Manaaki Whenua
Landcare Research

Post-eradication surveillance of possums on Māhia Peninsula

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Post-eradication surveillance of possums on Māhia Peninsula

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Summary

Project and client

- Hawke’s Bay Regional Council (HBRC) contracted Manaaki Whenua – Landcare Research to assess the Whakatipu Māhia post-eradication surveillance activities relating to possum eradication. A surveillance network has been designed that will have the power to quantitatively prove possum absence after the cessation of control.
- Consideration is now being given to the post-eradication activities of (i) preventing reinvasion and (ii) surveillance to maintain confidence in possum absence.

Objectives

- Assess the efficacy of the ‘virtual barrier’ of traps and bait stations by simulating possum movements into the peninsula.
- Provide guidance on the post-eradication surveillance network for Whakatipu Māhia that would be needed to maintain a high confidence in possum absence given continual immigration pressure.

Methods

- The virtual barrier was assessed by simulating possum movements into the peninsula via a correlated random walk model. The distances between the movement path and the locations of traps and bait stations were calculated, and those that were within a specified encounter distance had a probability of killing the individual. This was repeated for a large number of iterations across a range of parameter values.
- The required level of post-eradication surveillance for various levels of annual probability of reinvasion was calculated using the surveillance planning tool JESS4Pests.

Results

- The probability of an invading possum being intercepted at the virtual barrier ranged from 0.72 to >0.99 depending on the parameters specified for encounter distance and the probability of a kill given an encounter. Generally, the estimates were >0.95, giving some assurance that the virtual barrier has a high chance of preventing reinvasion.
- A post-eradication network of 100 cameras deployed for 2 months throughout Māhia Peninsula would be enough surveillance to maintain a probability of absence >0.95 if the probability of establishment is ≤0.01. For higher values, more cameras rather than longer deployment would be required.

Conclusions

- The overall probability of reinvasion depends on three factors: (i) the quantity and frequency of invading possums, (ii) the probability they pass through the virtual barrier, and (iii) the probability that survivors establish and begin breeding.
- The movement simulations provide some insight into the effectiveness of the virtual barrier, with moderate to high probabilities of possums being intercepted, although the variation in results makes it difficult to draw firm conclusions.
- Empirically assessing the virtual barrier would provide valuable information, such as the number and frequency of invading possums.
- Quantifying the relationships between the number of successful invaders and the probability of establishment would also be valuable for this and other PF2050 projects, although this would be difficult to do.
- Because there is no barrier that is 100% effective, Whakatipu Māhia would still require post-eradication surveillance to maintain confidence in possum absence.

Recommendations

- Given the variability in simulation results, it is recommended that HBRC empirically assess the virtual barrier using either GPS-collared possums or possums identifiable with a biomarker (or perhaps possum genomics).
- Future research relating to PF2050 projects should attempt to quantify the relationship between the number of survivors and the probability of re-establishment.
- HBRC should carry out post-eradication surveillance to remain confident of possum absence throughout Māhia Peninsula.

1 Introduction

Eradication projects require landscape-scale control to eliminate pests, followed by surveillance to confirm (or not) that the eradication has been successful (Gormley et al. 2021). Once a declaration of absence has been made, there is still ongoing post-eradication work required to (i) prevent new incursions and (ii) undertake surveillance to remain confident of absence. Whakatipu Māhia – Predator Free Māhia is a project that involves removing brushtail possums across 14,600 ha with the aim of eradicating them from Māhia Peninsula (HBRC 2019). The possum control work is well underway, and a surveillance network has been designed that will have the power to quantitatively prove possum absence after the cessation of control (Gormley 2022). Consideration is now being given to the post-eradication activities of preventing reinvasion, and surveillance to maintain confidence in possum absence.

2 Background

2.1 Preventing reinvasion

A ‘virtual-barrier’ of 68 leg-hold traps, 171 Possum Master traps, and 861 bait stations will be used to prevent possum incursions into Māhia Peninsula from the north (Figure 1). It is expected that incursions will be the result of natural movement (as opposed to human-aided dispersal), hence the focus of the network in the northern region of Māhia Peninsula.

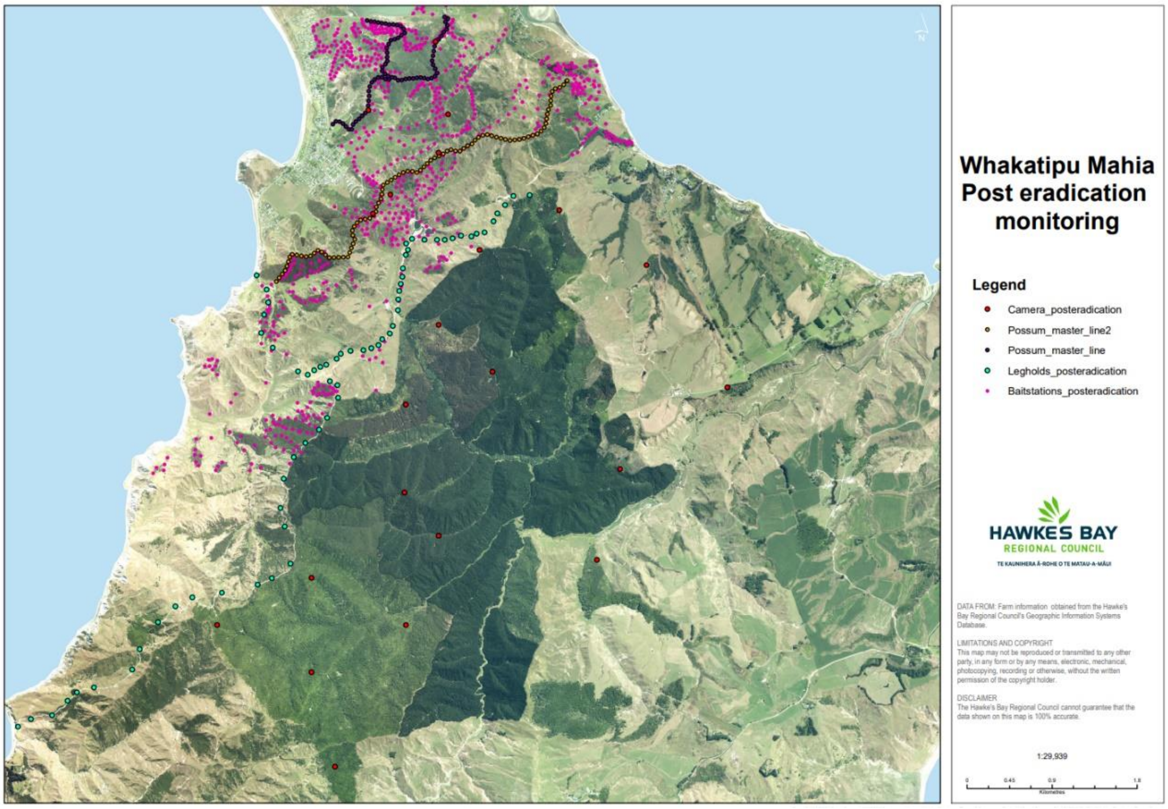

Figure 1. Whakatipu Māhia virtual barrier – a network of leg-hold traps (*n* = 68), Possum Master traps (*n* = 171), bait stations (*n* = 861), and cameras in the northern part of Māhia Peninsula to prevent possum reinvasion.

The probability that possums will reinvade an area depends on (i) the quantity and frequency of invading animals, (ii) the probability they pass through the virtual barrier, and (iii) the probability that survivors establish a breeding population (Figure 2). The virtual barrier is designed to prevent the second step in the process.

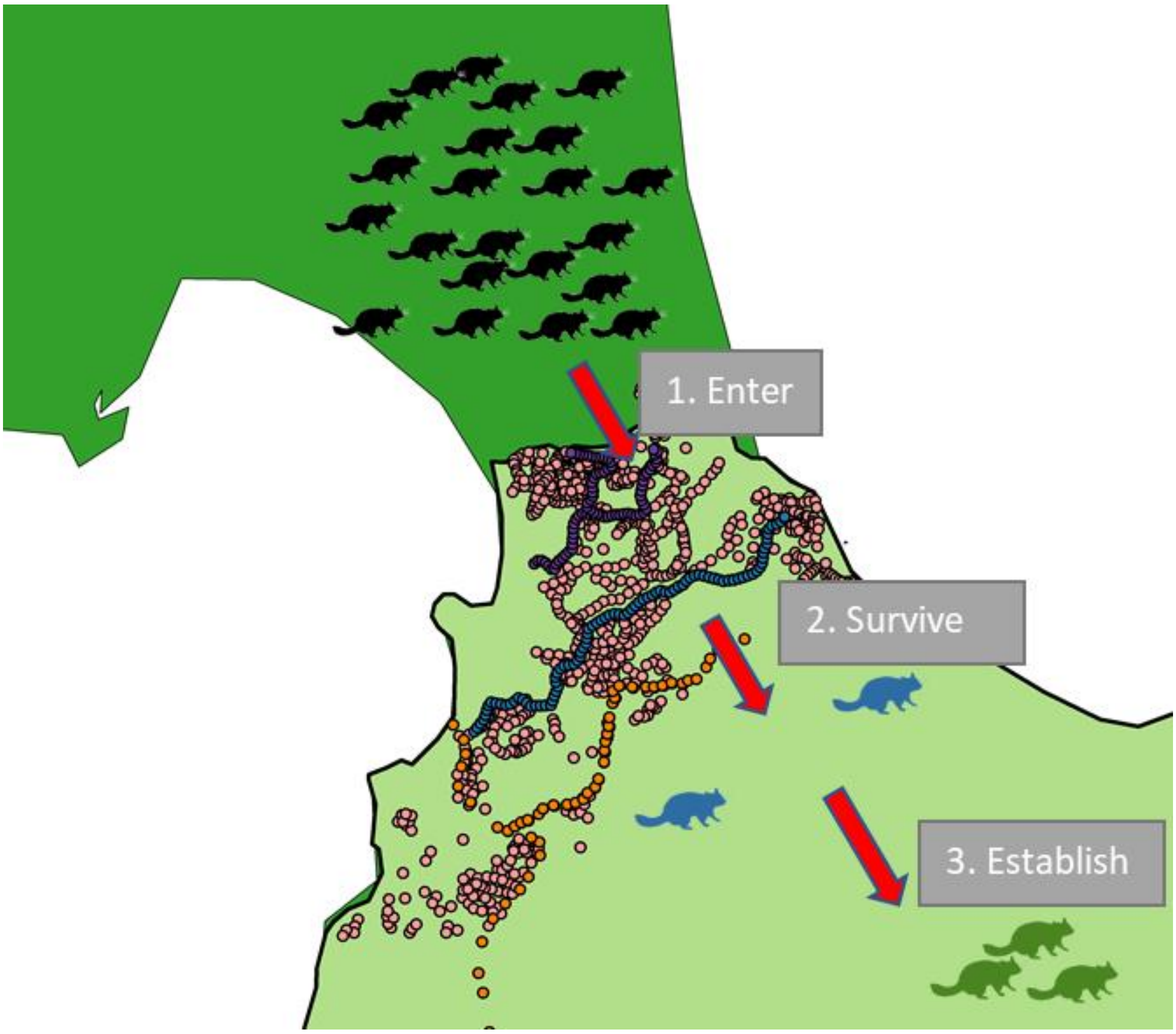

Figure 2. Processes for reinvasion. Possums must (1) enter the peninsula from the north, (2) pass through the virtual barrier, and (3) establish a new population on Māhia Peninsula.

2.2 Post-eradication surveillance

The proof of freedom process is based on carrying out surveillance after control has been completed to confirm successful eradication (Anderson et al. 2013). A prior probability of absence is combined with negative surveillance data, and, provided no individuals are detected, a probability of species absence is generated that provides a quantitative assessment of successful eradication (Anderson et al. 2013).

However, every year there is an annual probability of reinvasion; i.e. one or more individuals entering the eradicated area and establishing a viable population (Banks et al. 2018). Given that no barrier is 100% reliable, some ongoing monitoring is required to remain confident of possum freedom (and/or to quickly detect invaders so that targeted mop-up control can be applied).

In the post-eradication phase, where the species has been eradicated and we wish to maintain a level of confidence in their absence, post-eradication surveillance must be carried out to overcome the ongoing probability of reinvasion. The higher the annual probability of reinvasion, the higher the post-eradication surveillance required.

It is therefore important for managers to mitigate new incursions as much as possible to reduce the chance of possums reinvading and decrease the amount of required assurance surveillance.

3 Objectives

- Assess the efficacy of the 'virtual barrier' of traps and bait stations by simulating possum movements into the peninsula.
- Provide guidance on the post-eradication surveillance network for Whakatipu Māhia that would be needed to maintain a high confidence in possum absence given continual immigration pressure.

4 Methods

4.1 Assessing the virtual barrier

We assessed the virtual barrier of traps and bait stations by simulating possum reinvasion. Possum incursions were simulated by modelling movement as a correlated random walk (Fagan & Calabrese 2014). The initial direction was into Māhia Peninsula from a starting point just outside (Figure 3). Movement segments were sampled from a log-normal distribution for step length, and a normal distribution for turning angle relative to the current direction.

For each iteration, the distance between the path segment and each device was calculated. If a path segment was closer than a pre-specified distance (see below) from the device, the possum was considered to have 'encountered' the device along that path. For each 'encounter' there is a probability of interacting and dying from the device, termed Pr(kill|encounter). For each set of parameter values, this process was repeated 1,000 times to account for stochasticity. The proportion of simulated possums killed was used as the probability of being intercepted by the virtual barrier. Simulations were repeated across a range of parameter values to account for uncertainty (Table 1).

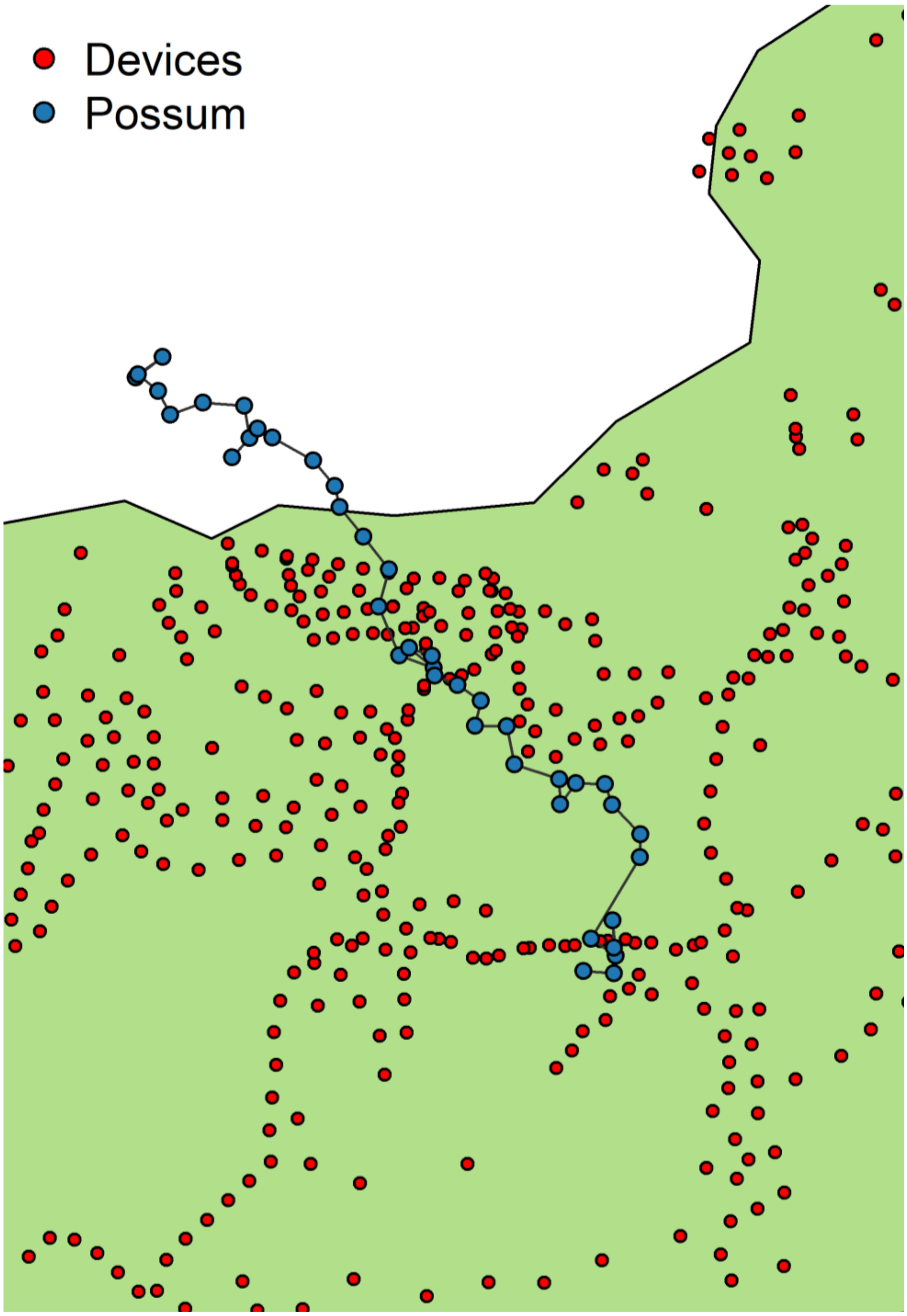

Figure 3. Illustrative map showing device locations (red circles) and a single simulated correlated random-walk path for a possum (blue circles) entering Māhia Peninsula from the north.

4.2 Post-eradication surveillance

The proof of freedom framework (Anderson et al. 2013) is based on carrying out surveillance to update a prior probability of absence of a pest. As long as no individuals are detected, the probability of absence after one time period of surveillance (e.g. a year) is given by:

$$PoA_1 = Prior_1/(1 - SSe \times (1 - Prior_1)) .$$

where SSe is the amount of surveillance, $Prior_1$ is the probability of absence prior to surveillance in period 1 (i.e. after control, but before any surveillance has been carried out), and PoA_1 is the probability of absence after the first year of surveillance. The resulting value for PoA_1 can be used as the Prior for year 2; i.e. $Prior_2 = PoA_1$, and this can be updated with surveillance in year 2 in order to estimate PoA_2.

However, each year there is an annual probability of reinvasion (termed PoR) of one or more individuals entering the eradication area and establishing a viable population. The prior for year 2 must therefore be adjusted downwards to account for this:

$$Prior_2 = PoA_1 \times (1 - PoR).$$

The required level of surveillance needed to overcome this downwards adjustment due to the annual reinvasion probability, and to increase our confidence to a desired target PoA_2, is given by:

$$SSe_{(Req)} = [1 - (PoA_1 \times (1 - PoR)/PoA_2)] / [1 - PoA_1 \times (1 - PoR)]$$

In the special case of post-eradication surveillance, PoA will be at the managers' required level for declaring absence (e.g. 0.95) and their desire to maintain that level of confidence in species absence (e.g. $PoA_1 = PoA_2$). The previous equation thus simplifies to:

$$SSe_{(Req)} = PoR / (1 - PoA \times (1 - PoR))$$

Therefore, the required level of surveillance is a function of the probability of reinvasion, PoR, and the current PoA that a manager wishes to maintain (Figure 4).

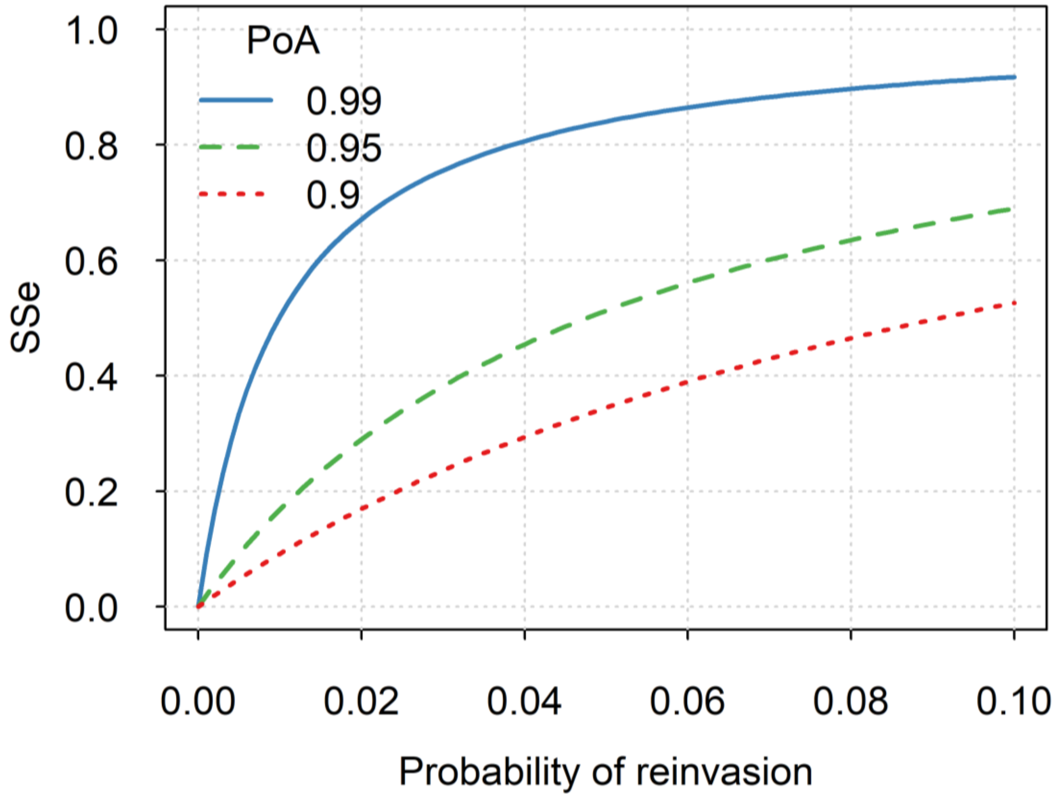

Figure 4. The required surveillance sensitivity (SSe) to maintain a specific level of probability of absence (PoA) for various levels of annual probability of reinvasion.

The higher the annual probability of reinvasion, the higher the post-eradication surveillance that needs to be carried out. For example, when PoA = 0.95, then if PoR = 0.05, SSe_{Req} = 0.512, whereas if PoR = 0.01, a lower SSe_{Req} of 0.168 is required. This difference equates to approximately a quarter of the on-ground surveillance effort. Similarly, the higher the PoA that needs to be maintained, the higher the surveillance required for the same level of PoR.

We use the results from assessing the virtual barrier to provide guidance on the approximate level of post-eradication surveillance required to maintain a desired PoA, conditional on estimates for introduction pressure and probability of establishment. The required surveillance was converted into the number and duration of devices using the planning tool JESS4Pests.[1]

[1] https://landcare.shinyapps.io/JESS4Pests

5 Results

5.1 Assessing the virtual barrier

The probability of an invading possum being intercepted by the virtual barrier varied greatly by encounter distance and the probability of a kill given an encounter. The probability that a possum would be intercepted increased as the probability of a kill given an encounter increased. The probability of being intercepted also increased as the encounter distance increased due to the devices effectively having more coverage. A longer mean step length resulted in a slightly lower probability of being intercepted, which was unexpected.

Table 1. The probability of a possum being intercepted by the virtual barrier for various combinations of step length, encounter distance, and probability of being killed, given encounter with a device for simulated random walks. Probabilities of being intercepted >0.95 are shown in bold.

Mean step length (m) [SD]	Encounter distance (m)	Pr(Kill|Encounter)	PIntercepted
50 [20]	10	0.2	0.72
		0.4	**0.96**
		0.6	**1.00**
	20	0.2	**0.98**
		0.4	**1.00**
		0.6	**1.00**
100 [20]	10	0.2	0.60
		0.4	0.82
		0.6	0.84
	20	0.2	0.92
		0.4	**0.98**
		0.6	**1.00**

Sweetapple et al. (2021) estimated the probability of capture of possums in leg-hold traps, given an encounter, to be approximately 0.46 (95 CI = 0.38–0.54), which gives greater confidence in the results in Table 1 for scenarios where Pr(kill|encounter) = 0.4 or 0.6. In these cases, the probability of being intercepted was often >0.95. There was some evidence from the Sweetapple study that possums that successfully escape from a trap have a lower chance of subsequent encounters, meaning that the probability of being intercepted would be lower than the values presented here.

5.2 Post-eradication surveillance for probability of absence

Modelling using the surveillance planning tool JESS4Pests showed that a network of 100 cameras deployed for 2 months at a spacing of 1200 × 1200 m (approximately one every 250 ha) would deliver an SSe = 0.22; that is, a 22% chance of detecting a possum if a single individual is present. This estimate used values of g0 = 0.2 (where g0 is the probability of detection on a single night for a device in the middle of an individual's home range), and sigma = 130 m (which equates to a home range of c. 30 ha). This level of surveillance would be enough to maintain PoA > 0.95 if the annual probability of reinvasion (PoR) is 0.01. If PoR = 0.05, then surveillance equivalent to SSe = 0.51 would be required.

Increasing the deployment time of the 100 cameras would not be enough to achieve this required sensitivity: doubling the length of deployment time only increases the surveillance sensitivity from SSe = 0.22 to SSe = 0.27. The decreasing marginal gains as deployment time is increased is due to the large spacing between cameras relative to possum home range. Instead, an increase to c. 250 cameras (a spacing of 750 × 750, or one every 60 ha) would be required to achieve the required level of sensitivity if PIntro = 0.05.

6 Conclusions

The probability of reinvasion into Māhia Peninsula after elimination of possums depends on three factors: (i) the quantity and frequency of invading animals, (ii) the probability they pass through the virtual barrier, and (iii) the probability that survivors establish and begin breeding.

The results of the movement simulations provide some insight into the efficiency of the virtual barrier; i.e. the probability that invading animals will successfully pass through the network of traps and bait-stations. The probability that possums would be intercepted by the barrier was moderate to high depending on the parameter values, and in many cases was >0.95. However, the variation in results makes it difficult to draw firm conclusions.

Given the wide-ranging results from the simulations it is recommended that the virtual barrier be empirically assessed. There are a number of ways to do this, each with its own pros and cons. One method is to capture a known number of possums outside the control area and fit them with GPS collars, and then, over time, measure how many of them enter the region and attempt to make their way through the network. This would not only assess the barrier, but also provide information on parameters such as the encounter distance, movement-related parameters required by the correlated random walk model (such as distances and turning angles), and the rate of invading animals. Practically, however, this may not be feasible. Catching and collaring individuals is possible, but the proportion of those that move into Māhia Peninsula may be too small to draw any reliable conclusions without a very large sample of collared possums.

An alternative is to batch mark individuals that reside outside the peninsula with a biomarker (e.g. rhodamine). Animals captured by the virtual barrier could then be more accurately distinguished from unmarked animals (which would be assumed to be residents that were survivors of the control operation). This method relies on a very high proportion of dead individuals being recovered, which may be difficult to achieve. Another drawback is that a known number of individuals would need to be marked, and this may be difficult to assess.

The probability of invading possums being intercepted is only one factor that must be considered in an overall probability of reinvasion (Figure 2). Information on the other two components of reinvasion (the number of animals per year that will attempt to enter Māhia Peninsula and the probability of successful invaders re-establishing and breeding) is currently missing.

The number of animals that will attempt to move onto the peninsula each year could be partially informed by the approaches mentioned above. The probability of establishment given successful incursion will partly depend on the number of individuals that successfully avoid the post-eradication network. At the simplest level, a single possum is highly unlikely to be able to establish a new population, but this likelihood will increase with the number of successful individuals (Figure 5). The actual relationship between the number of survivors and the probability of establishment is presently unknown and would need quantifying.

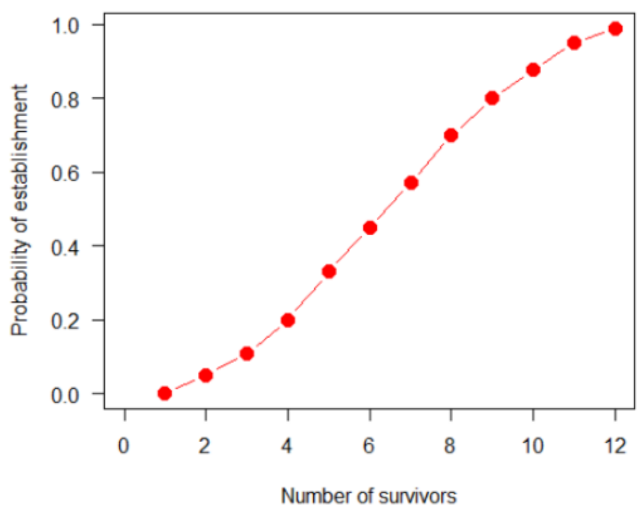

Figure 5. Hypothetical relationship between the number of survivors and the probability of establishment (illustrative only).

Genetic approaches may be able to partially answer some of the questions relating to possum reinvasion. If possums that are currently outside Māhia Peninsula are able to be genetically distinguished from those inside the peninsula, the capture of any possums post-eradication would provide some information on whether they were new incursions or survivors from the control phase.

The Whakatipu Māhia surveillance network for proof of absence is expected to achieve a system-level sensitivity of SSe = 0.7–0.85 (depending on the parameters assumed; Gormley 2022). This level of surveillance in the post-eradication phase would only be required to maintain PoA ≥ 0.95 if the probability of reinvasion was >0.1. A lower probability of reinvasion (e.g. 0.01 or 0.05) translates to vastly reduced surveillance networks in terms of number of devices and length of deployment, and would only be achievable by a network of either 100 or 250 cameras (depending on PoR) deployed for a period of 2 months. This is still a substantial investment in terms of resources and ongoing monitoring costs. However, early detection of possums on the peninsula would provide the best opportunity for targeted mop-up control, thereby maximising the chance of maintaining possum absence.

7 Recommendations

- Given the variability in simulation results, it is recommended that HBRC empirically assess the virtual barrier using either GPS-collared possums or possums identifiable with a biomarker (or perhaps possum genomics).
- Future research relating to this and other PF2050 projects should attempt to quantify the relationship between the number of survivors and the probability of re-establishment.
- HBRC should carry out post-eradication surveillance to remain confident of possum absence throughout Māhia Peninsula.

8 Acknowledgements

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9 References

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