Comparing inward and outward strategies for delimiting non-native plant pest outbreaks

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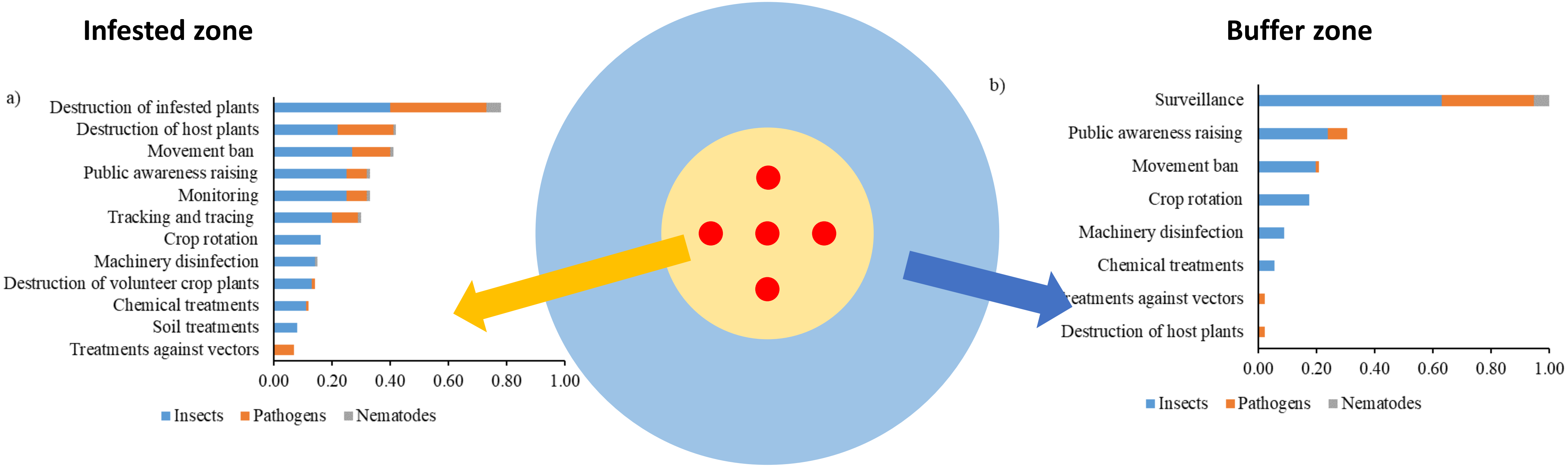
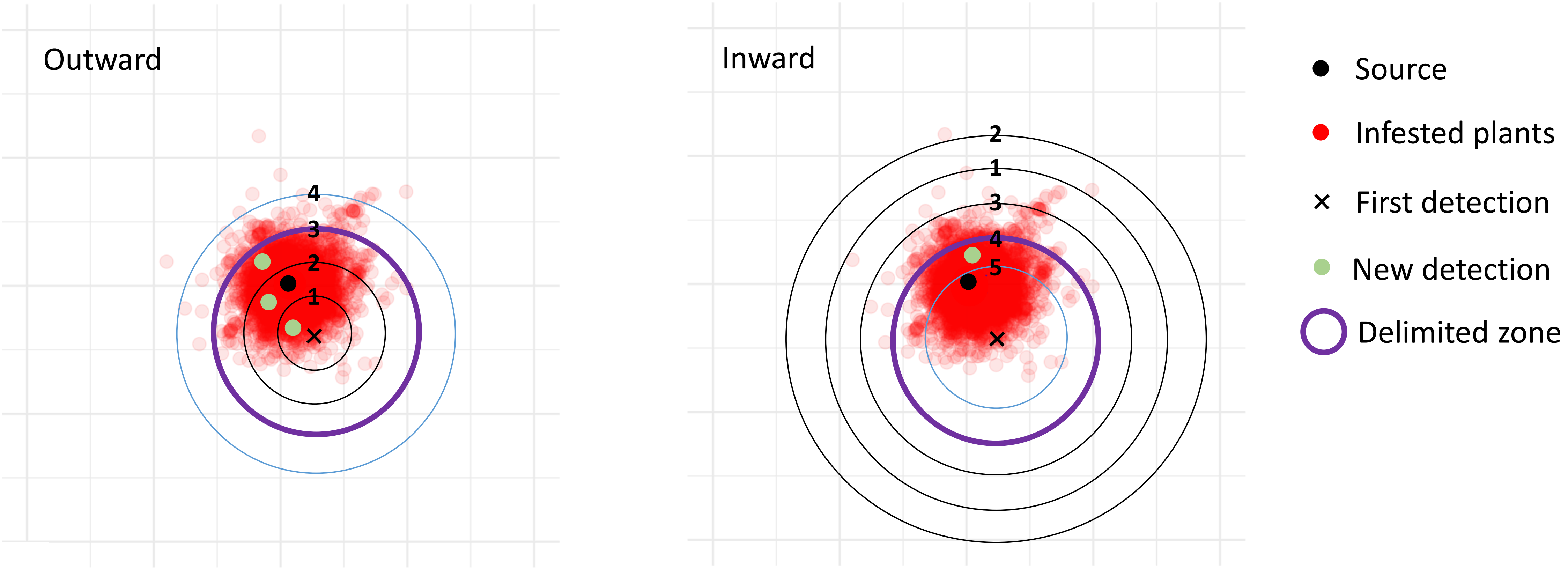
- FAO (2023) defines an outbreak of a non-native plant pest as “a recently detected pest population, including an incursion”.
- To facilitate eradication of outbreaks, it is important to determine the spatial extent of the population (FAO 2023).
- Typically, the demarcated area consists of an infested zone and a buffer zone (European Union 2019).



Source: https://doi.org/10.1007/s10340-023-01591-y

Illustration of the outward and inward strategies



Effectiveness and effort

Inward strategy

Outward strategy

Growth and spread model

- Growth model:

$$N_k = \lambda^k * N_0$$

- Marginal kernel derived from:

❑ **Gaussian cross-section kernel**:

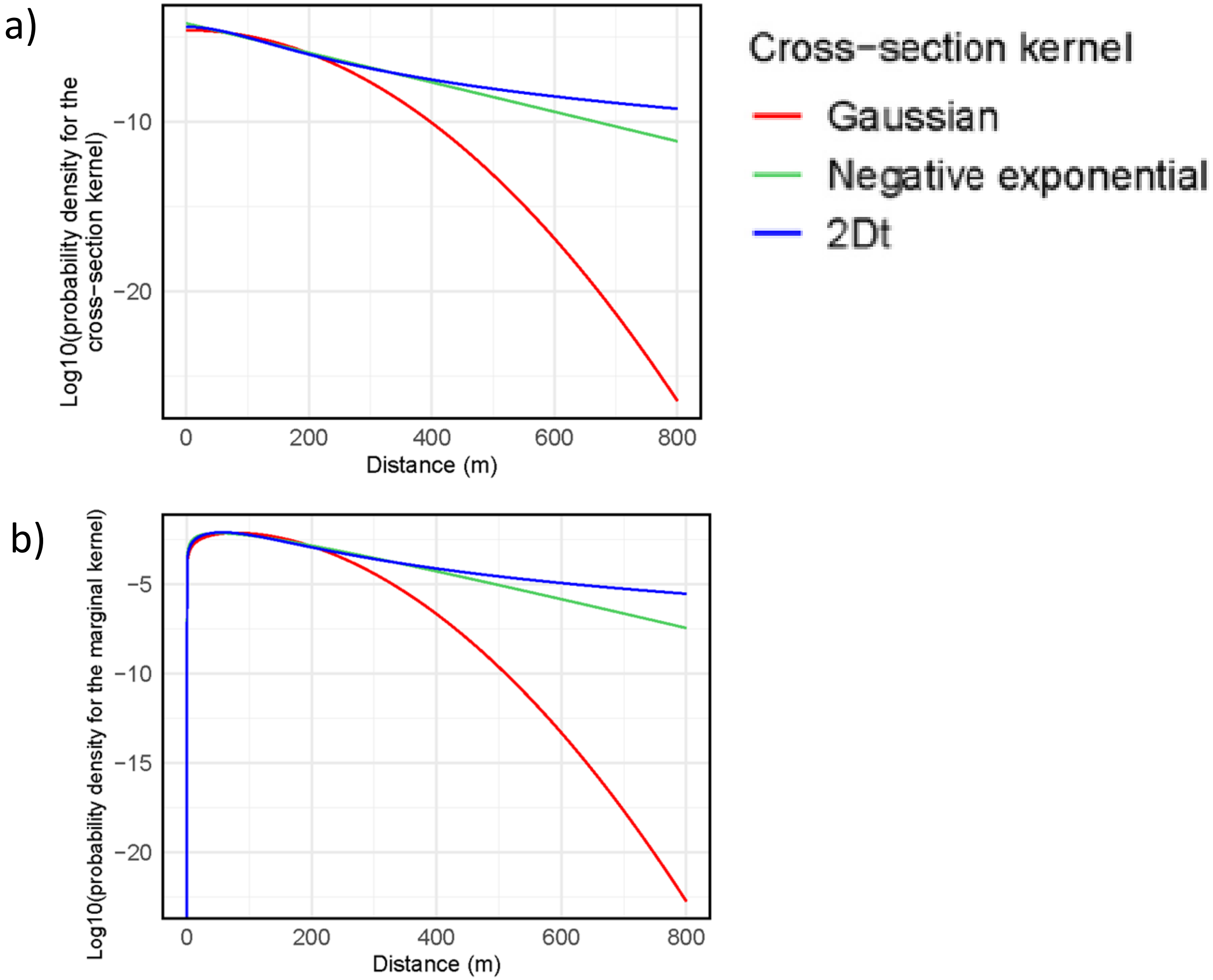
$$k_M(r) = 2\pi r\left[\frac{1}{\pi(a_1)^2}\exp\left(-\frac{r^2}{(a_1)^2}\right)\right]$$

❑ **Negative exponential cross-section kernel:**

$$k_M(r) = 2\pi r\left[\frac{1}{2\pi(a_2)^2}\exp\left(-\frac{r}{a_2}\right)\right]$$

❑ **2Dt cross-section kernel**:

$$k_M(r) = 2\pi r\left[\frac{b-1}{\pi(a_3)^2}\left(1+\frac{r^2}{(a_3)^2}\right)^{-b}\right]$$



Parameterizing the model taking *Xylella fastidiosa* as an example

Parameter	Symbol	Value	Units	References
Outbreak				
Number of initial infested plants	N_0	1	-	-
Yearly multiplication factor	λ	19	Offspring/parent/year	(White et al. 2020)
Mean dispersal distance in a year for marginal kernels	D	100	m	(White et al. 2017)
Years of spread in outbreak simulation	k	3	year	-
Delimiting survey				
Average position of the frontier	R_F	784	m	Model testing
Width of a survey band (one eighth of R_F)	R_s	98	m	Model testing
Radius of the potentially infested zone (from one fourth of R_F to four times R_F)	R_{inward}	[196, 392, 784, 1,568, 2,352, 3,136]	m	Model testing
Assumed age of outbreak at the time of first detection	t_d	3	year	-
Confidence level	CL[1]	95%	-	(EFSA, 2020b)
Design prevalence	DP[1]	0.1%	-	(EFSA, 2020b)
Method sensitivity	MeSe[1]	0.55	-	(EFSA, 2020b)
Number of trees per square meter	TD	0.2	Number per m^2	https://www.agromillora.com/shd-olive-crops/

Sample size required

Scenarios

Strategy	Dispersal kernel	Size of PIZs	Confidence level + Design prevalence + Survey band	Scenarios
Inward	3	6	6	**108**
Outward	3	1	6	**18**

Dispersal kernel: Gaussian, Negative exponential, 2Dt
Size of PIZs: from one fourth of R_F to four times R_F
Confidence level: 0.95, 0.9, 0.99
Design prevalence: 0.001, 0.0001, 0.01
Survey band: one eighth of R_F and one fourth of R_F

500 replicates for each scenario

Metrics for assessing effectiveness and sampling effort

Effectiveness:

Across 500 replicates

- proportion of cases in which all infested plants were enclosed
- proportion of cases in which no infested zone was delimited
- proportion of cases in which a strategy performs better/equal/worse than the other

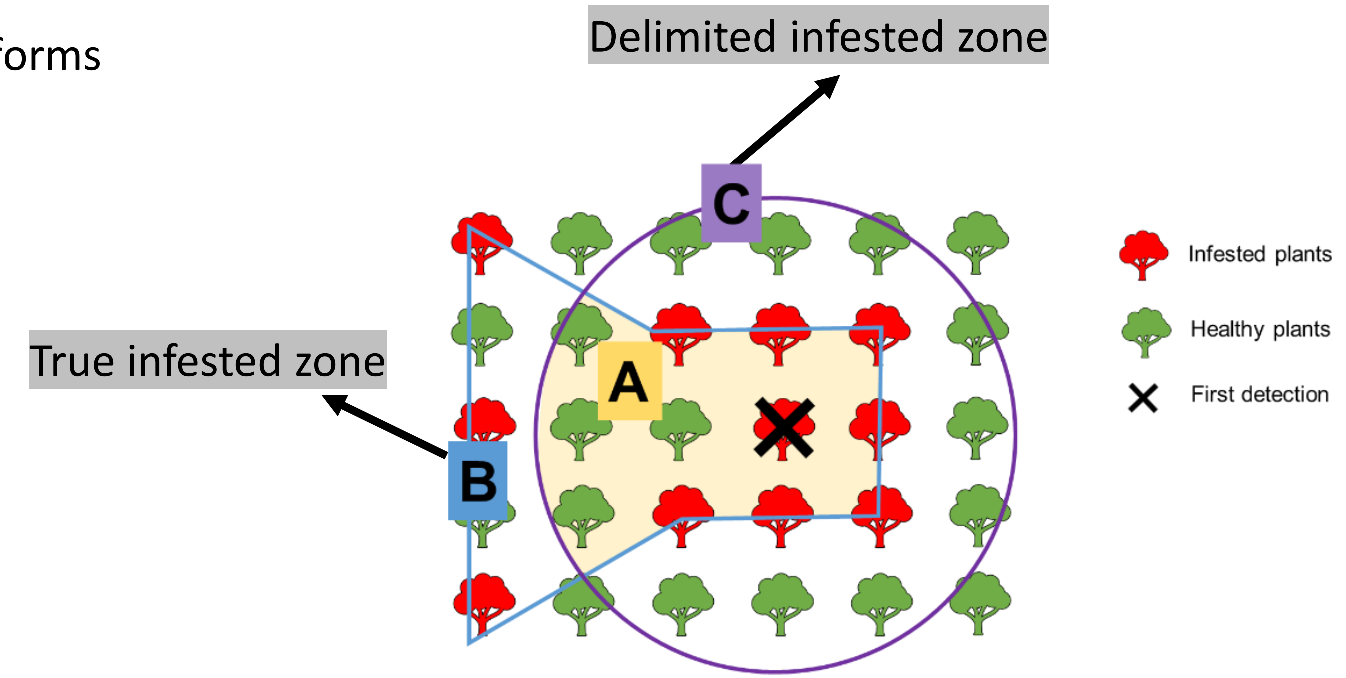
For each replicate

- Proportion of delimited infested plants
- $Sensitivity = \frac{A}{B}$
- $Specificity = \frac{A}{C}$

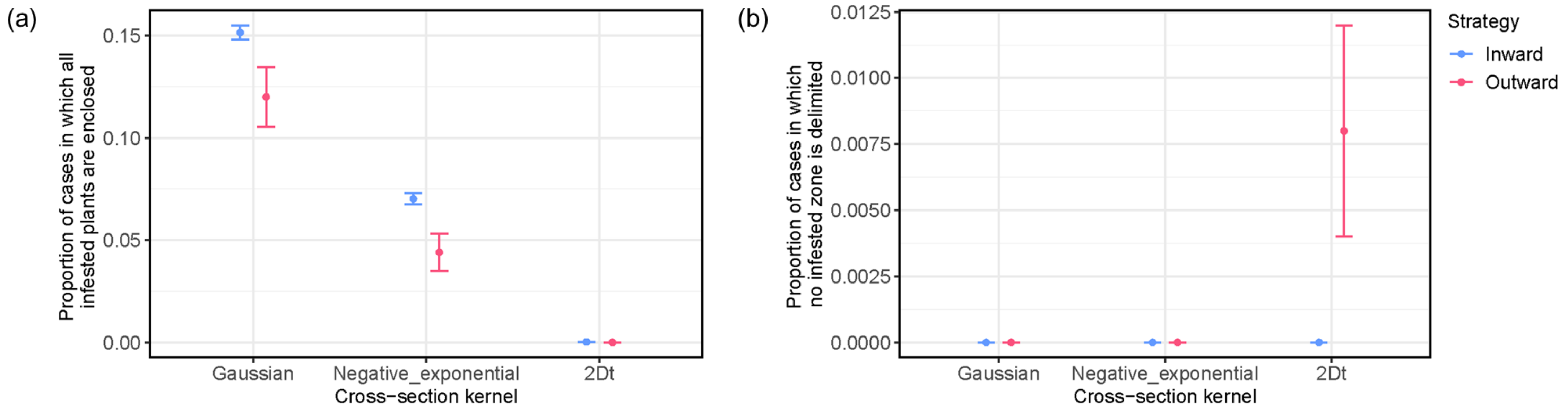
Effort:

For each replicate

- Sample size
- Number of bands surveyed

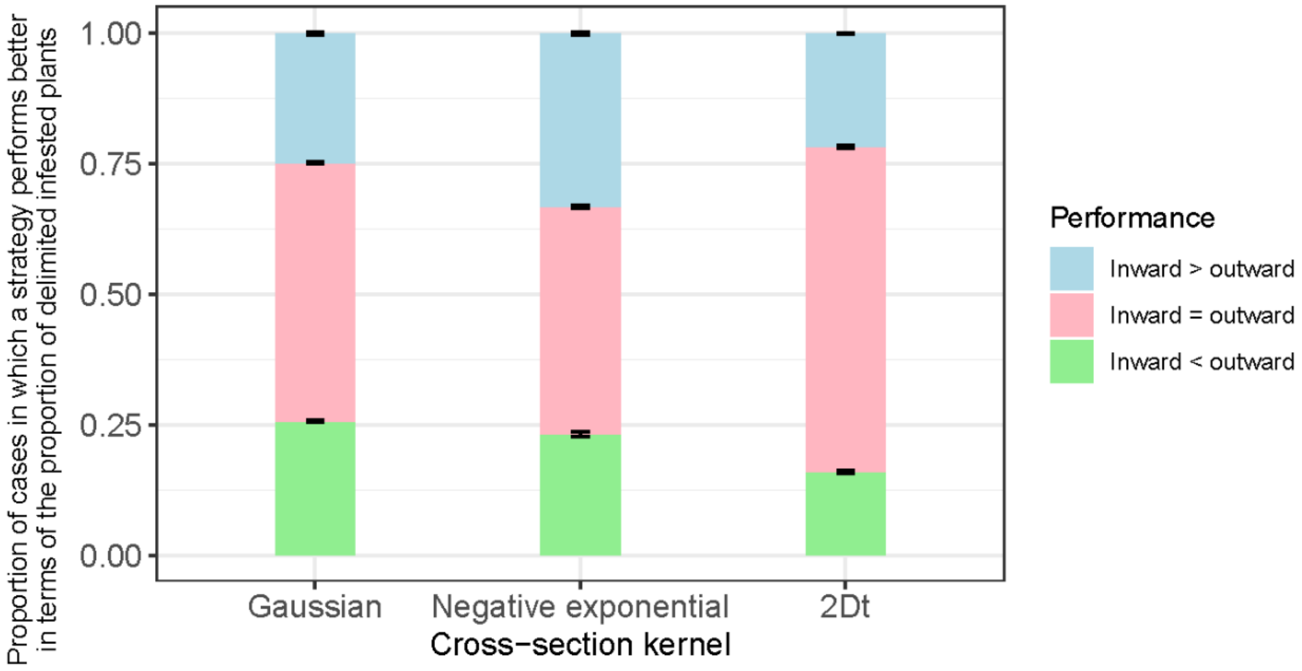


Effectiveness across 500 replicates:



- a) fatness of the tail of dispersal kernel: Gaussian < negative exponential < 2Dt
  Proportion of cases in which all infested plants were enclosed: Gaussian > negative exponential > 2Dt
- a) the inward slightly outperforms in terms of enclosing all infested plants
- b) in some cases, the outward strategy did not delimit any zone

Proportion of cases in which a strategy outperforms in terms of delimited infested plants



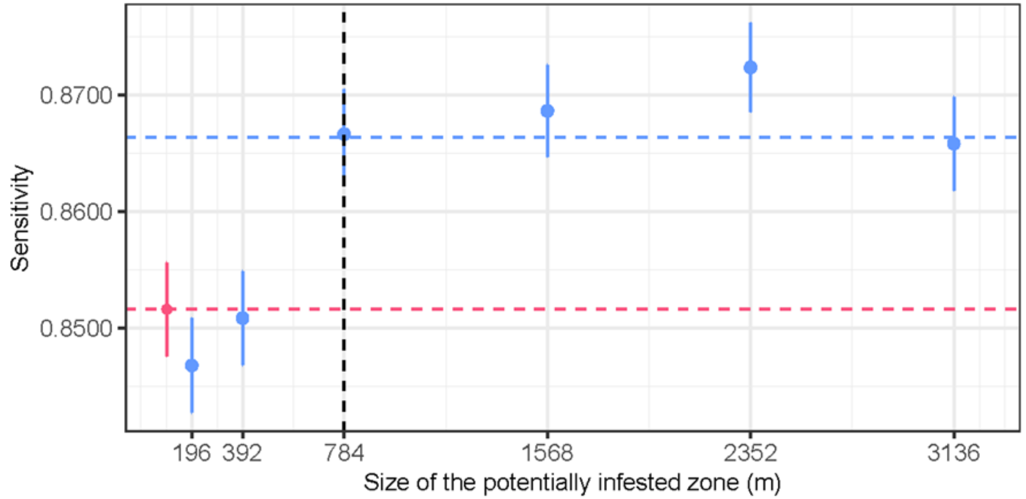
- In approximately half of the outbreak cases, the inward and outward strategies performed equally well in terms of the proportion of delimited infested plants

Effectiveness and effort for each replicate:

Taking the negative exponential kernel as an example

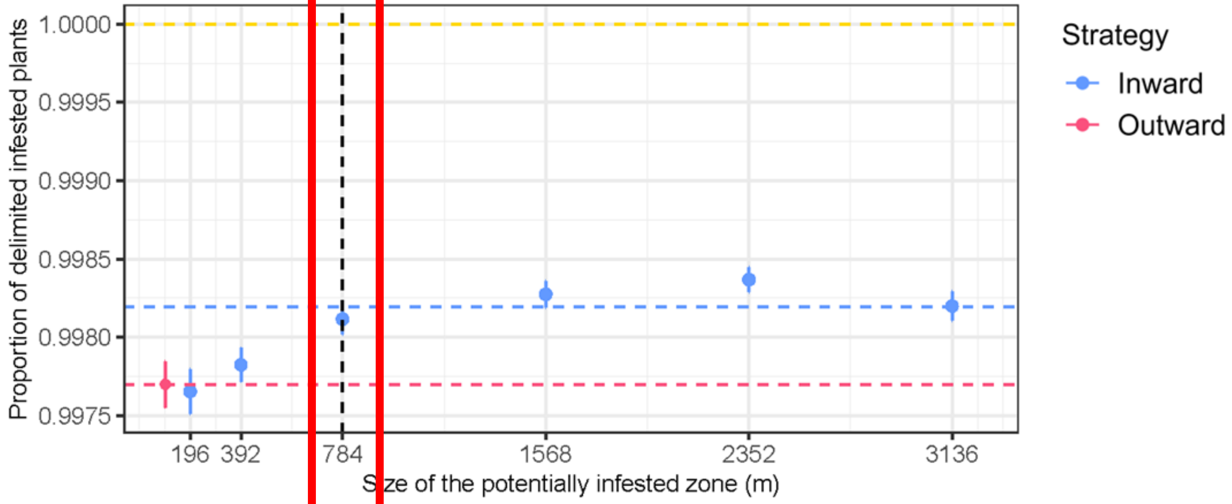
Sensitivity

(b)



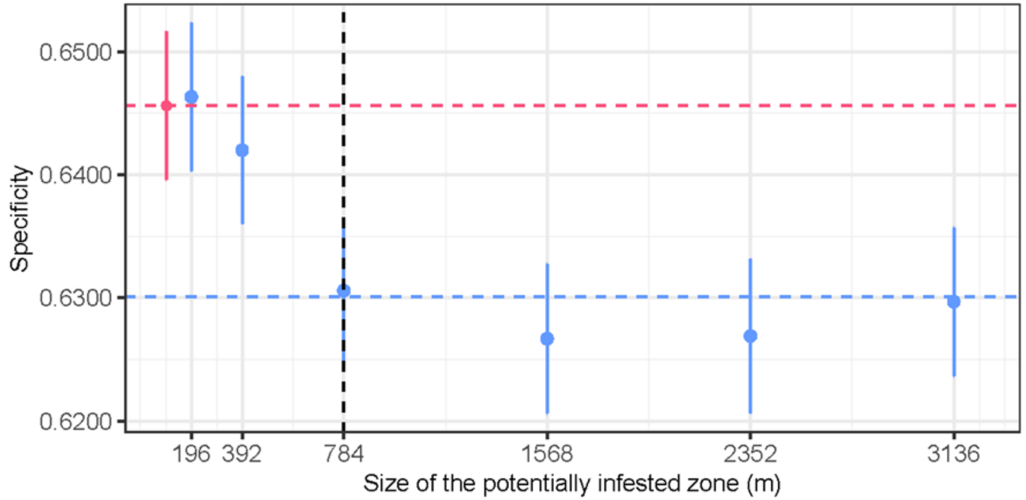
Proportion of delimited infested plants

(a)



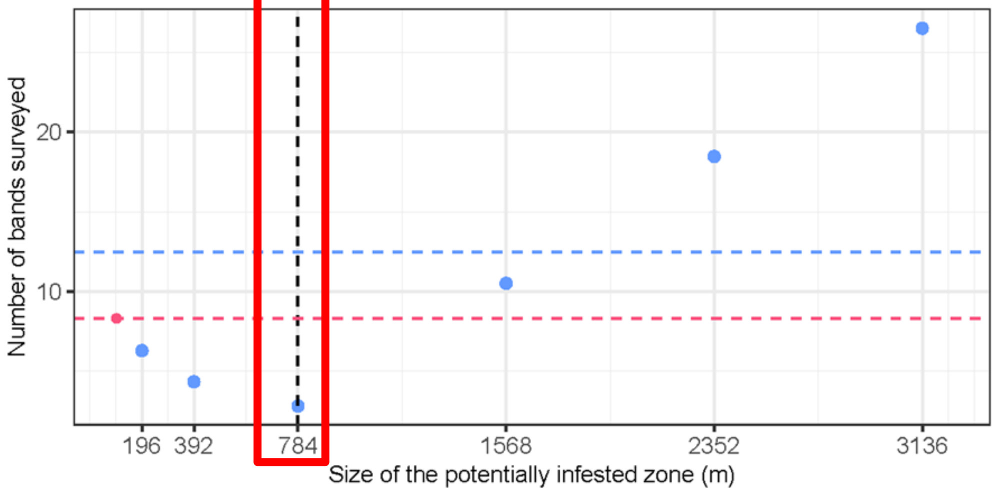
Specificity

(c)

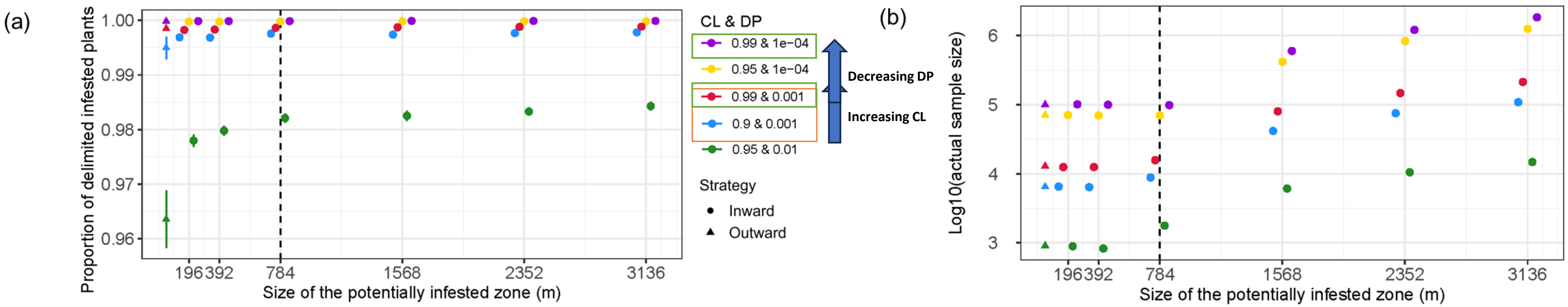


Number of bands surveyed

e)



Effects of confidence level and design prevalence on the effectiveness and effort



Increasing the confidence level and **decreasing** the design prevalence **increased** the proportion of delimited infested plants but at a **large** cost of additional sampling

Take home messages

- Overall, both strategies delimited a high proportion of the infested plants but both had a low probability of enclosing all infested plants.
- The comparison between the two strategies suggests that the inward strategy works best if the position of the frontier can be determined with sufficient certainty.
- We argue that uncertainty is very common in the delimitation phase because of uncertainty on the spread rate of the pest and timing of introduction, and consequently, the size of the outbreak.
- Altogether, the results of this work suggest that delimitation of pest outbreaks is difficult, laborious, and prone to error.
- This analysis can provide a basis for designing more effective sampling design, such as applying a variable bandwidth or a safety factor to the delimited zone to maximize the probability that all infested plants are enclosed.

Thank you for listening!
Questions are welcomed!