Search and destroy: Cost-effective surveillance for pest management

My most recent study determines where and how much we should invest in surveillance to detect a pest or disease. Other researchers have developed habitat suitability maps to identify hot-spots and prioritise resources, but I've also incorporated variable detection rates and a cost-benefit analysis to create a cost-effective design. It can tell us whether we're better off searching many sites quickly, or a few high-risk sites thoroughly. Not only can we calculate how much surveillance expenditure is justified and how to prioritise sites under a limited surveillance budget, we can also assess the value of developing a habitat suitability map compared to relying on current knowledge.

This method is sufficiently flexible for use in a range of terrestrial and marine environments, where natural features and/or economically valuable species are threatened by invasive species. I've applied it to the surveillance and treatment of orange hawkweed (*Hieracium aurantiacum*) in alpine Victoria, Australia, where I was able to calculate optimal visit lengths for over 4000 x 4ha sites in a spreadsheet *(see figure below)*.

Relevant publications

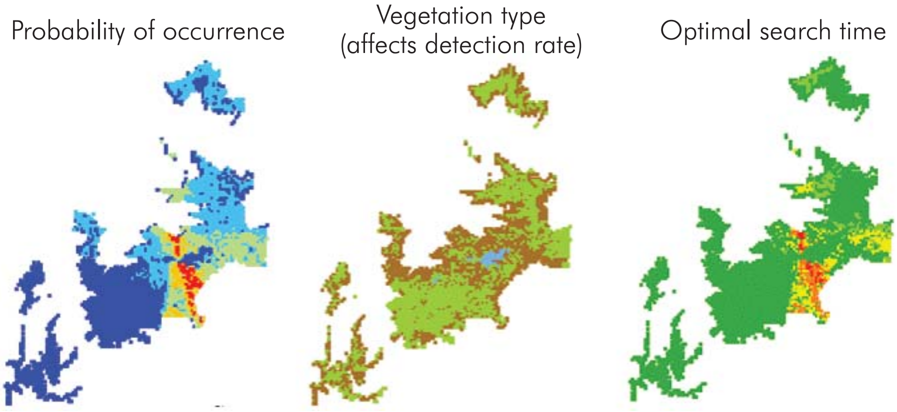
Rout TM, Hauser CE and Possingham HP. In press. Optimal adaptive management for the translocation of a threatened species. Ecological Applications.

Moore AL, Hauser CE and McCarthy MA (2008) How we value the future affects our desire to learn. Ecological Applications 18(4): 1061–1069.

Hauser CE and Possingham HP (2008) Experimental or precautionary? Adaptive management over a range of time horizons. Journal of Applied Ecology 45: 72–81.

Hauser CE, Pople AR and Possingham HP (2006) Should managed populations be monitored every year? Ecological Applications 16(2): 807–819.

Orange hawkweed surveillance on the Bogong High Plains, Victoria



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Day 2, 9.15m

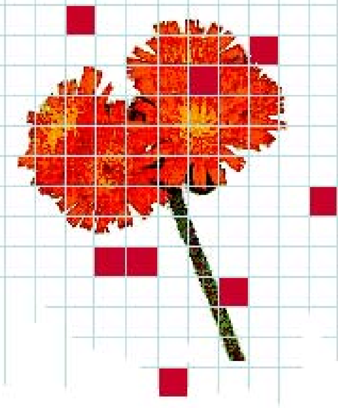
Area of work: ecological modelling and decision-making in the face of uncertainty

Specialty: I aim to develop rational, repeatable and transparent approaches to environmental management that account for uncertainty, incomplete knowledge and scarce data. I'm particularly interested in optimal monitoring (applying cost-benefit analysis to investment in monitoring), adaptive management (strategic management for gaining knowledge and data) and robustness (ensuring acceptable outcomes in the face of uncertainty).

Take-home messages:

To prioritise surveillance for pests and diseases, we should consider:

- where the pest is most likely to be,
- where we'll be able to find it quickly (and where it conceals itself), and
- the value of early detection in protecting assets and natural features.



Streamlining ‘search and destroy’

cost-effective surveillance for pest management

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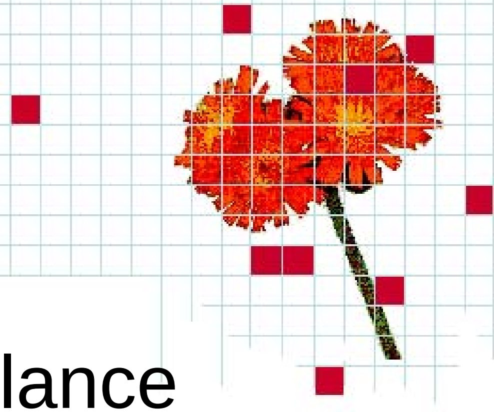
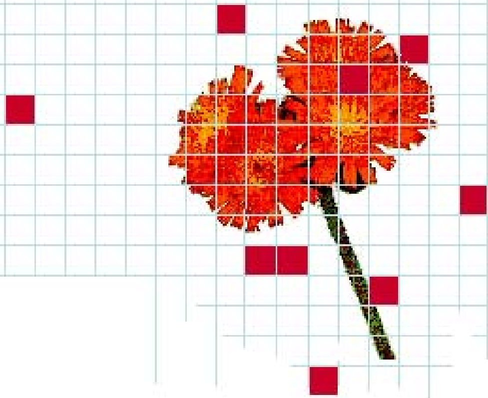
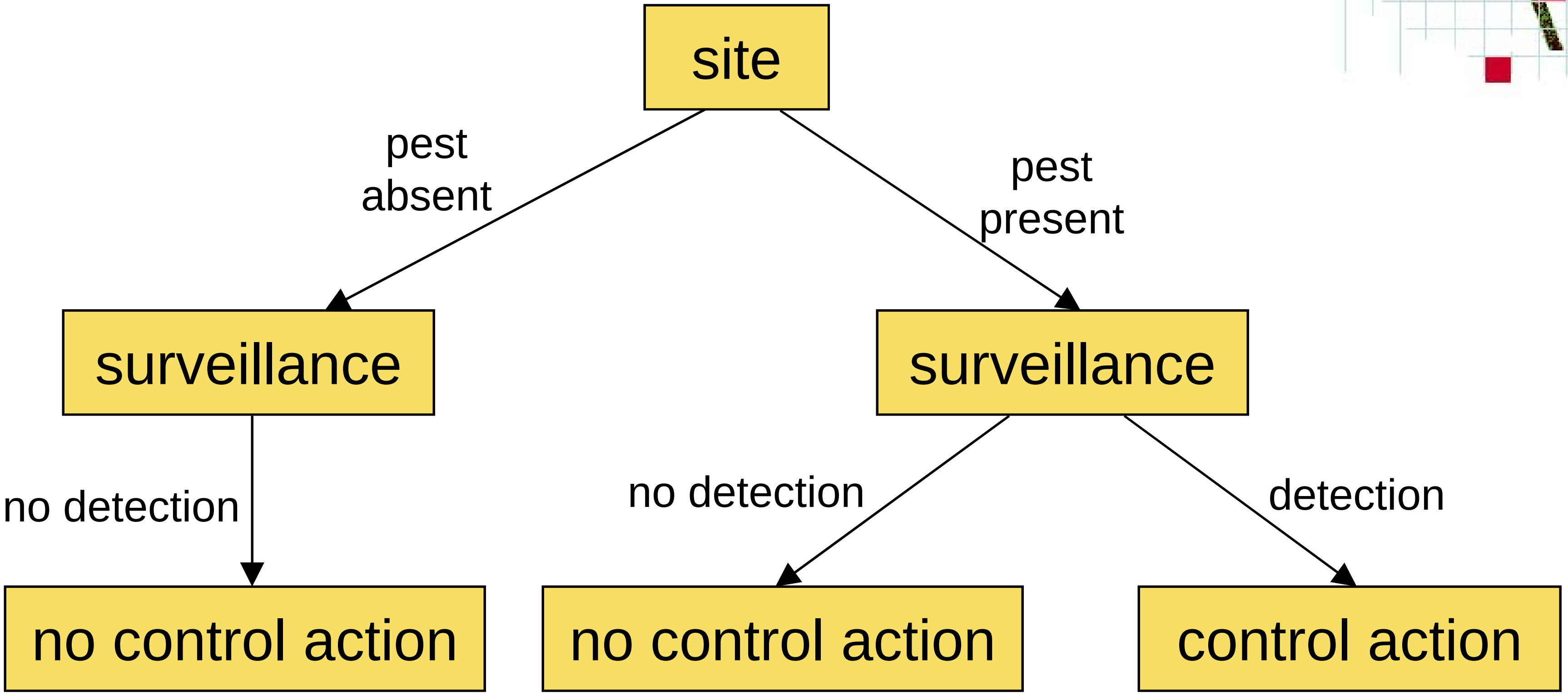
Optimal monitoring



- Making the most of monitoring/surveillance
- How much is enough?
- Explicitly link monitoring accuracy to costs, decisions and outcomes
- Surveillance for a pest or disease – where and how hard should we look?

Simple model





site

pest absent

pest present

surveillance

surveillance

no detection

no detection

detection

no control action

no control action

control action

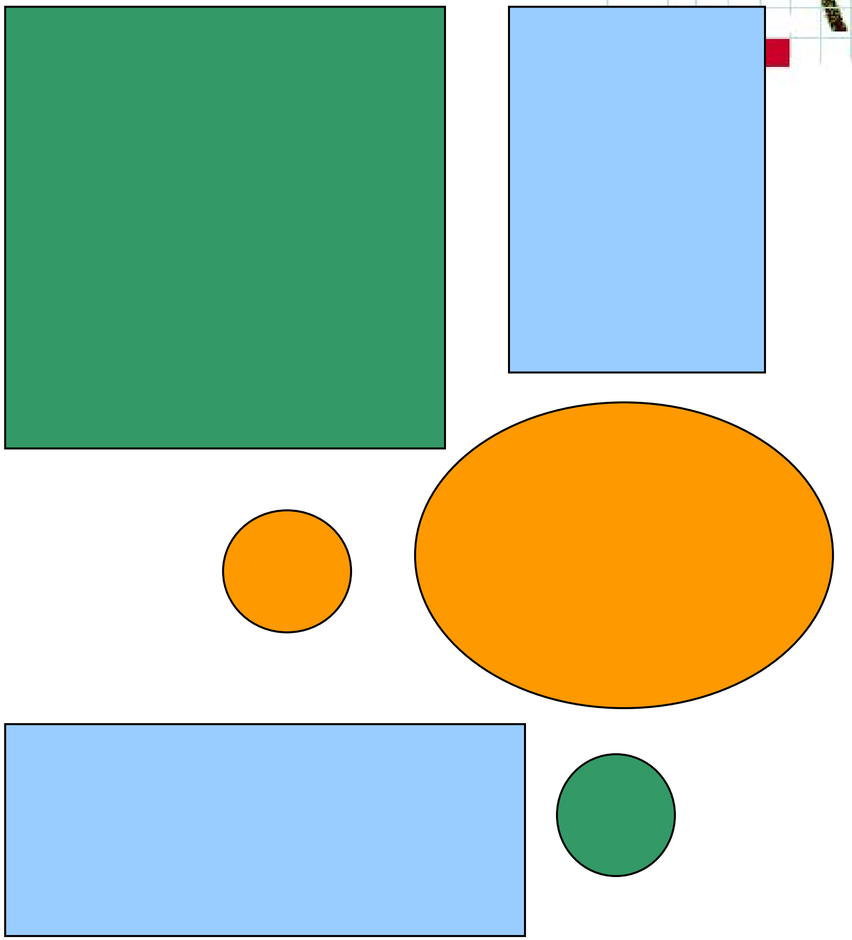
- surveillance

- surveillance
- pest escape

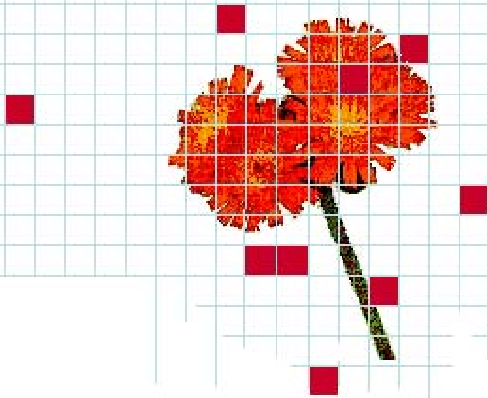
- surveillance
- control
- (no escape)

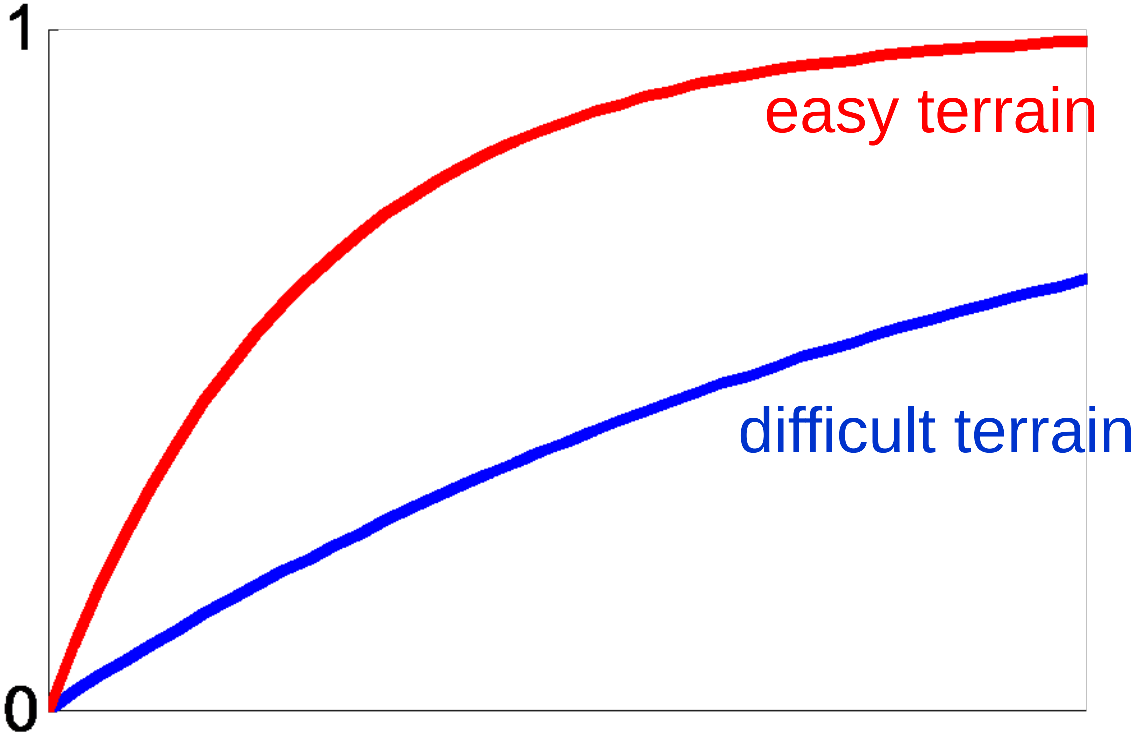
Spatial variation

- We usually have a heterogeneous landscape
- Varying…
  - probability of pest presence
  - ability to detect the pest
  - ability to control the pest
  - value of pest freedom
- *How should we allocate a surveillance budget over space?*



Surveillance model

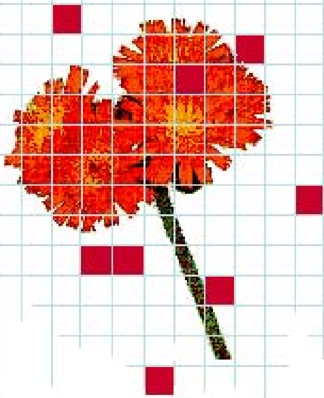




probability
of detection
at an
infested site

surveillance effort

The optimal allocation



- Surveillance budget *B*
- Minimise incursion management costs
  (control, damage, spread)
- To each site *i*, allocate:

$$x_i^* = \begin{cases} \dfrac{\ln\left[\left(c_i^U - c_i^D\right) p_i \lambda_i\right]}{\lambda_i} + \dfrac{\bar{\lambda}(k)}{\lambda_i}\left[\dfrac{B}{k} - \bar{x}(k)\right], & i = 1, 2, \ldots, k \\ 0, & i = k+1, k+2, \ldots, n \end{cases}$$

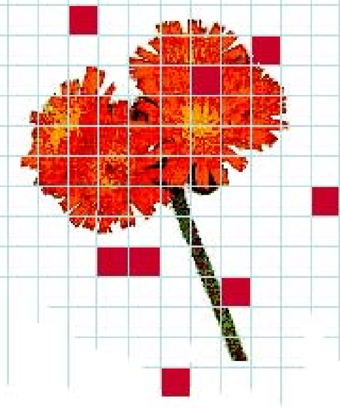
where

$$\bar{\lambda}(k) = \frac{k}{\sum_{i=1}^{k} \lambda_i^{-1}}, \quad \bar{x}(k) = \frac{1}{k}\sum_{i=1}^{k} \frac{\ln\left[\left(c_i^U - c_i^D\right) p_i \lambda_i\right]}{\lambda_i},$$

and k satisfies

$$\left(c_k^U - c_k^D\right) p_k \lambda_k > \exp\left[\bar{\lambda}(k)\left(\bar{x}(k) - \frac{B}{k}\right)\right] > \left(c_{k+1}^U - c_{k+1}^D\right) p_{k+1} \lambda_{k+1}.$$

The optimal allocation



- We can prioritise sites using the score

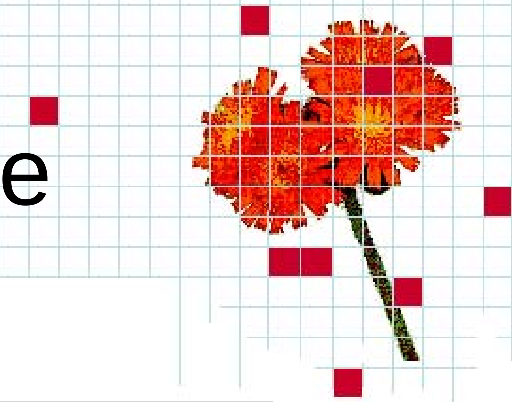
$$p_i(c_i^U - c_i^D)\lambda_i$$

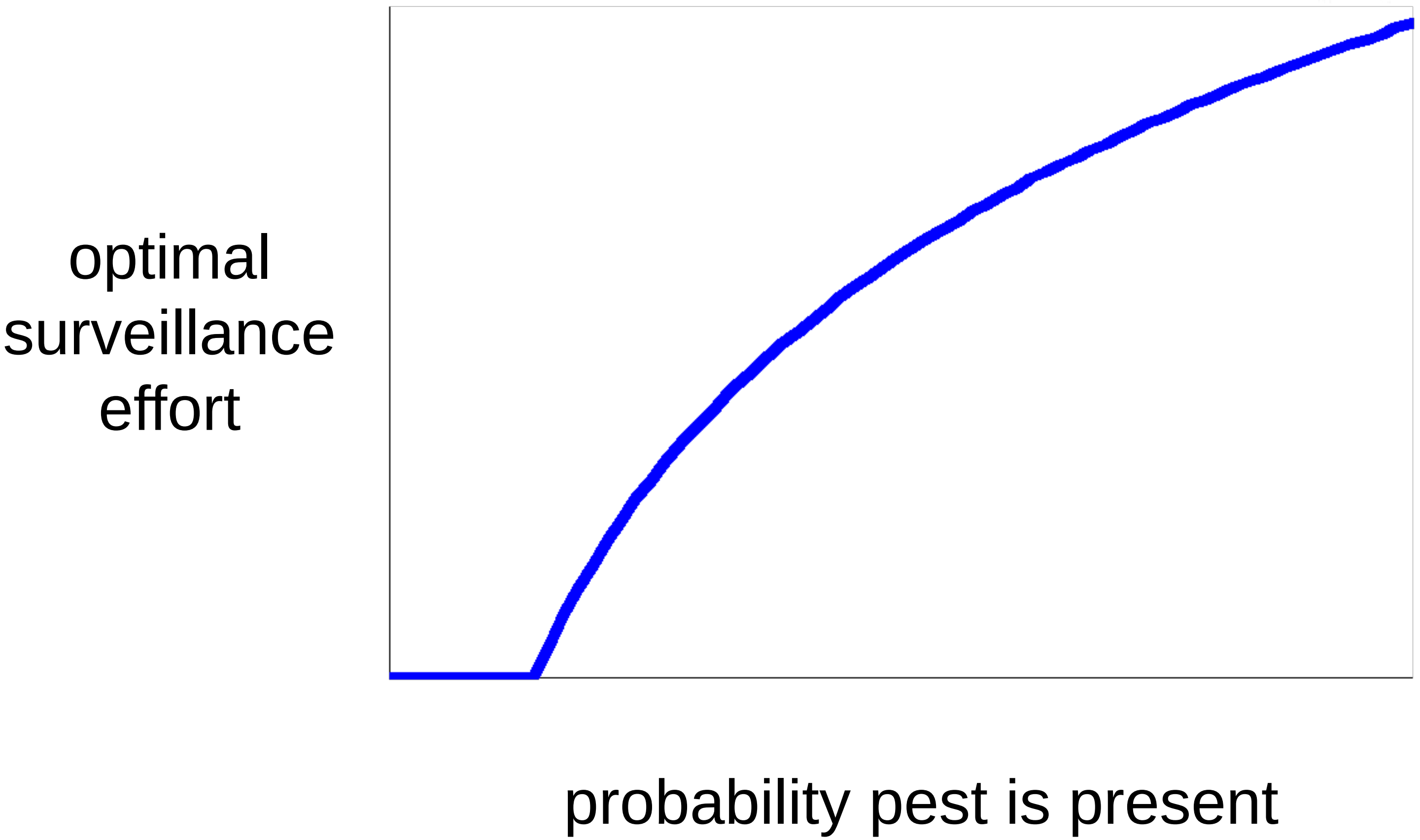
- That is, we target sites where:
    - the pest is most likely to be
    - the surveillance method is most effective
    - successful detection is of most benefit

      (high value of pest freedom, control is cost-effective)

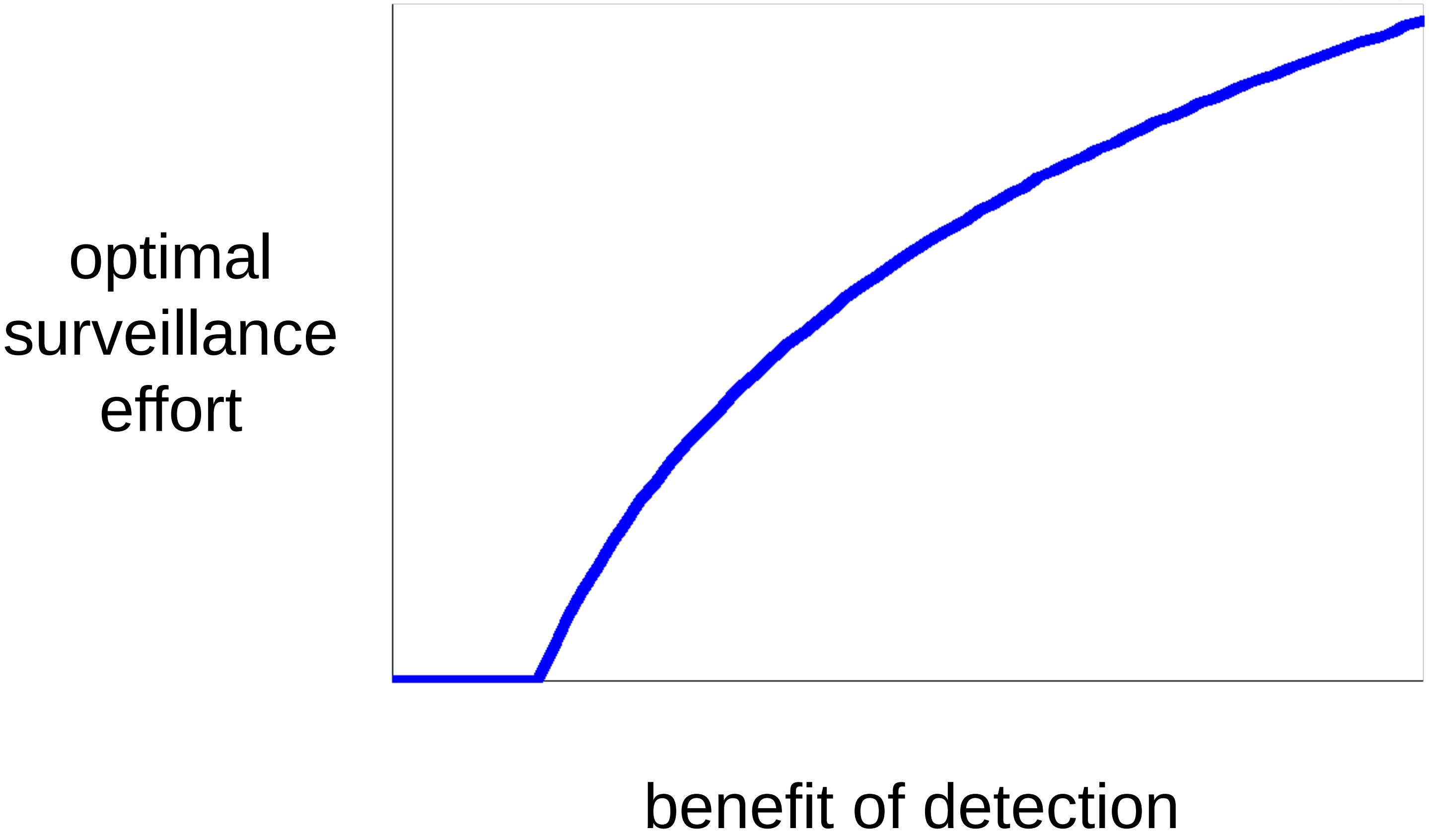
- The solution also tells us *when to stop* searching a site and move down the priority list…

Effect of probability of presence

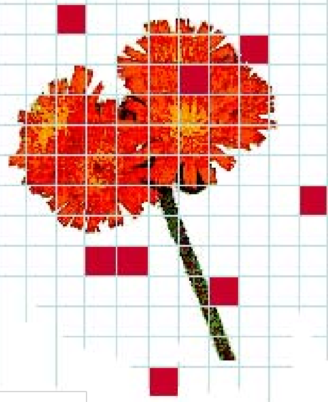


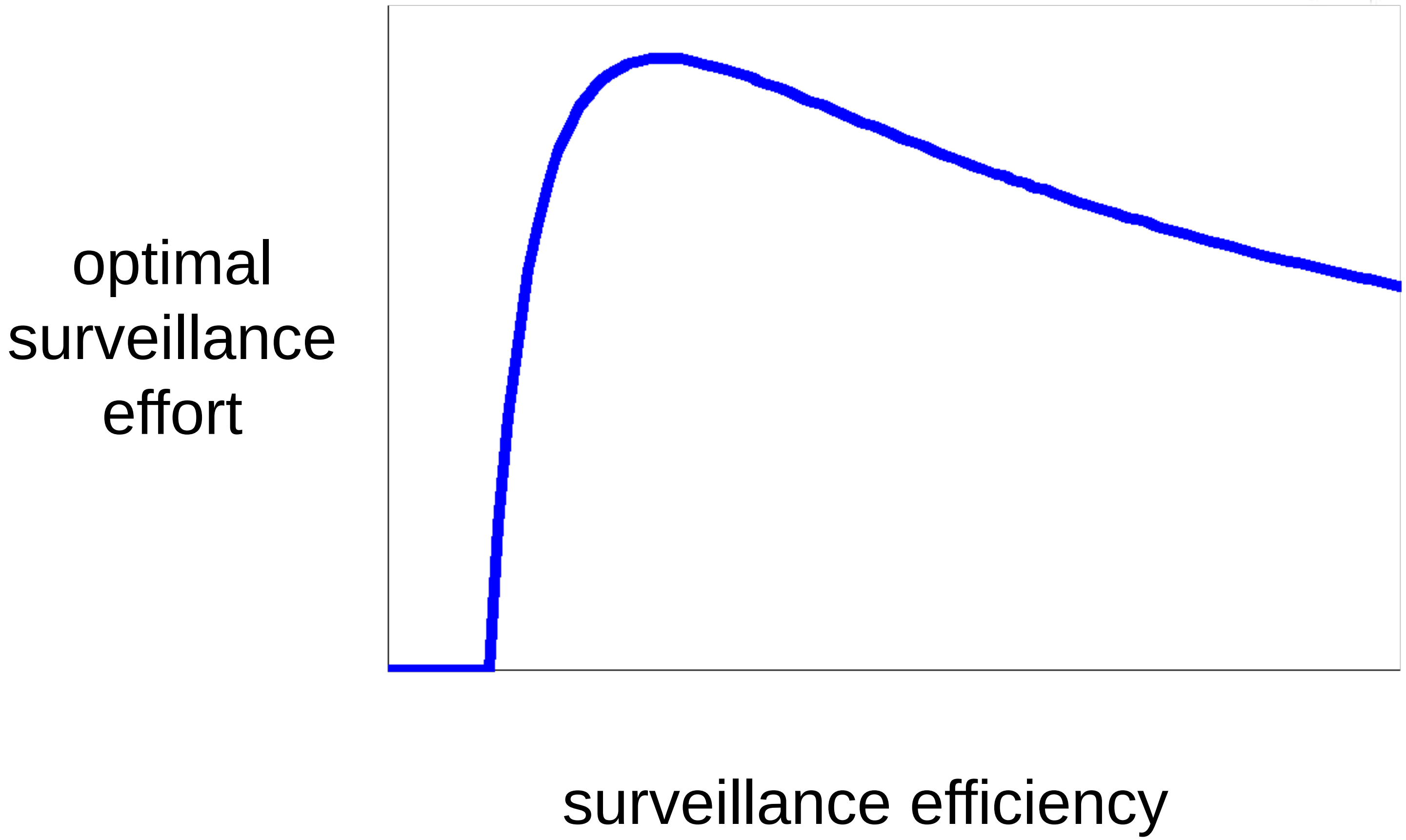


Effect of ‘benefits of detection’

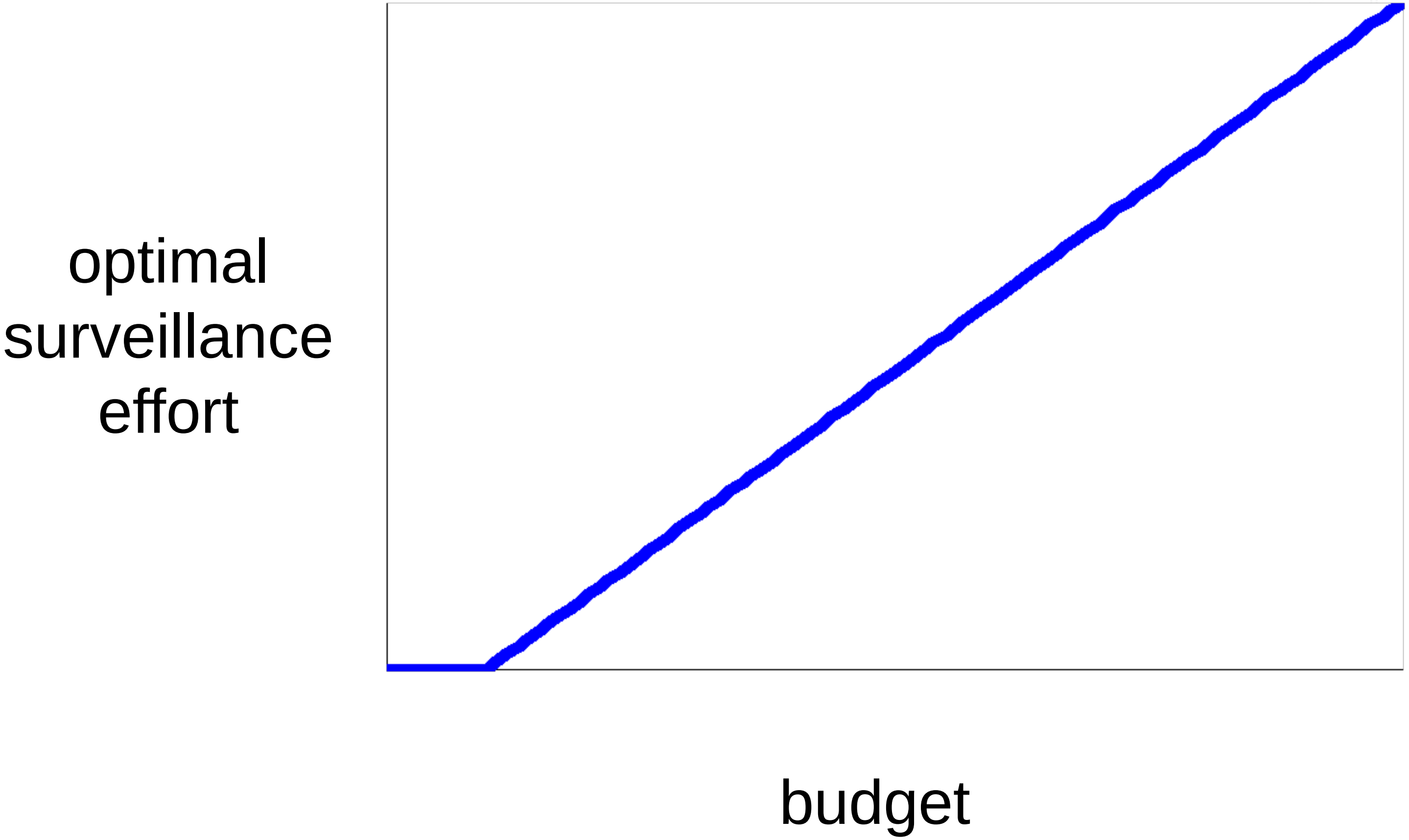


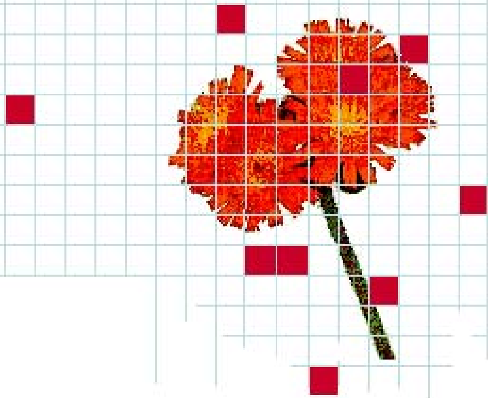
Effect of surveillance efficiency





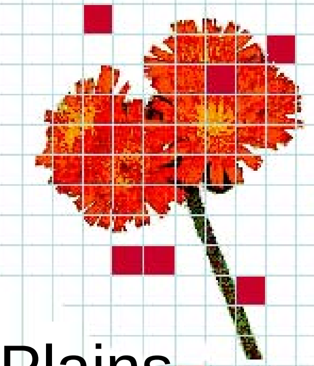
Effect of budget





This surveillance allocation can be calculated in a spreadsheet!

Orange hawkweed (*Hieracium aurantiacum*)

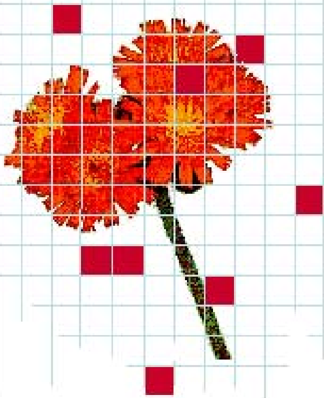


- Parks Victoria currently survey the Bogong High Plains for orange hawkweed each summer, and treat known infestations

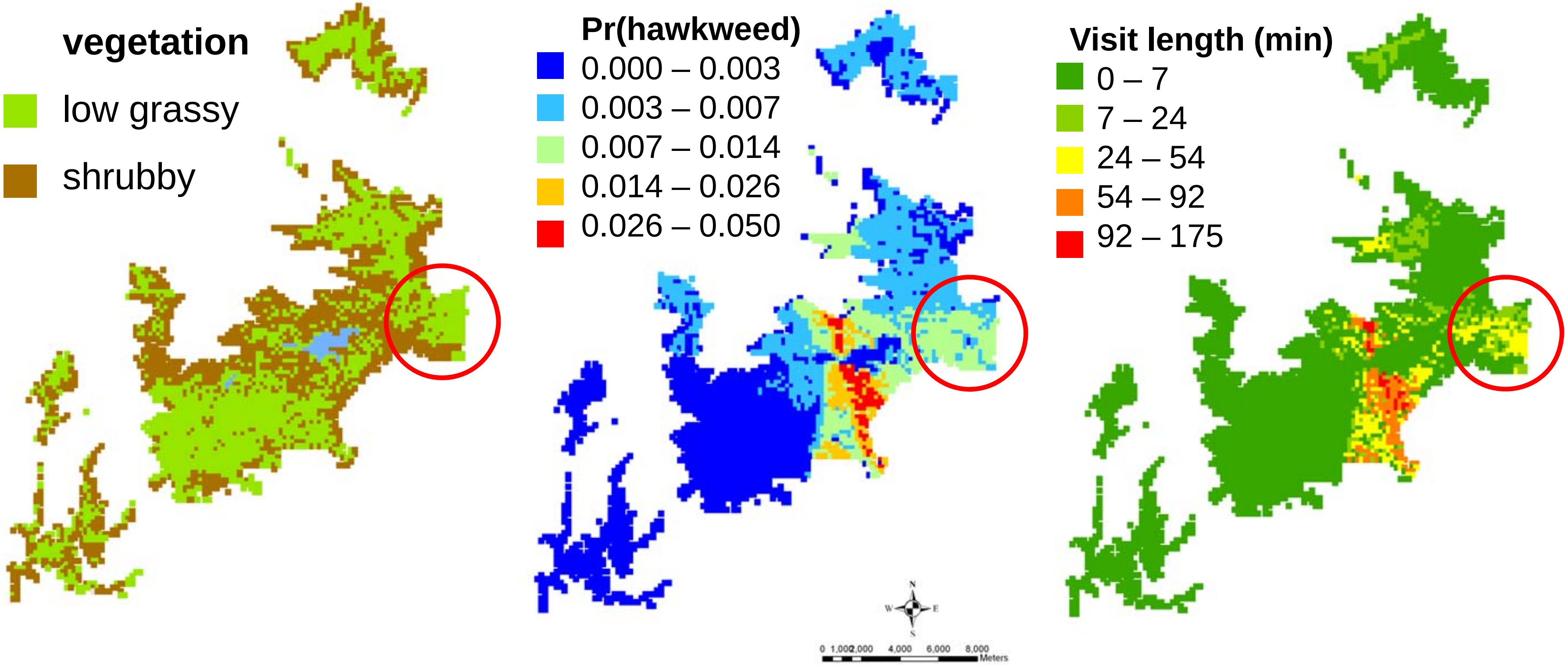
- Probability of hawkweed occurrence has been modelled as a function of disturbance level, wetness, vegetation community, potential dispersal
  - Williams, Hahs, & Morgan (2008). A dispersal-constrained habitat suitability model for predicting invasion of alpine vegetation. *Ecol. Appl. 18, 347-359.*

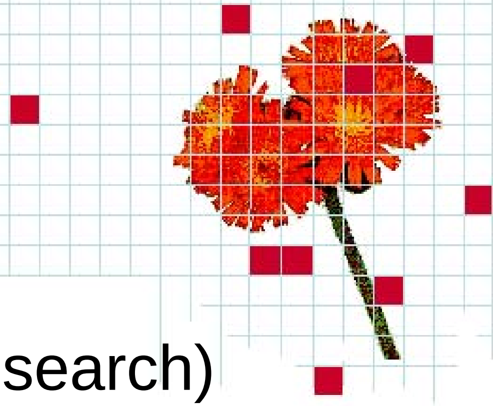
- The key constraint on surveillance is the number of search hours available

Orange Hawkweed example



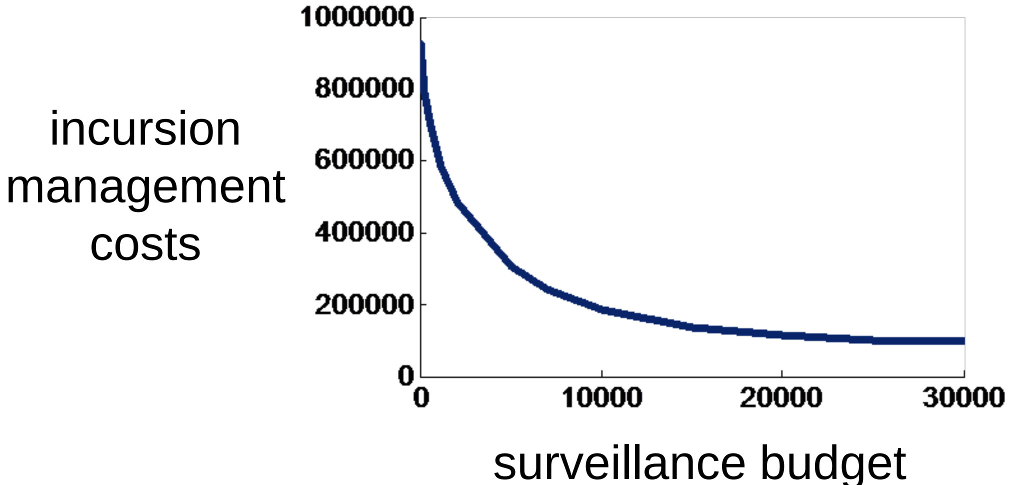
4219 x 4ha grid cells



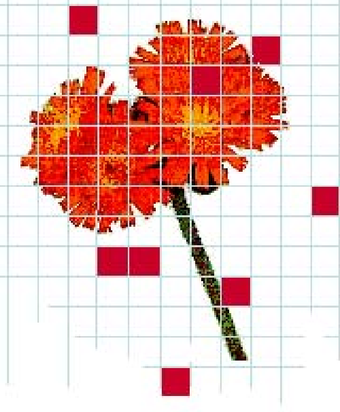


General rules

- Search a wide range of low grassy (easy to search) sites, but only briefly
- Search the highest priority shrubby (difficult to search) sites for a long time
- Skip the lower priority shrubby sites
- For larger budgets, include more sites in the plan and search them all for longer



Conclusions



We should search where we think a pest is most likely to be

BUT

the effectiveness of our surveillance method

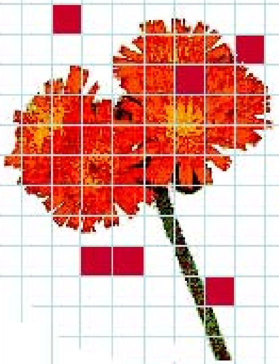
and

the costs and impacts of surveillance

should also be taken into account.

A clear objective and a model of the surveillance process can tell us where to start and **when to stop** looking.

Acknowledgements



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