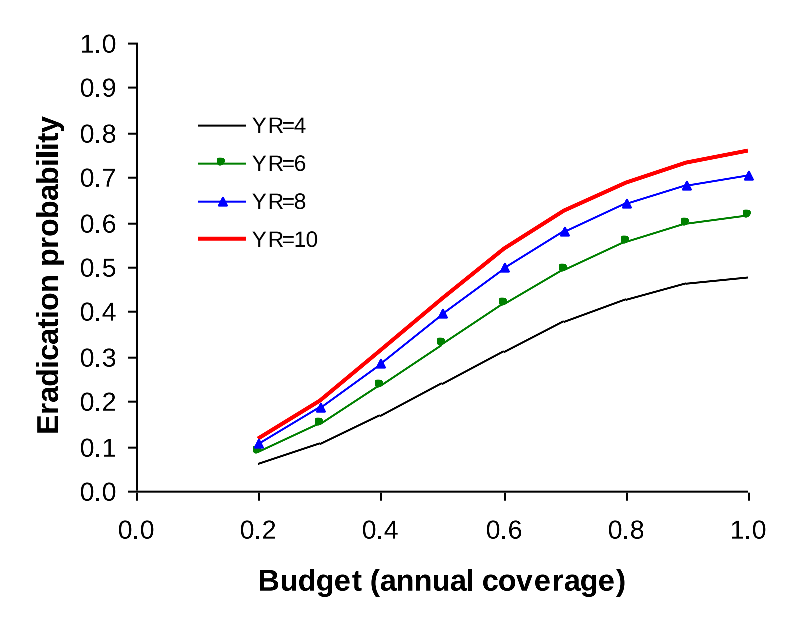
Probability and time to eradication



Calculations based on logit model

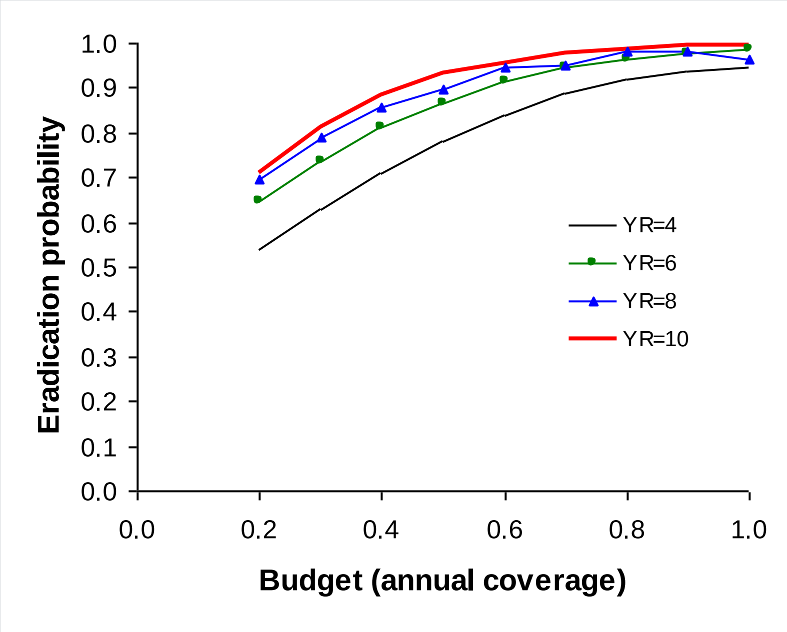
Probability and time to eradication

$q = 0.0$



optimal search intensity = 3,748

$q = 0.5$



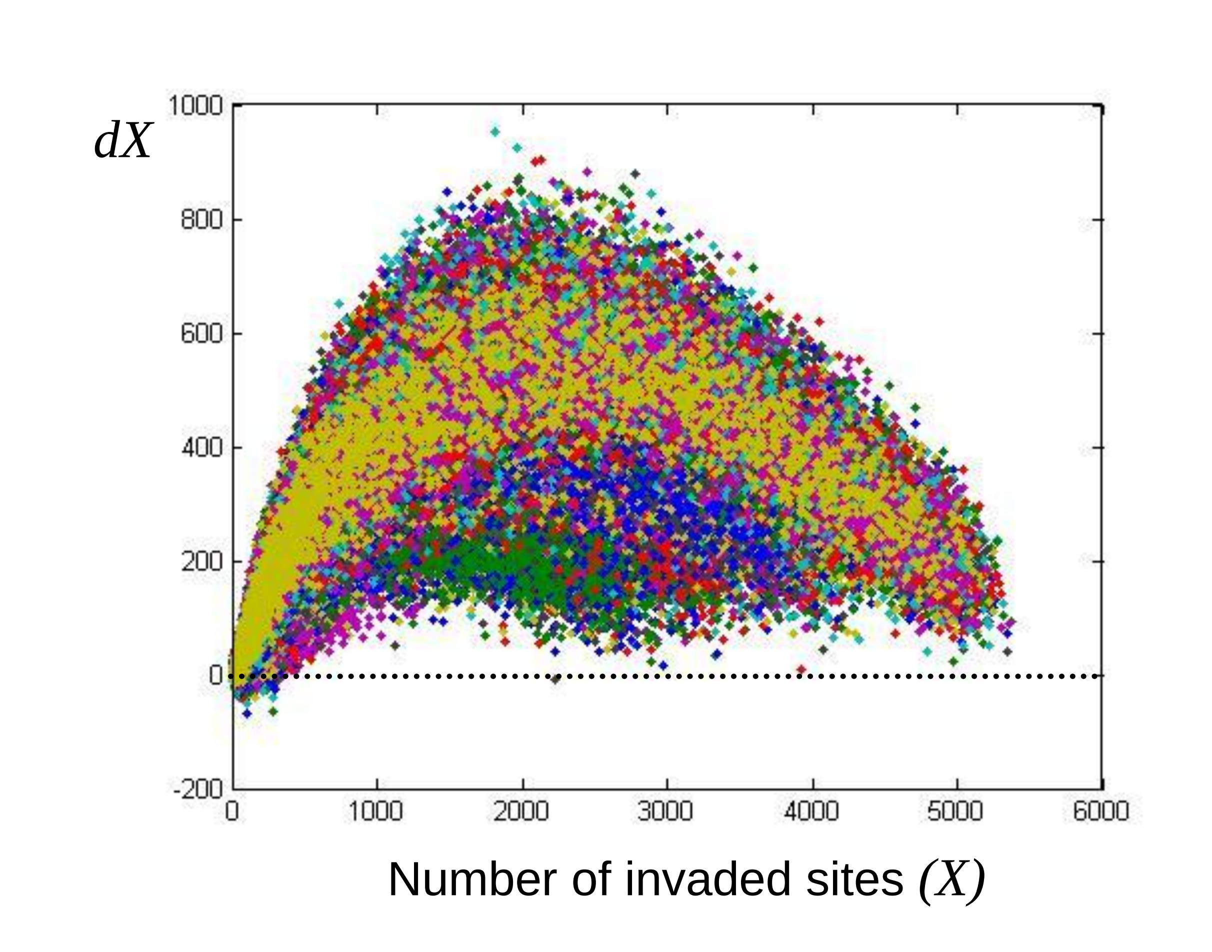
optimal search intensity = 1,933

Optimal strategies

Target year to eradication	Optimal strategy: Search effort (h/ha)	Search radius (m)	Area searched per find	Search intensity[a] (h/find)	Proportion searched[b]
q = 0.0					
4	7.1	1,040	337	3,494	0.21
6	7.2	1,060	356	3,785	0.23
8	7.3	1,060	352	3,731	0.23
10	7.1	1,080	368	3,983	0.24
Mean	7.2	1,060	353	3,748	0.23
q = 0.5					
4	7.1	880	245	2,159	0.13
6	6.4	820	212	1,746	0.11
8	5.9	880	245	2,164	0.13
10	6.0	810	206	1,662	0.10
Mean	6.4	850	227	1,933	0.12

State transitions

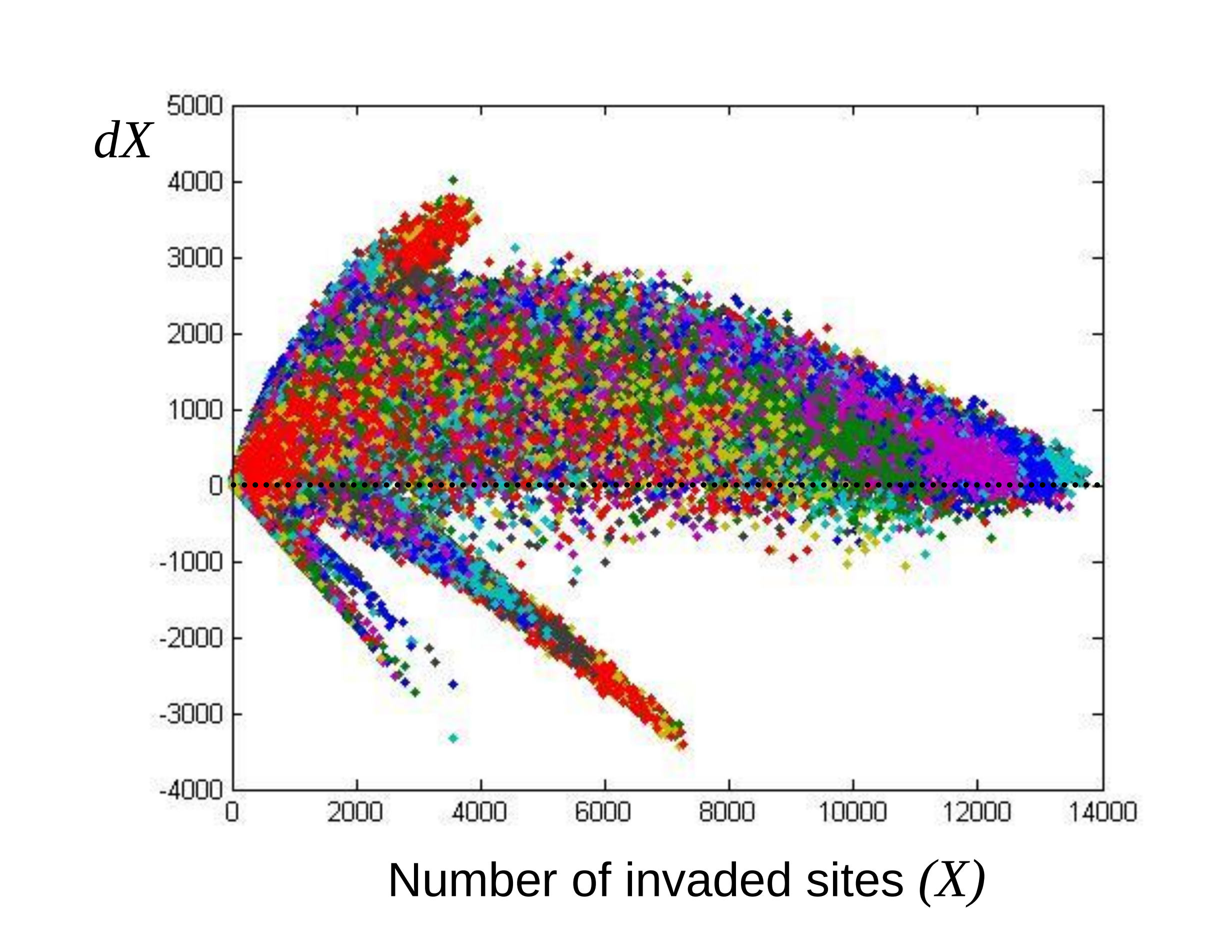
With passive surveillance



q=0.5, S=(0.2,...,0.8), N=1,950,000

State transitions

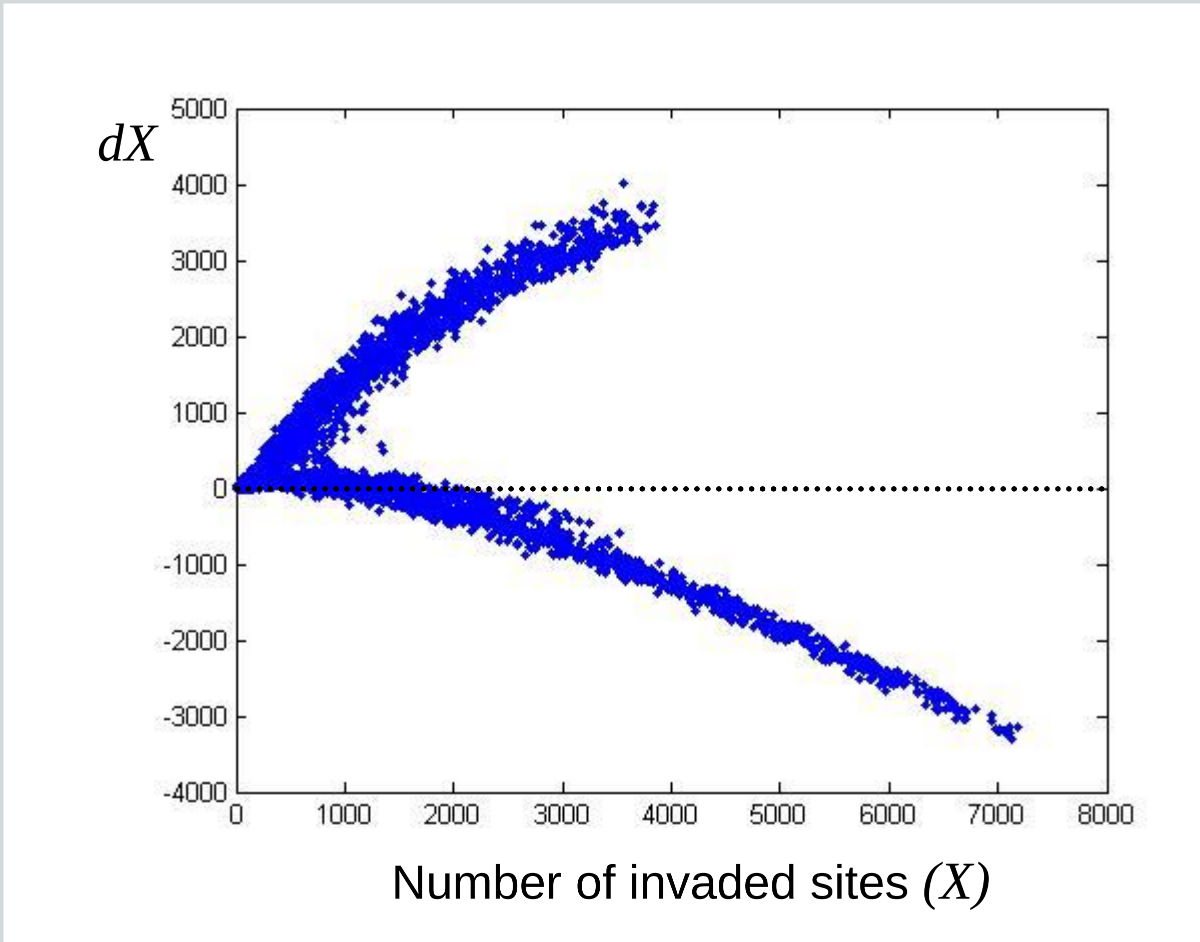
With no passive surveillance



q=0.0, S=(0.2,...,1.0), N=1,950,000

State transitions

With no passive surveillance



q=0.0, S=0.2, R=1, N=6,500

What Next?

- **Estimate MC of passive surveillance (ACERA project 1004-2d)**
- **Search for state variables to describe spatial arrangement**
- **Solve dynamic optimisation problem**
- **Find rules of thumb**