Research Report for Predator Free Dunedin **03/03/2020**

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Overview

In this report I will outline the simulations undertaken using a model originally developed by Audrey Lustig of Manaaki Whenua to explore the reinvasion of possums onto the Otago Peninsula. I will summarize my key results and the management implications that have arisen, as will be further expanded on in my Master's thesis (hand-in date: 31/03/2020).

Model methods

See Lustig et al. (2019) for a full description of the model used in this study. Briefly, a habitat map of carrying capacity values is overlayed with a possum population of adults that give birth, maintain a stable home range and die of natural causes or trapping, as well as a population of juveniles that disperse and settle to become adults (see Table 1 for parameter values which were taken from the relevant literature). Juvenile dispersal is an individual-based process that is both habitat and density-dependent. Finally, various trapping regimes can be simulated to affect the possum population, with the density of traps in an area determining the probability of an adult or juvenile possum being trapped.

Study setup and aims

I was interested in the possum population trajectory on the Peninsula under scenarios of varying control effort (see Table 2). Current trap locations were obtained from the Otago Peninsula Biodiversity Group (OPBG) for the 'Trap 150' scenario, and extra traps were added in manually for the other trapping scenarios (Fig. 1).

Through the running of these simulations, the aims of the study were to:

(1) Determine possum population trajectories and potential reinvasion pathways onto the Otago Peninsula;
(2) Describe the trapping layout and effort necessary to prevent reinvasion of the Otago Peninsula, while considering the relative merits and implications of various scenarios and;
(3) Through application, demonstrate the potential for this important spatial modelling tool to inform mainland mammalian pest management in Dunedin and elsewhere in New Zealand.

Table 1. The baseline possum parameters used in the model, with reference to the source of values.

Parameter	Value	Source
Maximum dispersal distance	12km	Glen and Byrom (2014)
Minimum reproductive rate per female	0.5	Hone et al. (2010b); Hickling and Pekelharing (1989b)
Mean reproductive rate per female	0.7	Hone et al. (2010b); Hickling and Pekelharing (1989b)
Maximum reproductive rate per female	1.02	Hone et al. (2010b); Hickling and Pekelharing (1989b)
Life expectancy	12 years	Cowan (2001)
$g_0\ (adult)$	0.05	Glen and Byrom (2014)
$g_1\ (juvenile)$	0.05	Glen and Byrom (2014)
σ	63	Glen and Byrom (2014) -Cowan?
Number of nights trapping per month	25	
Number of months trapping per year	12	
K of non-study city area	50%	
Resolution	200m	

Table 2. The name and description of each scenario run in the model.

Scenario name	Description
Hotspot	Complete eradication, no possums remaining on the Peninsula. No control.
Hotspot 50	Partial eradication with 50 possums remaining on the Peninsula. No control.
Trap 150	Complete eradication, no possums remaining on the Peninsula. 150 traps in current OPBG locations.
Trap 300	Complete eradication, no possums remaining on the Peninsula. 300 traps in the Buffer Zone.

Table 2. contd. The name and description of each scenario run in the model.

Scenario name	Description
Trap 500	Complete eradication, no possums remaining on the Peninsula. 500 traps in the Buffer Zone.
Corridor Targeted	Complete eradication, no possums remaining on the Peninsula. 300 traps located in areas of high dispersal activity (from results).

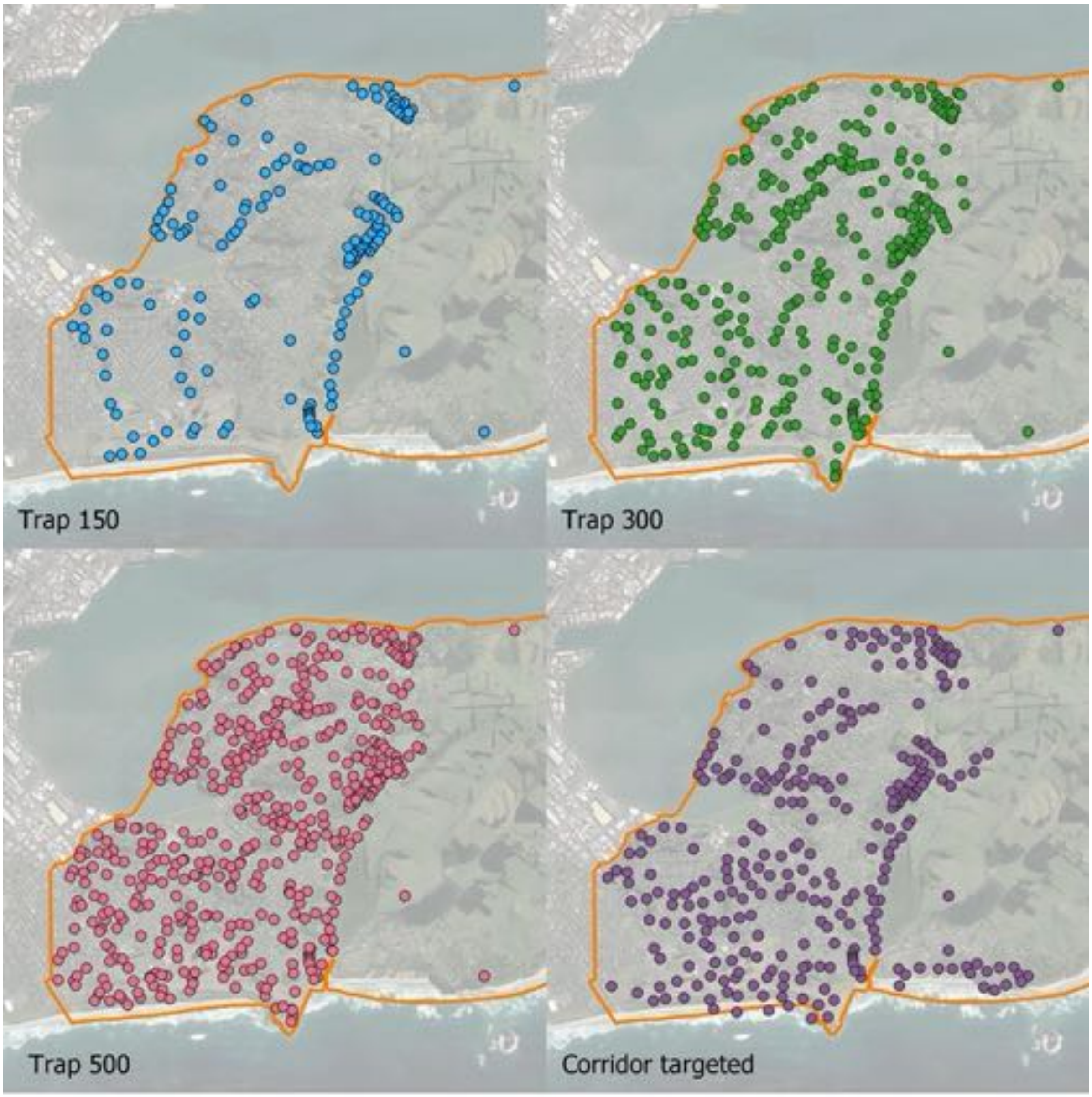

Figure 1. The location of traps in four of the simulated trapping scenarios, which were then converted to a density of traps per cell for input into the model. a) the current 150 traps set up in the Buffer Zone, b) with 300 traps, c) with 500 traps and d) with 300 traps but more of them concentrated in areas of higher dispersal frequency (see Results).

Results and implications

In the absence of control and with the assumption of complete eradication, possum reinvasion onto the Peninsula was gradual over the 40 simulated years (Fig. 2a,b). The final abundance at year 40 (averaged over 40 replicates) was over 1400 individuals (Table 3). There was a relatively high consistency of this pattern across replicates (std. error = 95.76), however, 12.5% ($n = 5$) of simulations saw no reinvasion of possums to any substantial extent or number over the 40 years (Table 3).

Overall, there was a very low monthly rate of immigration onto the Peninsula by juveniles. Instead, most of the population growth was *in situ* reproduction (juveniles being born from those individuals who did make it through to the Peninsula), meaning that preventing individuals from first crossing over the Buffer Zone will be the most important element in preventing re-population. The landscape of the Buffer Zone is predicted to act as a physical barrier to immigration, due to both its small area and the low quality possum habitat it is attached to (South Dunedin suburbs).

Predicted 'hotspot' areas of possum congregation (high final abundance [4 -5 possums ha^{-1}]) are displayed in Figure 3, and appear to reflect high habitat quality. These 'hotspot' areas also saw the largest number of possum movements per cell, while other regions of moderate-high habitat quality seemed to act as habitat corridors when the surrounding areas were of a lesser quality (Fig. 4). In particular, the 'Sandymount' area, and the forest above the Portobello township, as well as the grounds of Larnach Castle, had the largest continuous hotspot habitat (Fig. 3). At the western end of the Peninsula, the South and North coast has forest habitat that possums accumulated in and often moved through, and the forest corridors of the Buffer Zone also saw a high possum density at the end of the 40 years (Fig. 3).

Importantly, when there were 50 individuals remaining on the Peninsula at the beginning of simulations, the rate of increase in Peninsula possum abundance was far greater than in the Hotspot scenario (Fig. 5). The population reached carrying capacity (~3300 individuals) at year 15 and remained in an equilibrium state beyond this point (Fig. 5, Table 3). This demonstrates that a low number of residual possums has the potential to expand far more rapidly than immigration alone will cause.

Results predict that although immigration pressure is very low, and trapping substantially reduces final possum abundance compared to the Hotspot scenario (Fig. 6), reinvasion is not likely to be prevented by current trap layouts. The first substantial population growth on the Peninsula occurred after ~15 years in the 'Trap 150' scenario, and total population growth was slow, reaching an average abundance of 630 individuals after 40 years (Fig. 6, Table 3). However, approximately one third of replicates had negligible levels of reinvasion (< 10 individuals over 40 years), lowering the total average. Of those replicates where reinvasion occurred, the average population size at 40 years was higher (~1000 individuals) and increased rapidly from year 20 (117 individuals) to 40 (Table 3).

The trap 300 and 500 regimes were substantially more effective at preventing significant reinvasion of the Peninsula over 40 years (Fig. 6). Targeting corridors that were identified by the model (Corridor Targeted) significantly reduced possum reinvasion onto the Peninsula to almost negligible reinvasion (Table 3).

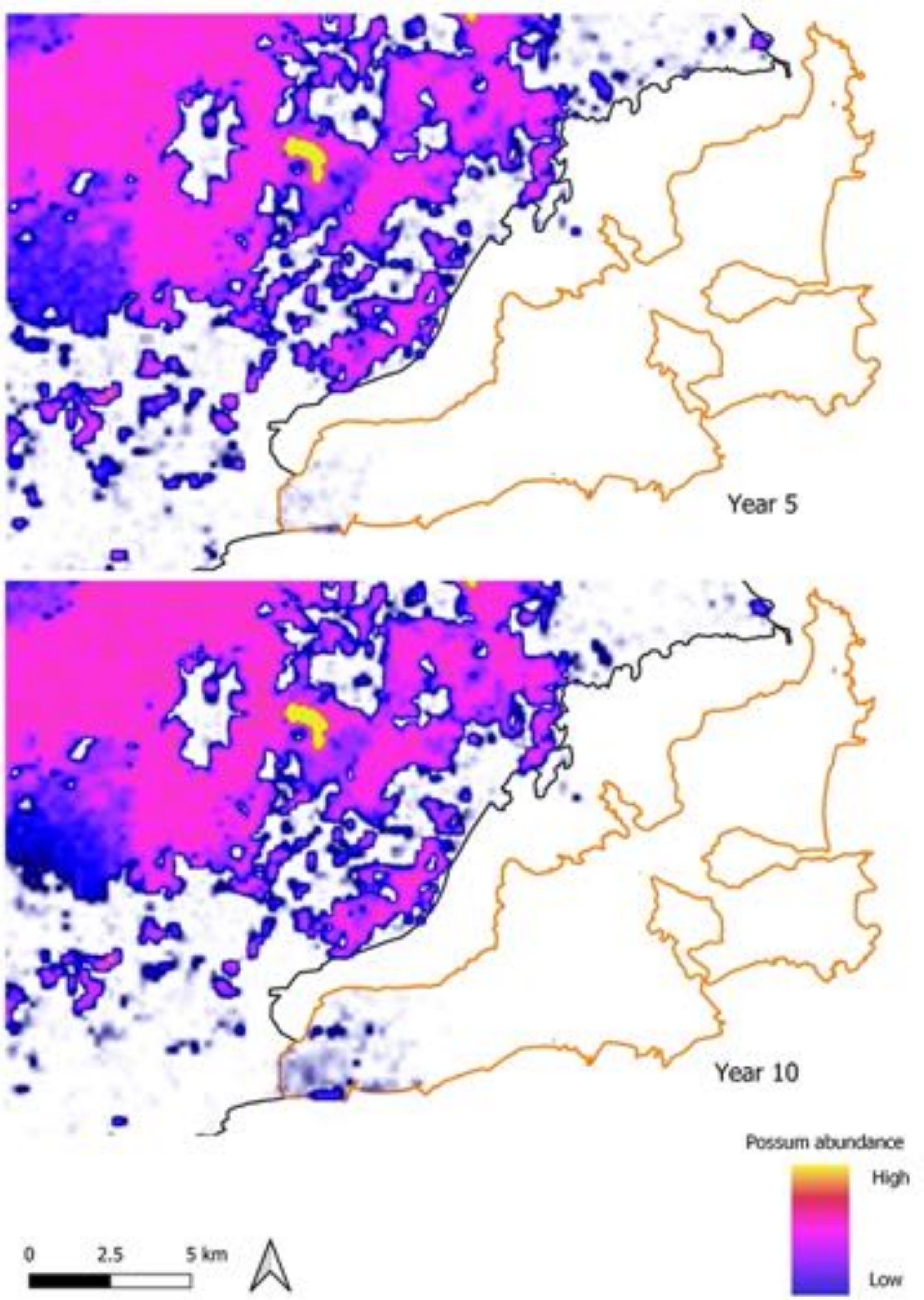

Figure 2a. The possum abundance, averaged over 40 replicates, at year 5 and 10 following complete eradication and with no control occuring.

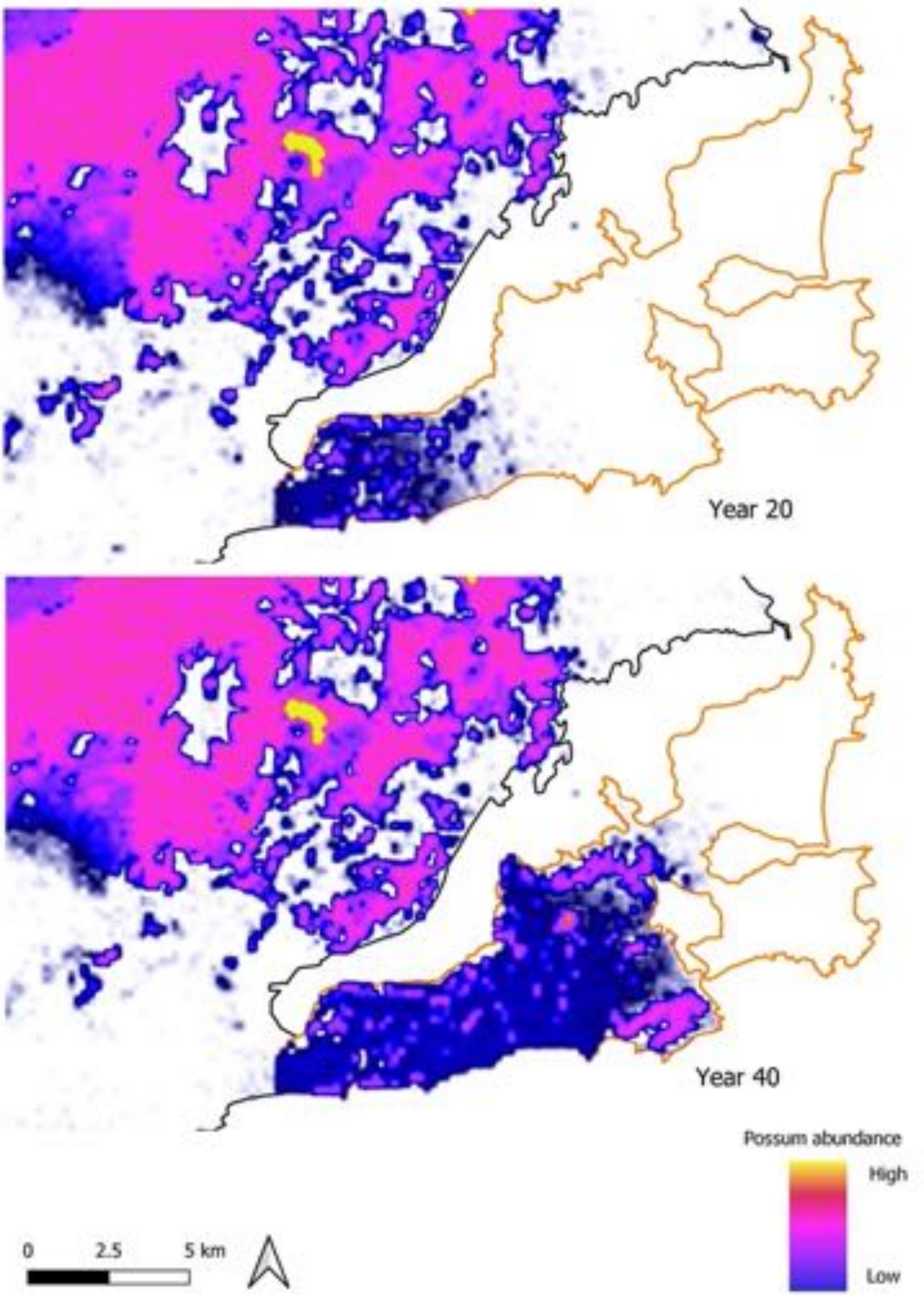

Figure 2b. The possum abundance, averaged over 40 replicates, at year 20 and 40 following complete eradication and with no control occuring.

Table 3. The summarised output of possum abundance from the model scenarios explored. Bold values are the total average over all replicates, while un-bolded values are the average over replicates where invasion to any non-negligible (> 10 individuals) extent occurred.

Simulation	Proportion invaded*	5 year abundance	10 year abundance	20 year abundance	40 year abundance
Hotspot	0.875	**5.9 (± 0.9)** 6.7 (± 0.9)	**37 (± 5.3)** 42.3 (± 5.5)	**323.9 (± 27.2)** 370.2 (± 21.9)	**1433.4 (± 95.8)** 1638.2 (± 48.9)
Hotspot 50	1	**507.6 (± 10.5)**	**2459.7 (± 23.9)**	**3352.8 (± 3.5)**	**3374 (± 2.9)**
Trap 150	0.625	**3.5 (± 0.7)** 5.5 (± 0.9)	**12.3 (± 2.4)** 19.6 (± 3.0)	**73.2 (± 13.8)** 117.2 (± 16.7)	**630.1 (± 96.3)** 1008.2 (± 92.2)
Trap 300	0.3	**0.8 (± 0.2)** 2.5 (± 0.48)	**0.9 (± 0.3)** 11.8 (± 3.7)	**19.4 (± 11.1)** 64.5 (± 33.6)	**166.0 (± 59.8)** 553.1 (± 147.9)
Trap 500	0.175	**0.7 (± 0.2)** 2.4 (± 0.9)	**0.85 (± 0.3)** 4.1 (± 1.2)	**3.9 (± 2.3)** 5.7 (± 11.3)	**63.4 (± 33.2)** 360 (± 144.2)
Corridor Targeted 300	0.075	**0.7 (± 0.2)** 2.3 (± 0.7)	**0.9 (± 0.3)** 4 (± 0.9)	**0 (± 0)** 0 (± 0)	**9.5 (± 6.0)** 126.3 (± 47.4)

* The proportion of replicates that saw any non-negligible number of possums move onto the Peninsula (> 10)

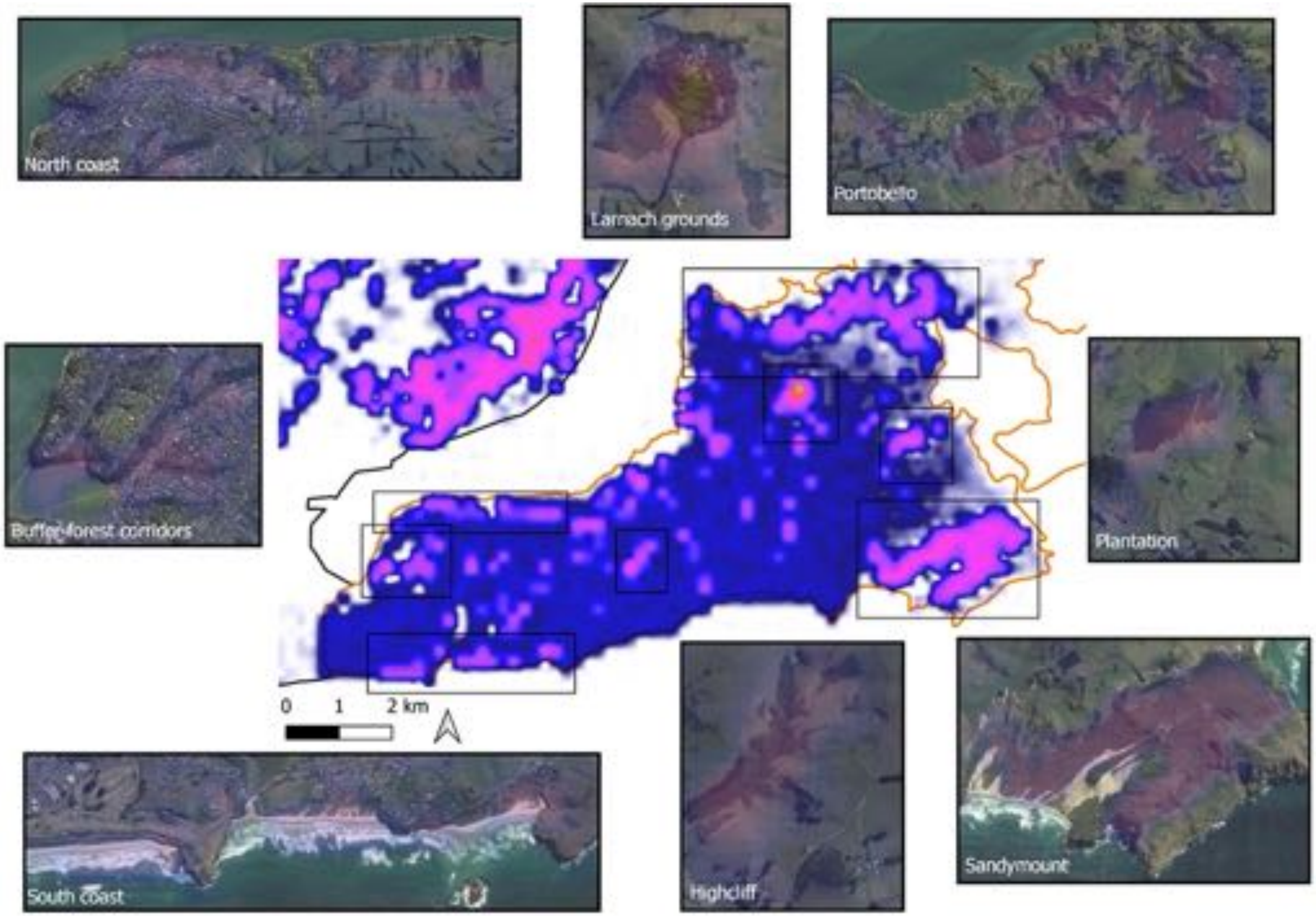

Figure 3. The location of 'hotspots' of possum abundance on the Otago Peninsula after 40 years of reinvasion (averaged over 40 replicates).

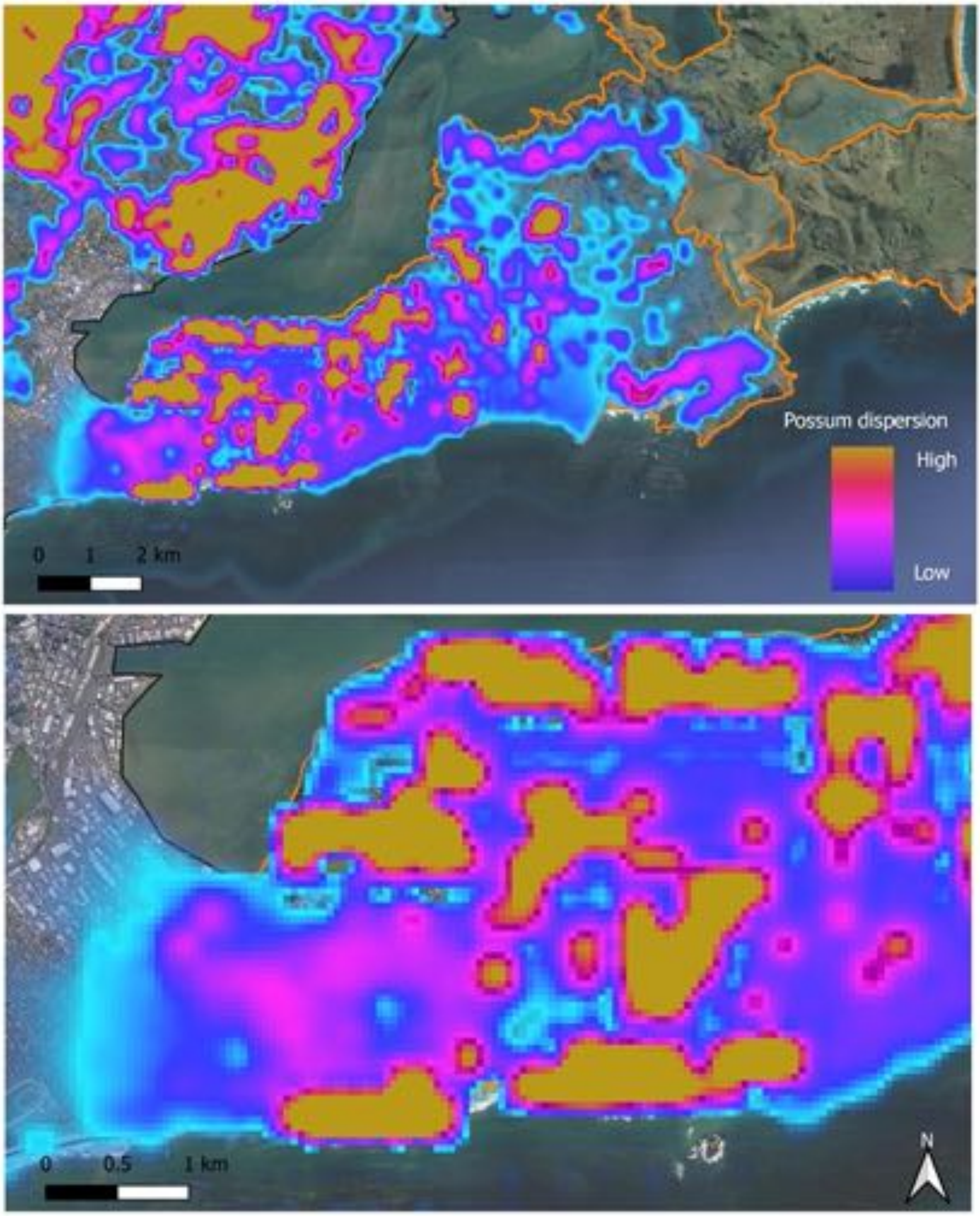

Figure 4. The accumulated dispersion map of possum movements as they reinvade the Peninsula in a scenario with no control and complete eradication. Dispersion was quantified as the number of individual movements made across a cell on the monthly time-step, averaged over 40 replicates.

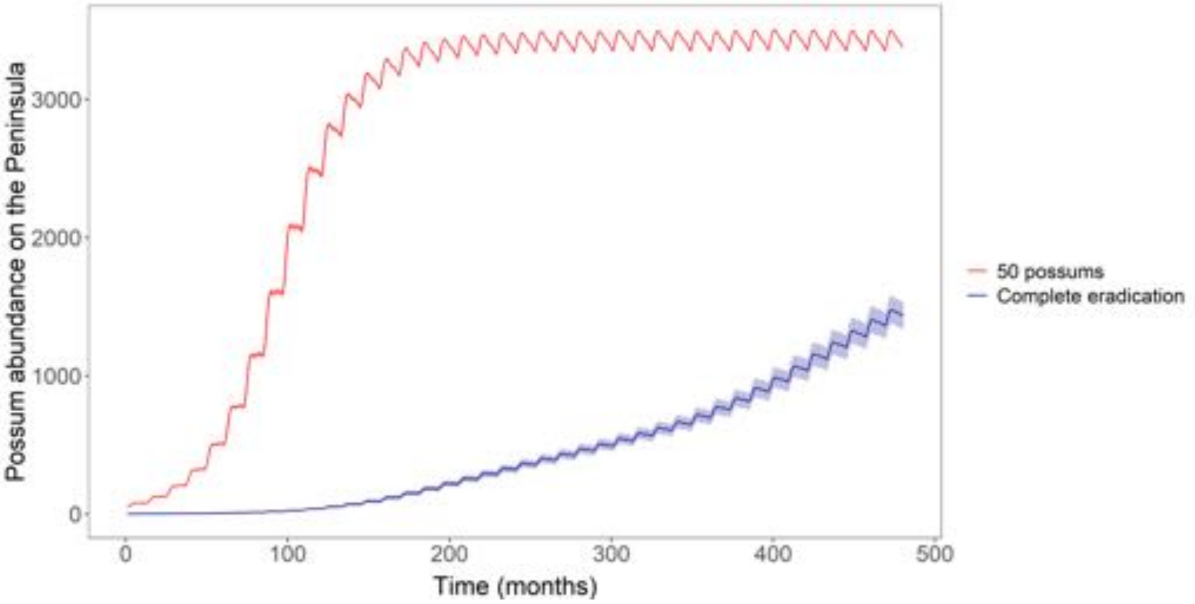

Figure 5. The total average abundance of possums in the Peninsula Study Area per month over time in the "Hotspot" and "Hotspot 50" scenarios (see Table 2 for scenario descriptions). Shaded bars are ± standard error.

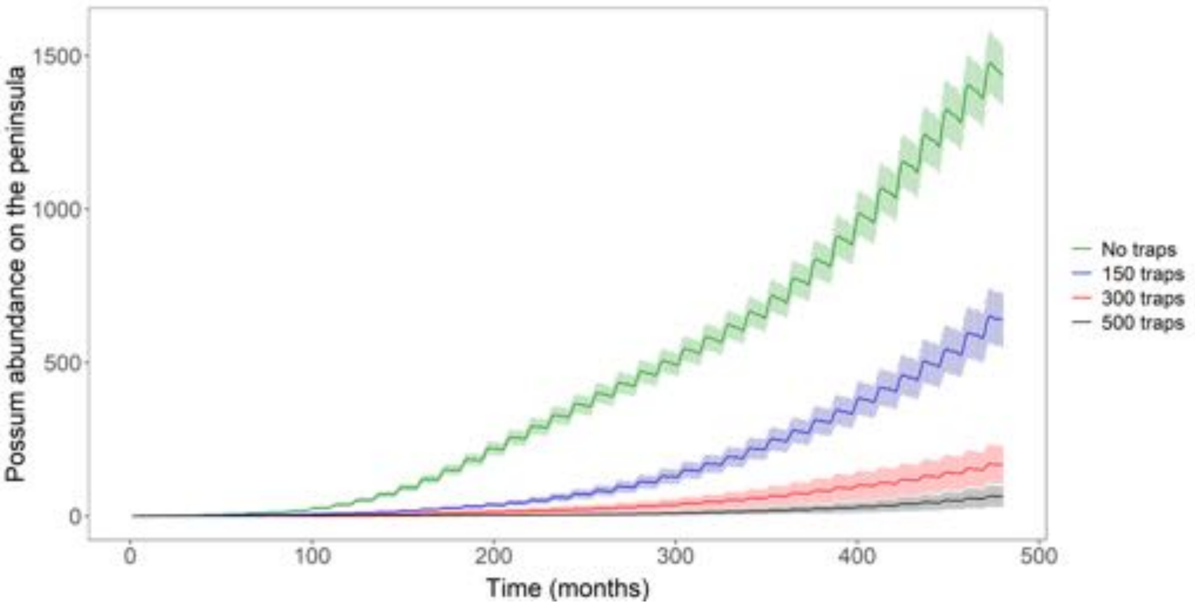

Figure 6. The total average abundance of possums on the Peninsula at the end of 40 year simulations in the 'Hotspot' scenario where there were no traps, compared with three trapping scenarios of increasing trap density (150, 300 and 500).

Conclusions

- Reinvasion of possums onto the Peninsula was gradual in the absence of control, with immigration somewhat limited by the geography of the Buffer Zone.

- However reinvasion became more rapid over time as *in situ* reproduction contributed new individuals to the Peninsula.

- Certain high-quality habitat may become 'hotspots' of reinvasion and dispersal movement

- When a population of possums remained on the Peninsula at the start of simulations, re-population was far more rapid due to *in situ* reproduction, and the Buffer Zone landscape barrier became essentially redundant in preventing population growth.

- The targeted trapping method was the most effective in preventing reinvasion, while the 300 and 500 trap scenarios both had a similar effectiveness, greater than that of the current 150 trap arrangement.

Recommendations

The results of the model highlight that the Peninsula will receive some protection from significant reinvasion by the natural landscape barrier of the Buffer Zone. However, there are key issues that should be the focus of future management decisions. In order to minimise reinvasion risk based on the predictions of the model, I recommend that the OPBG should:

1. Prioritise rigorous eradication to ensure no possums remain on the Peninsula at the end of the " final eradication phase".
    a. This includes being aware that even when the OPBG's eradication target of "no possum detections for 2 years" is reached, there may be enough of a residual, un-detected possum population to still expand.
    b. This may involve adopting novel detection techniques to identify the final few remaining individuals as research continues in this field over the next 5 years, and maintaining detection equipment throughout the Peninsula will be important in order to detect any newly dispersing juveniles.

2. Aim for 300-500 traps in the Buffer Zone, and target them at known habitat corridors, including the coastal reinvasion route.
    a. Monitor trap catch across the Buffer Zone to identify corridors and adjust trapping accordingly.

3. Maintain an ongoing long-term commitment to trapping in the Buffer Zone. This will be needed to prevent reinvasion, as possum expansion was delayed in most scenarios by almost 15 years due to the low amount of immigration occuring.

References

Lustig, A., James, A., Anderson, D. and Plank, M., 2019. Pest control at a regional scale: Identifying key criteria using a spatially explicit, agent-based model. *Journal of Applied Ecology*, *56*(7), pp.1515-1527.