Bounty schemes to assist in eradicating biological invasions

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Background

- In places with high densities of people chance encounters may result in many detections of invasive organisms.
- A surveillance scheme that shortens the duration of an eradication program could represent a substantial cost savings.
- Education programs coupled with bounty schemes can increase passive detection and reporting rates.
- Active surveillance of public land could complement a passive surveillance scheme.
- We explore the cost and effectiveness of a bounty scheme aimed at assisting the eradication of invasions through simulation modelling.

Method

The ‘world’ is represented by a rectangular grid of dimensions (n_r,n_c).

Each ‘cell’ has the following attributes:

- Habitat suitability, α_i
- Detectability (effective sweep width), λ_i
- Search speed, s_i
- Urban status (1=urban, 0=rural), u_i
- Ownership type (1=private, 0=public), o_i

The state of cell i is given by its invasion status x_i (0,1)

Method, cont.

Other parameters include:

- Probability of passive detection $p_p(u_i, o_i)$
- Dispersal kernel $k(d_{ij})$
- Probability of long-distance jump, p_L
- Total active search effort, M
- Minimum active search effort per cell, m_i
- Probability of killing treated invasions, p_k
- Probability of passive detections reported, p_B
- Cost of bounty payments, C_B
- Cost of search, C_m

Method, cont.

At each time period:

1. For each passive detection reported by the public an area of radius r_m is searched around the invaded site
2. If a new invasion is found step 1 is repeated
3. If active search effort is still available other cells in public spaces are randomly searched by applying effort m.
4. Any invasions found are treated and killed with prob p_k
5. Any remaining invasions produce w propagules which are dispersed based on the kernel
6. Propagules landing on a site survive based on habitat suitability

Dispersal is simulated using an adjacency matrix A

Probability of active detection is based on coverage (search theory)

Hypothetical Worlds

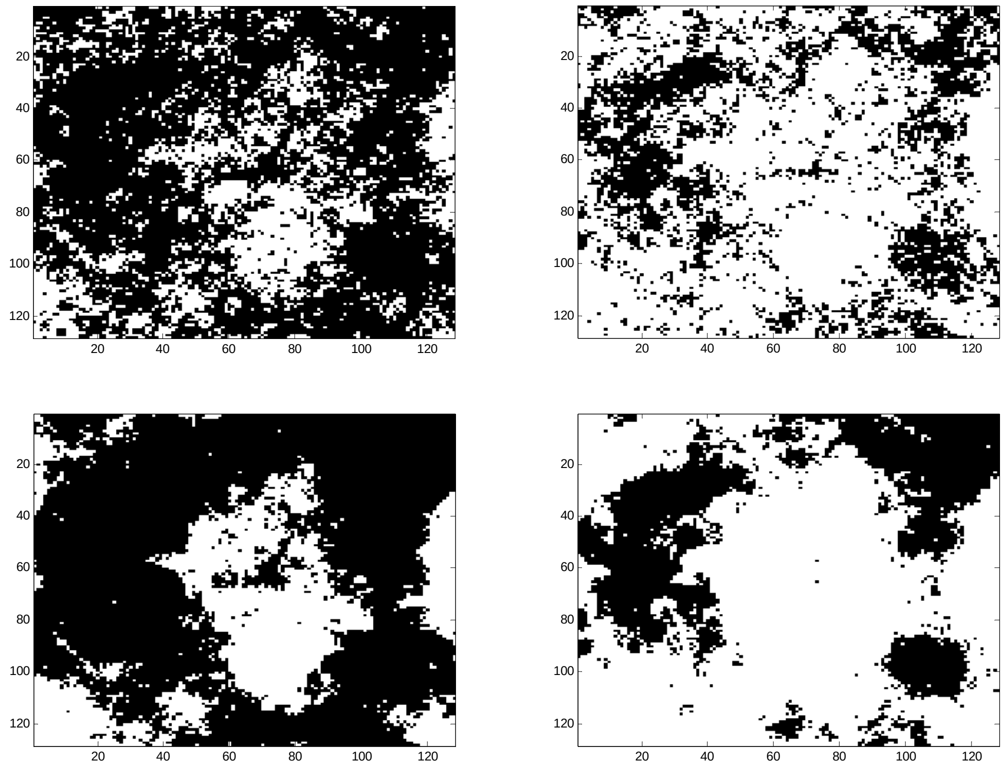
Proportion of private land

0.7 | 0.3

Landscape clustering

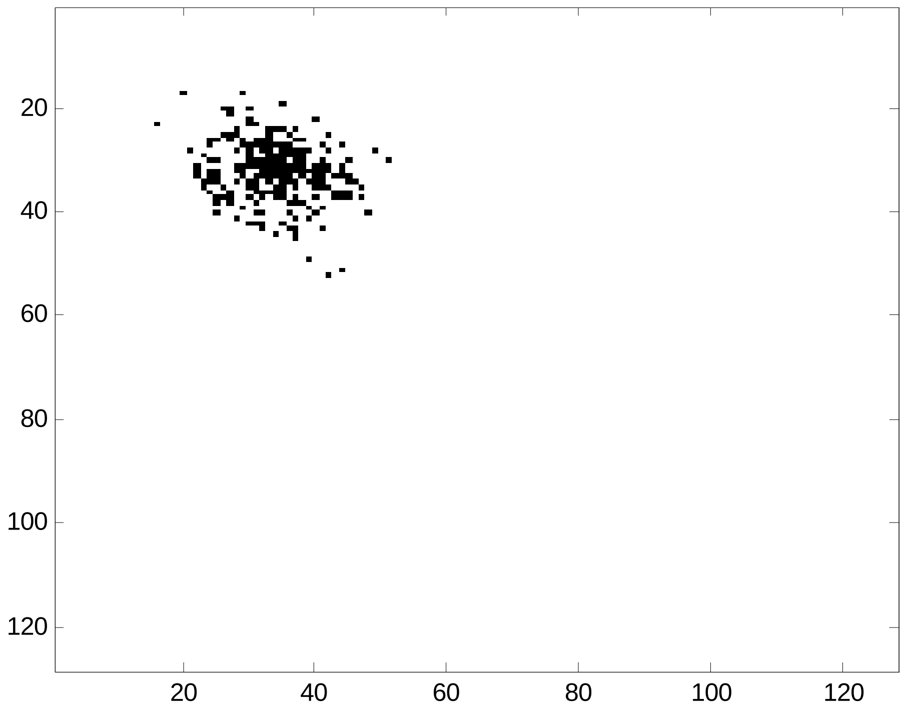
low (*D*=3.0)

high (*D*=2.5)



D = fractal dimension

Initial invasion (at time of discovery)

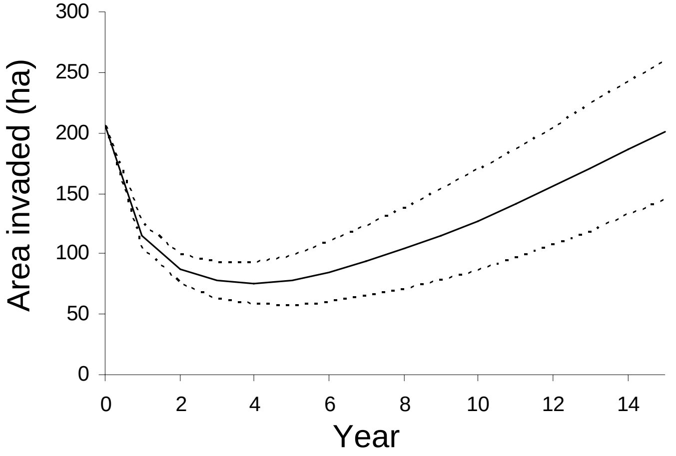


Total area invaded = sum of black pixels

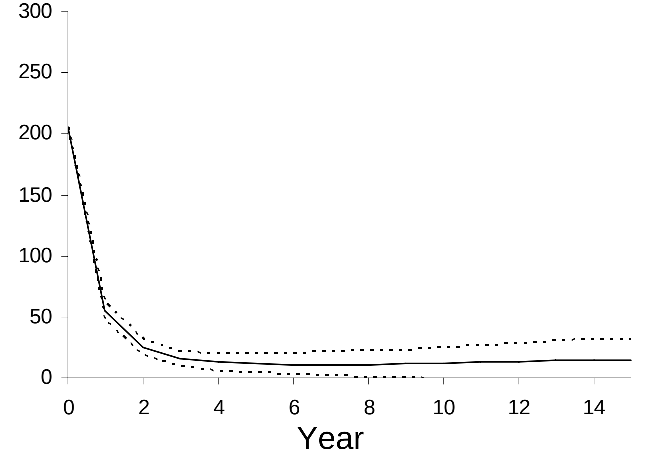
Invasion trajectories

(probability of passive detection)

(0.3)



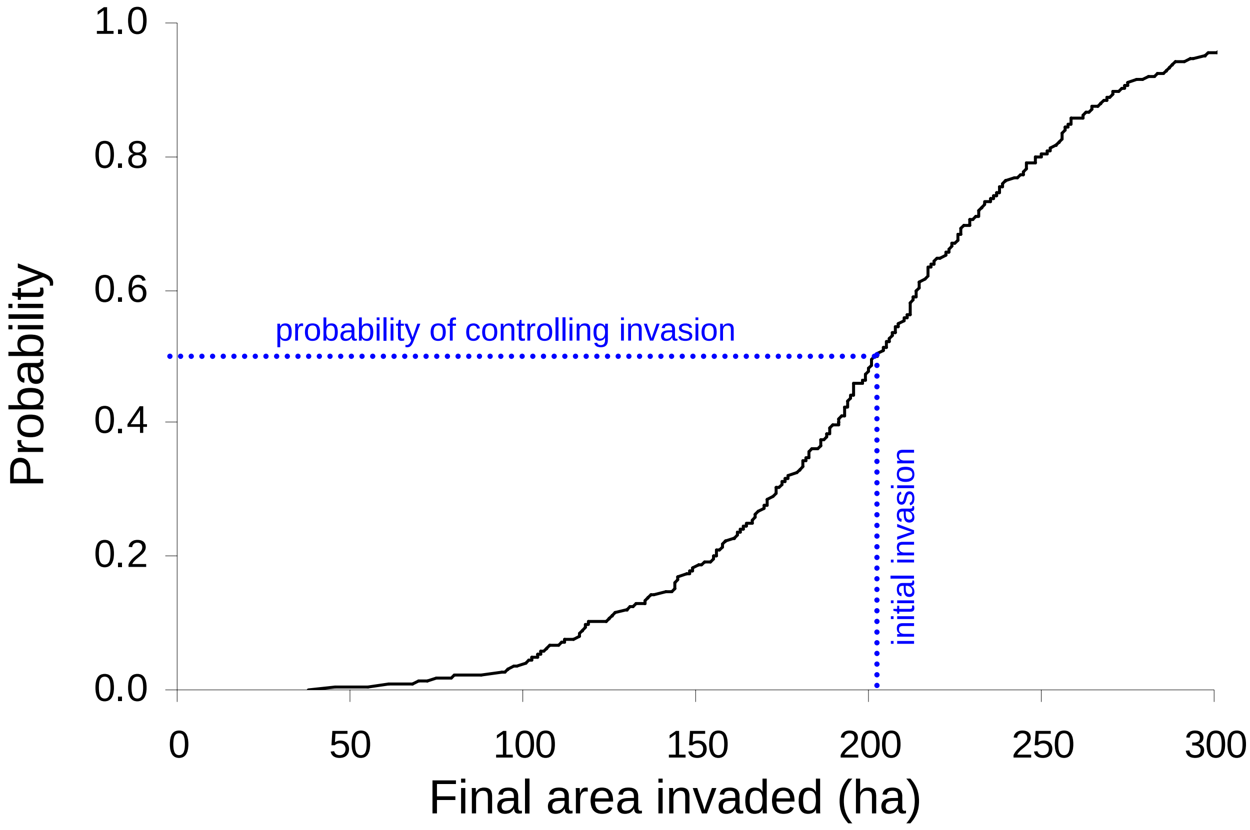
(0.7)



mean ± sd (500 iterations)

w=100; $p_p(priv)$=0.3-0.7; $p_p(pub)$=0.1; p_L=0.02; M=0

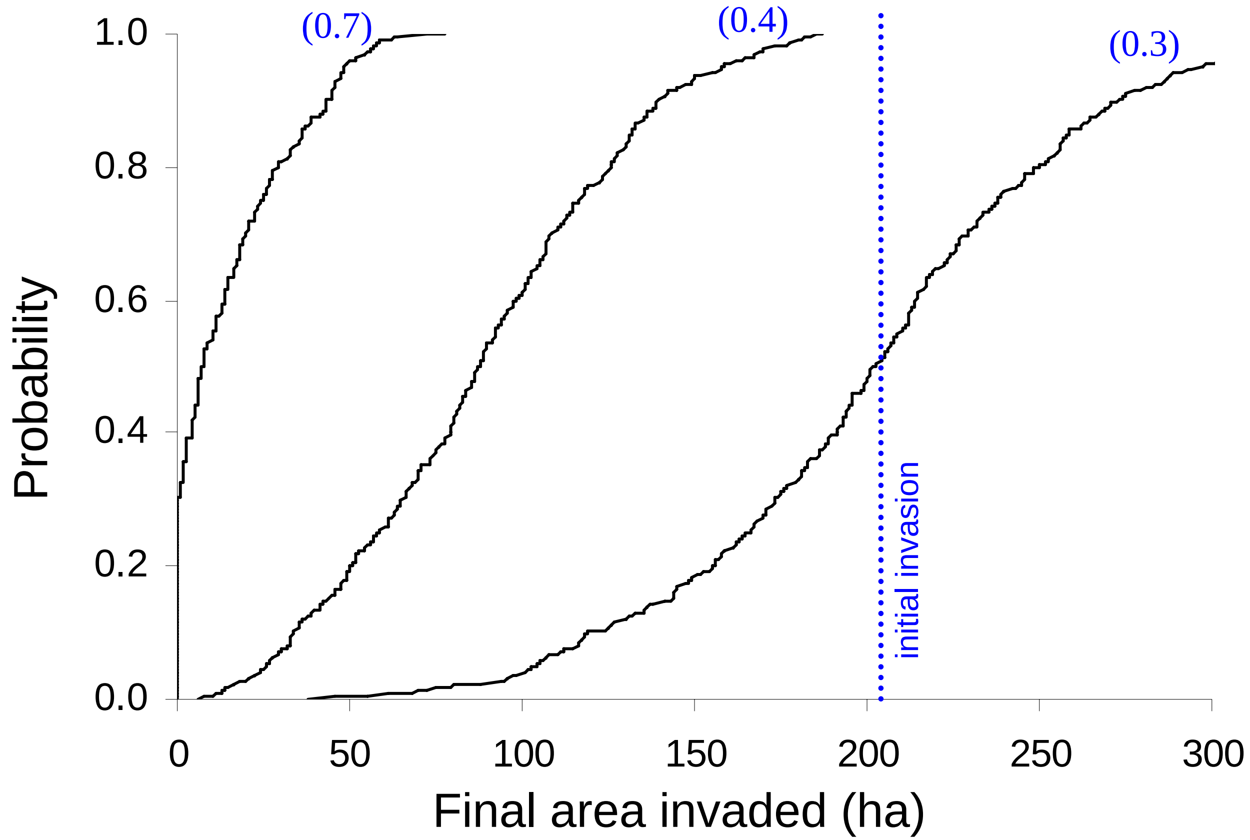
Probability of controlling an invasion



w=100; $\boldsymbol{p_p}$**(*priv*)=0.3**; p_p(*pub*)=0.1; p_L=0.02; M=0

Probability of controlling an invasion

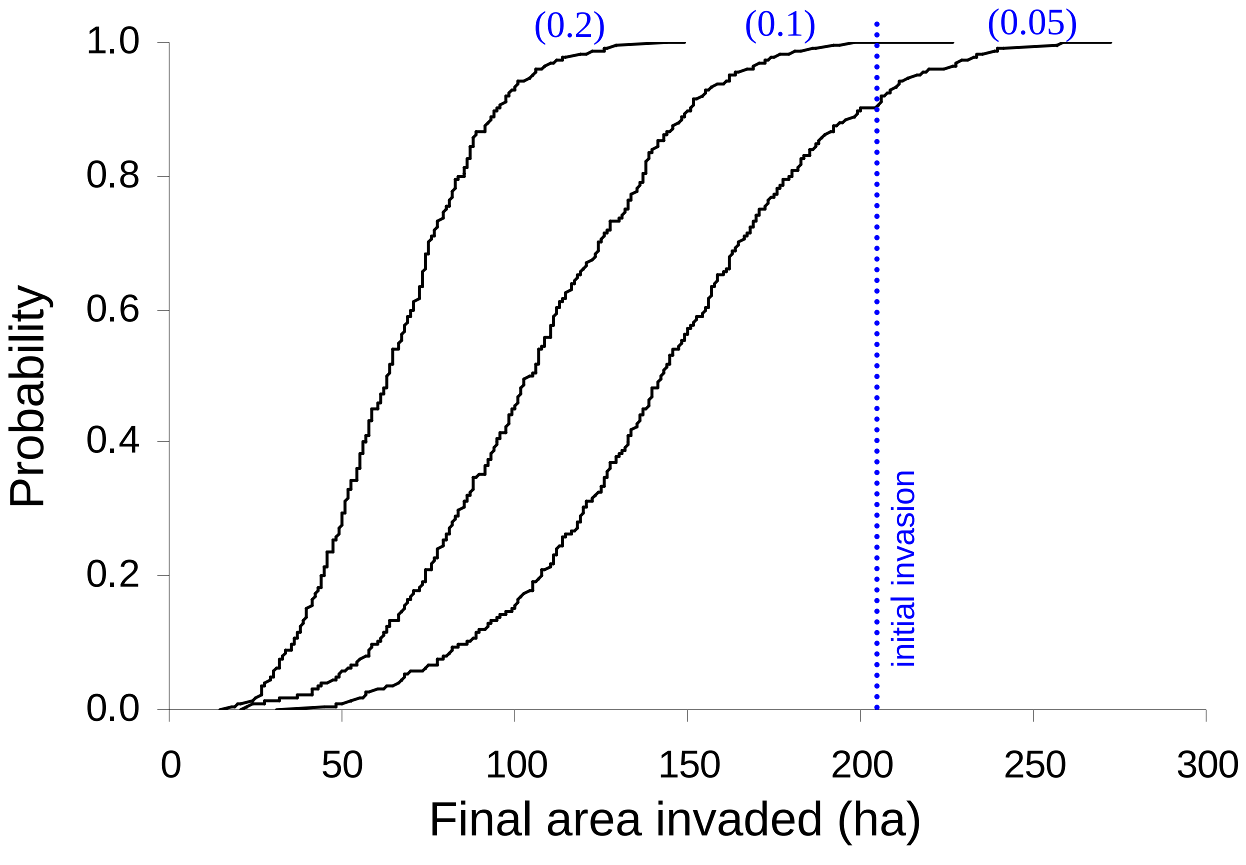
effect of passive detection probability



w=100; $p_p(priv)$=0.3-0.7; $p_p(pub)$=0.1; p_L=0.02; M=0

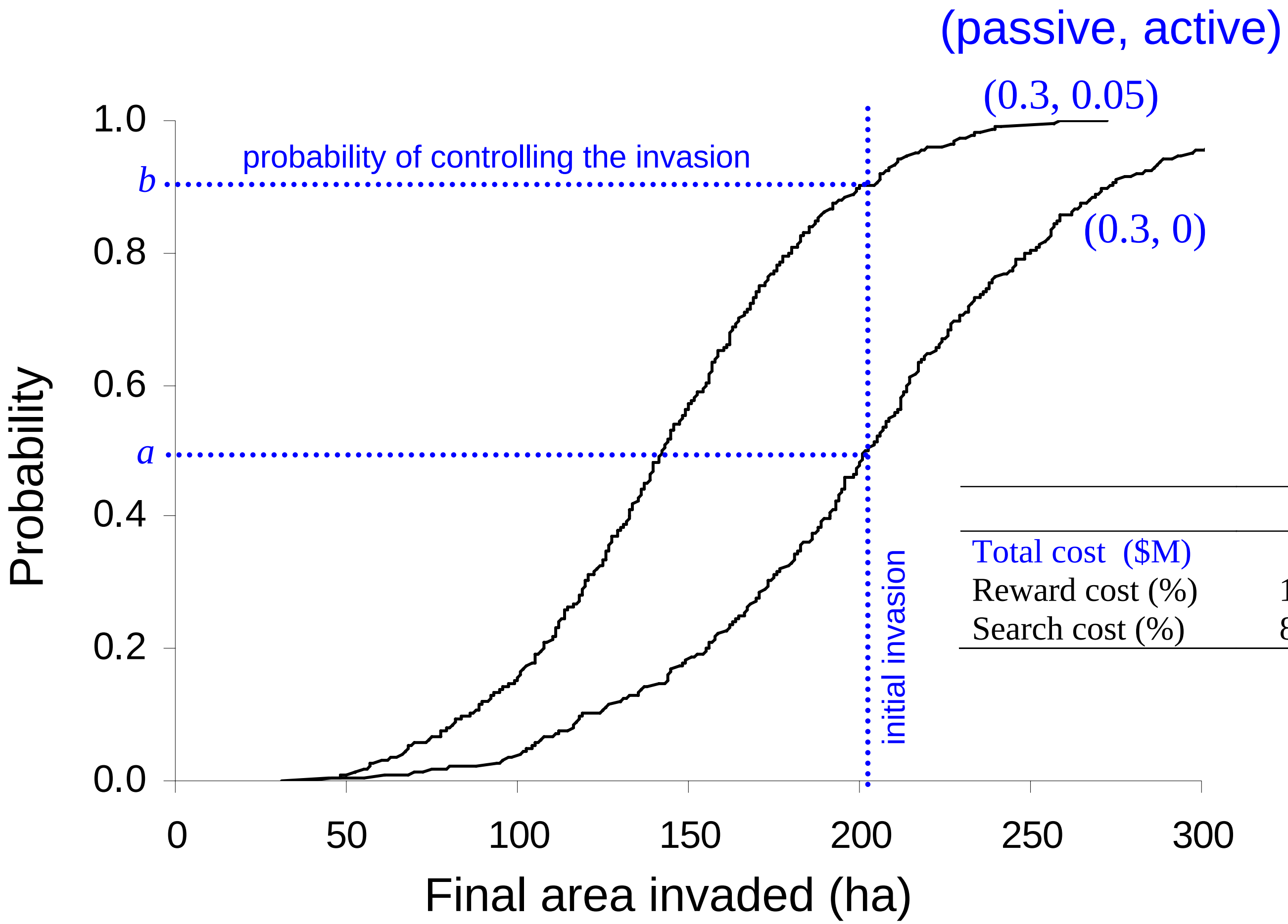
Probability of controlling an invasion

effect of active search intensity



w=100*;* p_p(*priv*)=0.3; p_p(*pub*)=0.1, p_L=0.02; *M*=1,638-16,394

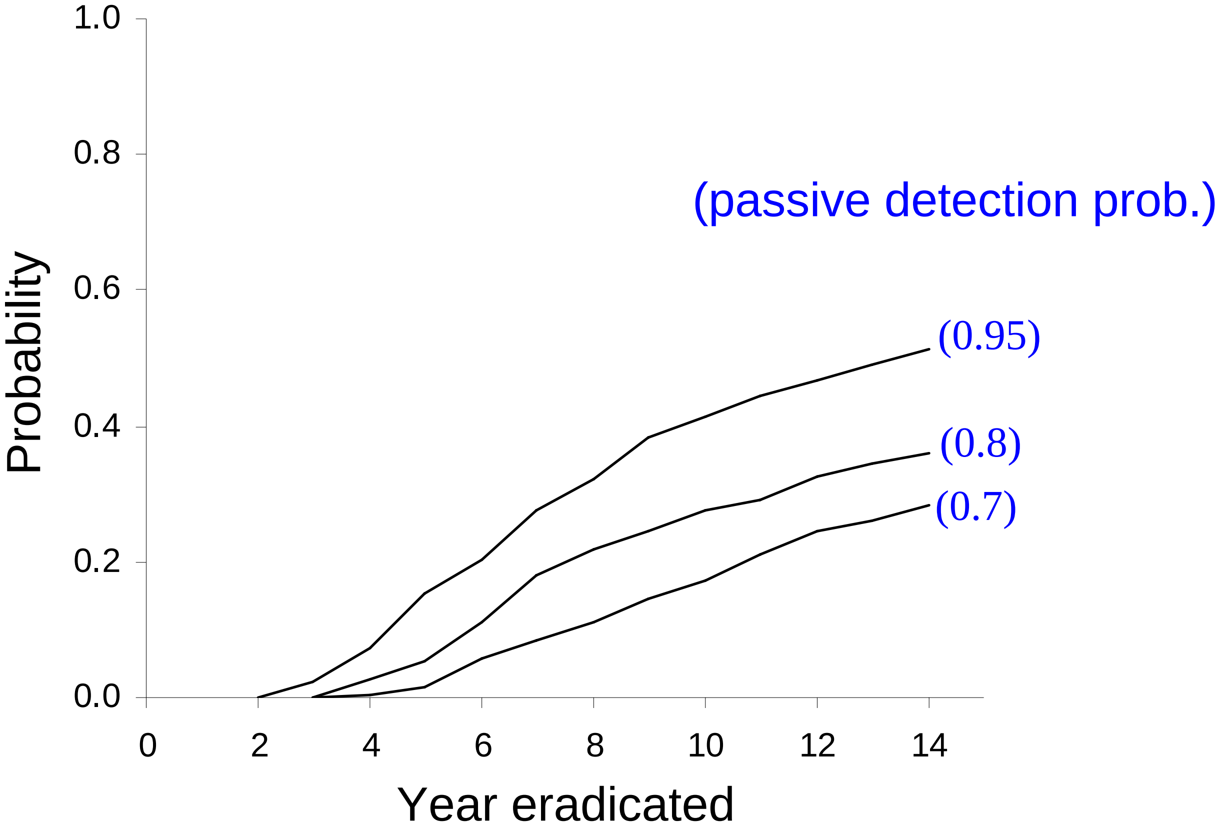
Interaction of active and passive detection



	b	*a*
Total cost ($M)	2.62	2.42
Reward cost (%)	12.64	15.32
Search cost (%)	87.36	84.68

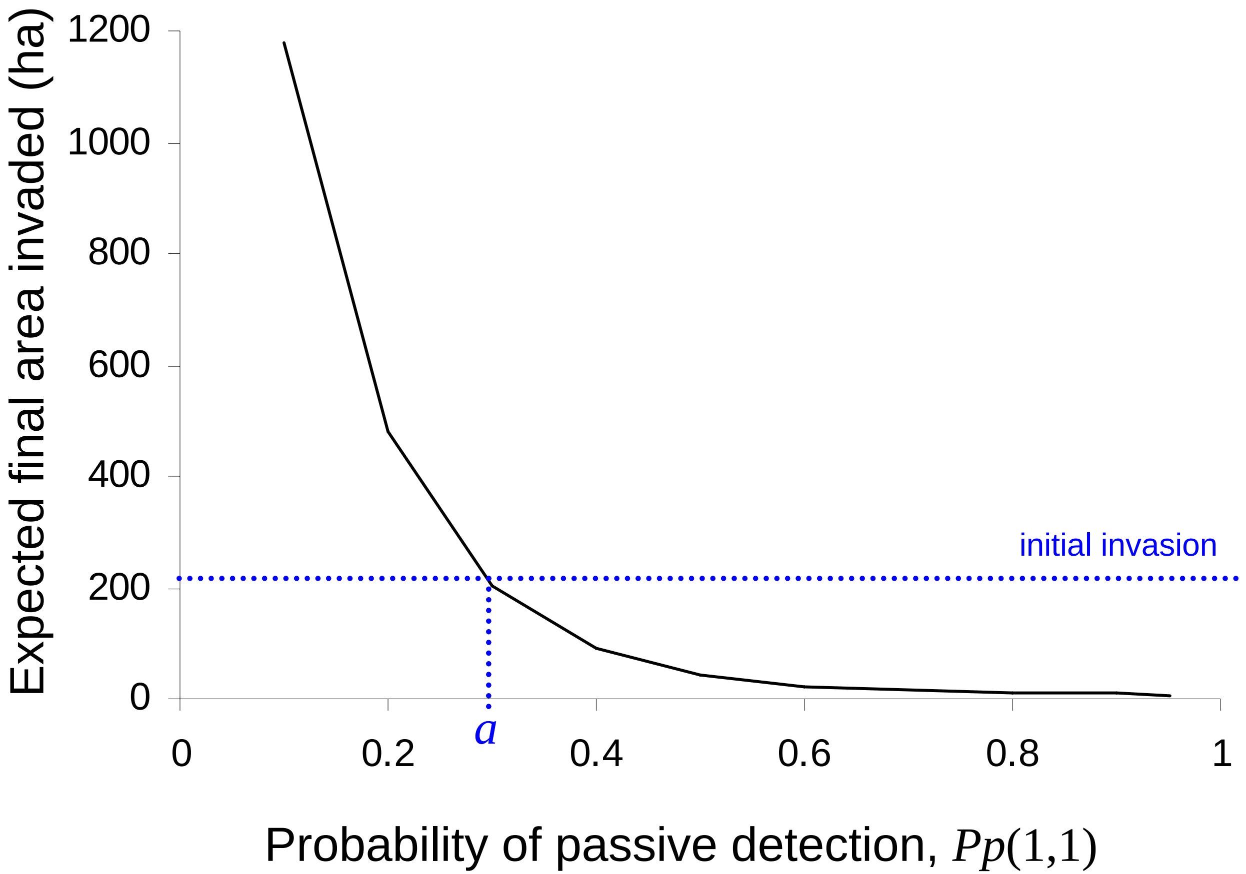
w=100; $p_p(priv)$=0.3; $p_p(pub)$=0.1, p_L=0.02; M=0-1,638

Probability of eradication



w=100; $p_p(priv)$=0.7-0.95; $p_p(pub)$=0.1, p_L=0.02; *M*=0

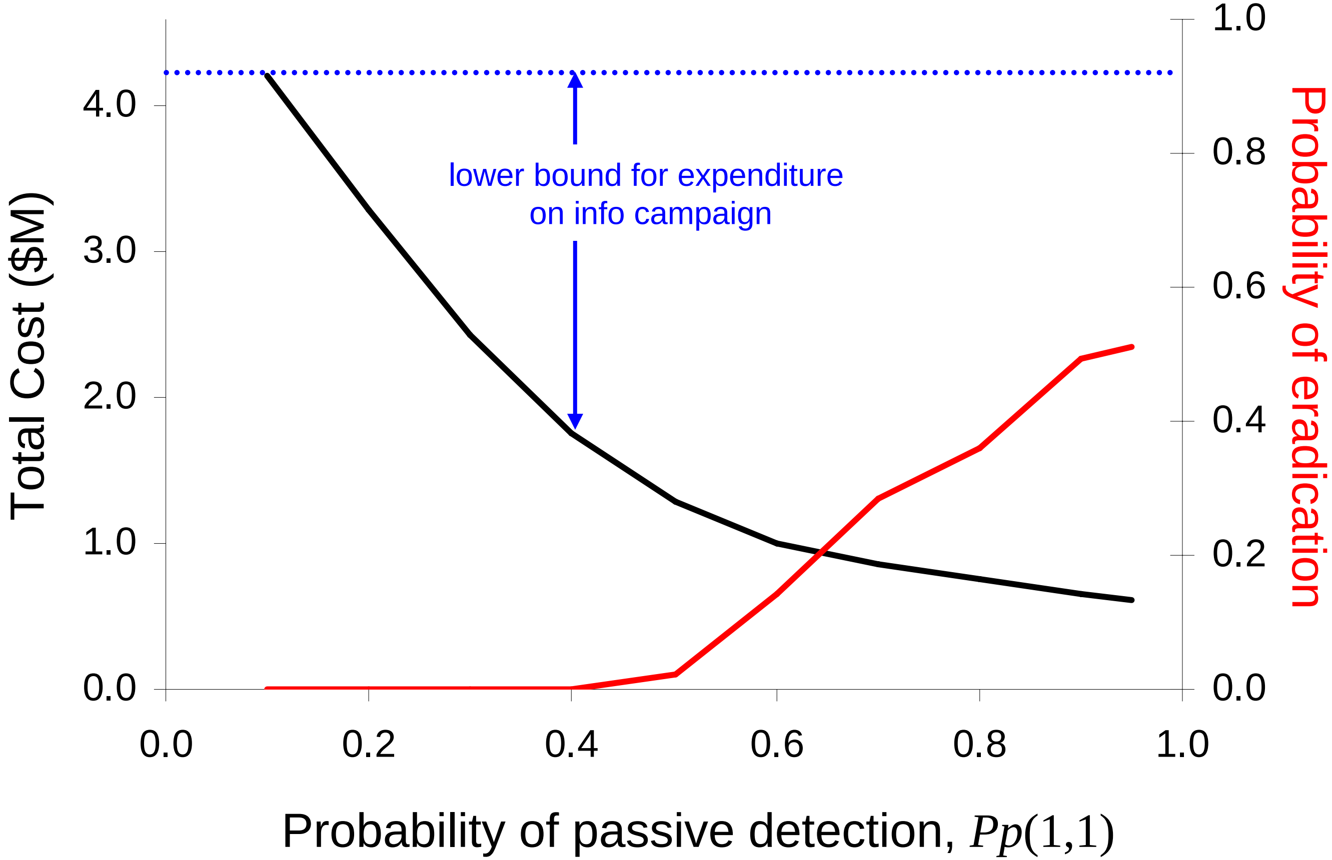
Effect of passive detection probability



T = 15 years

w=100; $p_p(priv)$=0.1-0.95; $p_p(pub)$=0.1, p_L=0.02; M=0-1,638

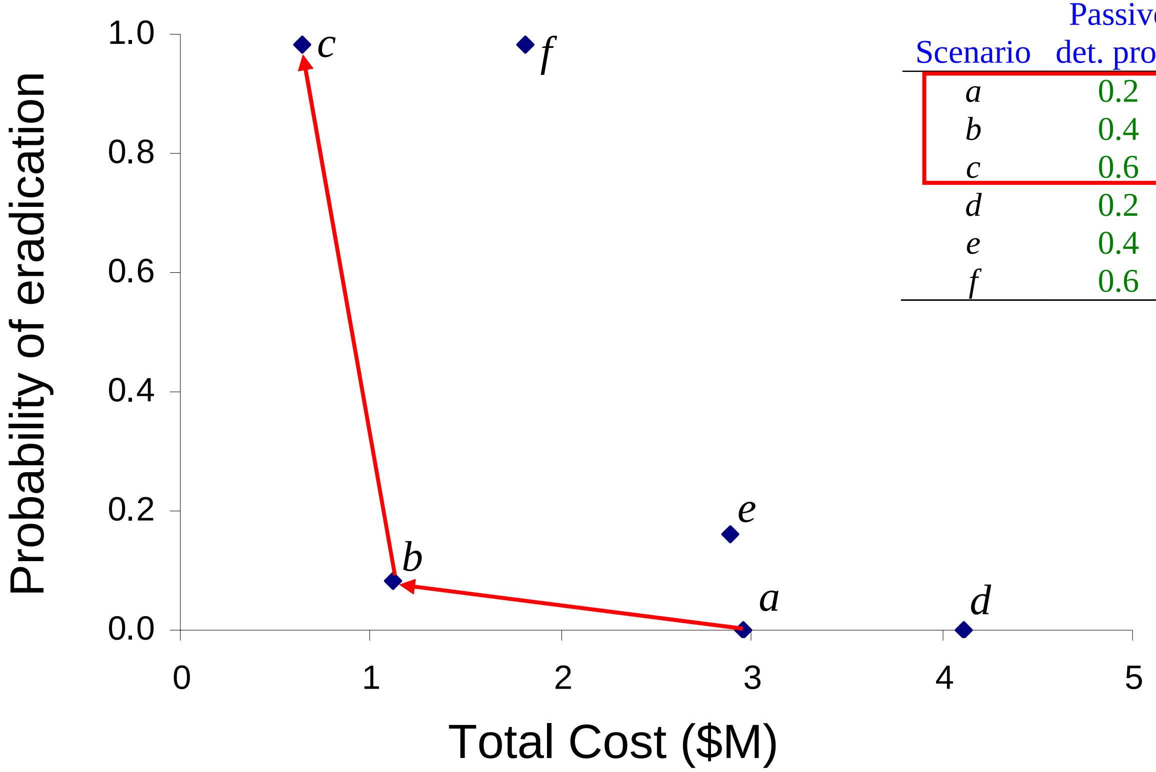
Effect of passive detection probability



T = 15 years

Total cost includes bounty payments, but not info campaign and response to false positives

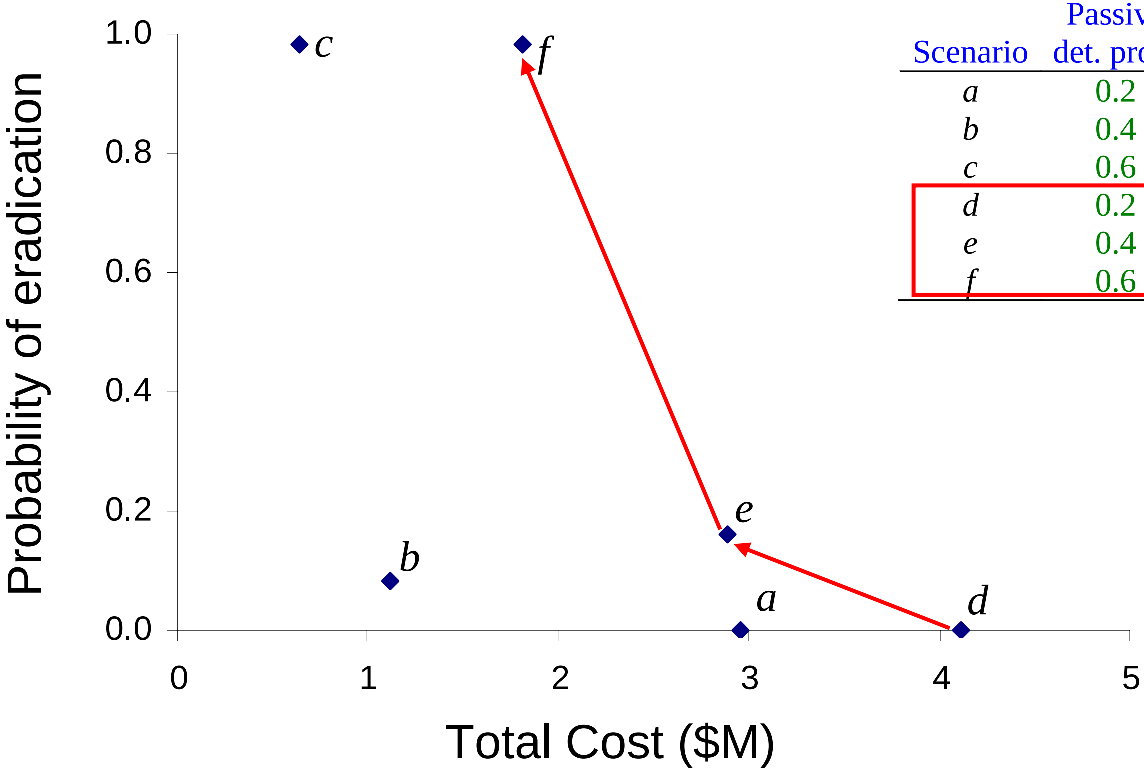
Dominance in success/cost space



Scenario	Passive det. prob.	Active search (% of area)
a	0.2	0
b	0.4	0
c	0.6	0
d	0.2	5
e	0.4	5
f	0.6	5

ignoring cost of info campaign: *c* > *b* > *a* unambiguously

Dominance in success/cost space



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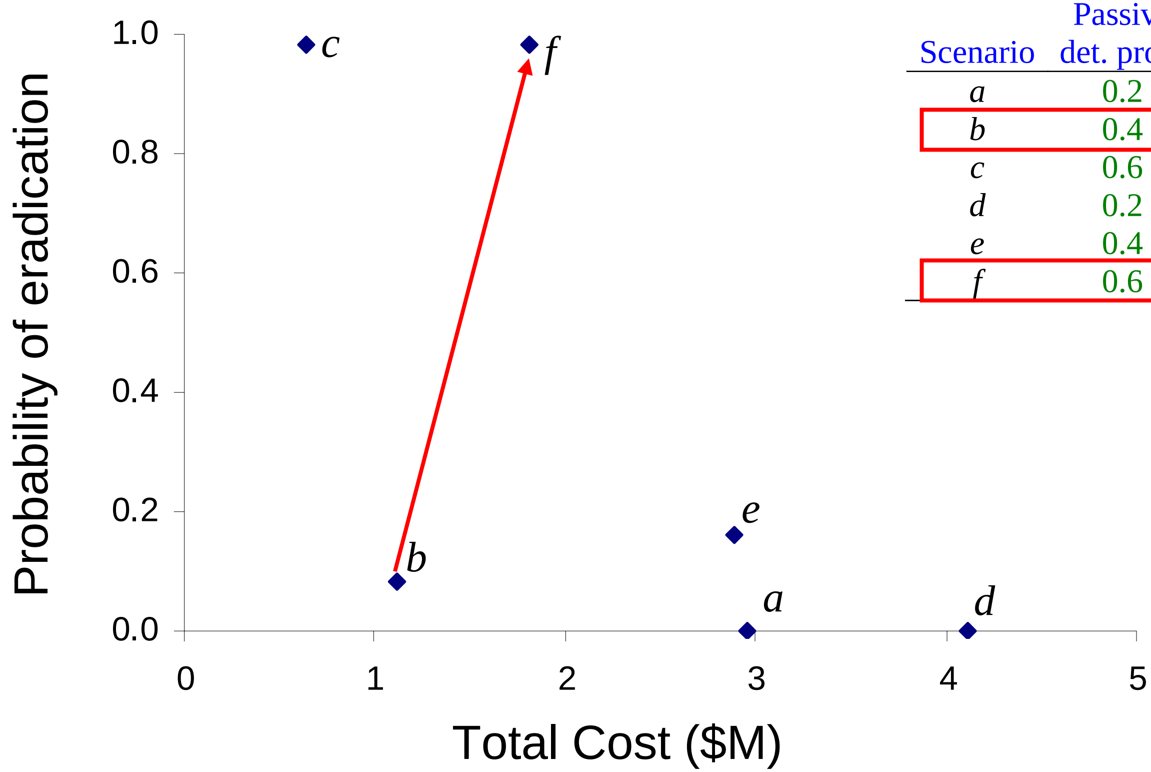
ignoring cost of info campaign: *f* > *e* > *d* unambiguously

Dominance in success/cost space



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but we can't say unambiguously that $f > b$ (what is the $ value of a vertical move?)

The fire ant story

- First detected in 2001 near Brisbane's main port
- Left untreated their cost is estimated at $8.9 billion over the next 30 yr
- Since the scheme commenced, the number of nests removed has declined from over 65,000 to 90 known infested properties
- Most detections have resulted from accidental encounters with private citizens rather than active searching
- In April-June 2008 a bounty scheme was in place a $500 reward for reports by private citizens of new infestations
- So far the scheme resulted in 29 reports of positive detections with a possible 27 reward payouts from 2196 public reports
- This represents a 940% increase in the level of public response compared to previous year
- There have been nine new outlying areas of infestation detected this 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

Conclusions

- Active search may result in containment, but is unlikely to achieve eradication at reasonable cost
- Passive search (enhanced by a bounty scheme) can result in significant cost savings and increased eradication probability
- Even small increases reporting rates can substantially reduce eradication costs and increase the probability of eradication
- The cost of bounty payments is minor compared to the cost of active (and follow-up) search and treatment
- The effect of information campaigns and bounty payments on probability of passive detection is an important topic for future research
- A useful extension would consider the risk of fraudulent activity that spreads invaders for financial gain
- The QLD fire ant invasion provides an opportunity for studying the potential cost and effectiveness of an urban bounty scheme