Low-cost aerial poisoning II: Refinement and testing of cluster sowing 2009–10

Animal Health Board R-10710

Landcare Research
Manaaki Whenua

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Contents

Summary

Project and Client

- Landcare Research conducted three further trials for the Animal Health Board (AHB project R-10710) to develop, test, and refine cluster and strip baiting during aerial 1080 poisoning; the fieldwork was conducted between September 2009 and June 2010.

Objectives

- Compare the control efficacy of cluster, strip, and broadcast baiting.
- Determine the effect of increased flight path spacing (FPS) on control efficacy.
- Determine the effect of the interval between prefeed and toxic baiting on control efficacy, including an interval of zero.

Methods

- New aerial baiting techniques were tested in small sub-areas as part of three large-scale poisoning operations, in Whanganui National Park, Cascade Valley and Maruia Valley.
- Each trial included a comparison between ‘standard’ broadcast baiting and cluster or strip sowing. All baiting was conducted using helicopters. We also compared the effect of FPS, and/or the interval between prefeeding and toxic baiting, on the possum and rat abundance indices achieved by cluster vs strip sowing.
- The effect of poisoning was assessed using Poisson-transformed Chew Card Indices (tCCIs) of possum and rodent activity. A range of ancillary information was also gathered including any ‘operational’ monitoring by other agencies, or in related research projects.

Results

- At Whanganui tCCIs for possums were reduced by 55.6 ± 15.7% (SEM) by broadcast baiting and 97.1 ± 2.1% by cluster baiting, but the difference was not statistically significant. In a second sub-trial, possum tCCI reductions were not significantly different with 70.6 ± 11.0% by broadcast baiting, 68.0 ± 4.2% by 130-m-FPS strip baiting, and 23.8 ± 10.4 by 180-m-FPS strip baiting. For rats, high reductions were achieved with broadcast baiting (98.0%), cluster baiting (99.9%) and 180-m-FPS strip baiting (96.5%) but only 61.3% at 130-m-FPS.
- At Cascade, a modified measure of possum tCCI reductions was variable when prefeed and toxin were sown on the same day (36–100%), but otherwise high with cluster sowing regardless of FPS (92–100%), and for broadcast sowing at high elevation (100%). However, there was only a modest reduction in the low-elevation broadcast block (64%). Trapping indicated similar residual abundance in the low-elevation block (Residual Trap-Catch Indices ranged 2.2–3.4%) except with same-day prefeed and toxic baiting (RTCI 8.6%).

- At Maruia total or near-total reductions of possum, rat and mouse CCIs were achieved regardless of sowing method, sowing rate, or prefeed interval, except when prefeed and toxin were sown on the same day.
- In total, 139 animals were found dead after control, mostly possums (105) and rats (19). Six deer, and four blackbirds were also found dead, but no native birds.

Conclusions

- The efficacy of aerial cluster baiting in reducing possum abundance has matched or bettered that of broadcast sowing in five of the six trials completed by 2010. In the most successful trial to date, at Maruia, very high efficacy was achieved against possums, rats and mice using just 167 g (~28 baits) per hectare, indicating gaps of up 150 m between baited areas and low numbers of baits per target animal did not adversely affect efficacy.
- In the Cascade trial, the reductions were more variable with both broadcast and cluster sowing. We suggest that this might reflect denser ground cover at Cascade.
- In the Whanganui trial, both broadcast and strip sowing had only modest impacts in possum CCIs, for reasons unknown. We conclude that the trial should be repeated.
- Rat reductions achieved at Maruia and Whanganui were high with both cluster and broadcast sowings. There were few rats at Cascade. At Whanganui, broadcast sowing achieved better reductions of rats than of possums. We speculate that this may be because bait fragmentation is less of a problem for prefed rats than for possums, because even fragments are individually lethal to rats given their small body size.
- No native birds were found dead after poisoning, so these trials give no indication that either cluster or broadcast aerial 1080 baiting kills a large proportion of native birds.
- The number of tomitits and/or robins seen alive sometimes decreased substantially after poisoning, but as no native birds were found dead, we suspect the reductions were seasonal effects. Nowhere were the numbers seen afterward reduced to zero.
- In total, four deer were found dead in the 27 cluster-sown blocks and two in the 11 broadcast blocks. There is therefore no indication cluster sowing increases deer by-kill.

Recommendations

The AHB should operationalise cluster baiting. Further refinement should include:

- Assessing bait fragmentation rates, pre-control possum and rat abundance, and ground cover density as potential determinants of cluster poisoning success
- Exploring further the effect of flight path spacing on the efficacy of cluster sowing in controlling possums and rats
- Determining the effect of bait screening on aerial poisoning efficacy (cluster and broadcast) and the efficacy of same-day poisoning with screened bait
- Determining the efficacy of ultra-low cluster sowing for high frequency control of possums and rodents, for both TB and conservation purposes.

1 Introduction

Landcare Research conducted three trials for the Animal Health Board (AHB project R-10710) to identify whether the cost of aerial 1080 poisoning and the amount of toxin used could be reduced with little or no loss of efficacy by sowing bait in small clusters rather than broadcasting it as usual. The field component of the trials was conducted between September 2009 and June 2010.

2 Background

This is the second of four planned reports documenting the development, refinement, and field testing of new techniques for aerial baiting of possums (and rodents). The work builds on previous research on aerial 1080 baiting showing that high reductions in indices of possum abundance could be achieved using far less toxic bait than usual if the bait was sown in strips or clusters (rather than broadcast evenly as is currently the norm), both when the clusters were delivered by hand (Nugent et al. 2008) or aerially with a specifically designed bucket (Nugent et al. 2009). Further research in the first year of this 4-year project (Nugent & Morriss 2010; the first report for this project) demonstrated that it was practically feasible to aerially sow as little as 250 g/ha of toxic bait in clusters, yet retain broadly similar efficacy (reductions in possum abundance indices) to those obtained with much higher sowing rates using broadcast sowing (2–3 kg/ha of toxic bait).

Here we report on a second set of three main trials conducted within this project. Overall these trials aimed to refine the cluster sowing method, and, in one trial, to also test strip sowing by helicopter as an alternative approach to applying bait that could be conducted with low-cost high-capacity fixed-wing aircraft (as was historically the norm). As the series of trials is evolutionary, with each of the three trials building to at least some degree on the previous ones, the objectives and designs for each differ.

The first of the three trials was conducted in Whanganui National Park in October–November 2009, with two broad aims. One aim was to refine the cluster-sowing approach further by using smaller toxic bait and less prefeed, and a second aim was to compare strip sowing as an intermediate alternative between cluster and broadcast sowing. The latter aim also included exploration of flight path spacing (henceforth FPS: the distance between the parallel flight paths flown by the aircraft when sowing bait).

The other two trials were conducted in mid-2010 in the Cascade and Maruia valleys respectively. They were aimed first at determining whether the cost of bait and helicopter flying time required for cluster sowing could be further reduced (without reducing possum control efficacy) by increasing the distance between flight paths from 100 m to 150 m. The second aim was to determine whether there was an optimal interval between prefeeding and the application of toxic bait. This second focus was prompted by concern that cluster sowing might rely much more heavily on a short-lived change in possum foraging behaviour compared with broadcast baiting. The cluster-sowing strategy developed in this project is based on aligned prefeeding whereby non-toxic prefeed is sown in a strip ~40 m wide (leaving strips of unbaited areas ~60 m wide when an FPS of 100 m is used). Clusters of toxic bait are then sown along the same flight paths used to sow prefeed, in the belief that the concentration of prefeed along those flightpaths will have ‘trained’ the possums to forage there. Warburton et al. (2009) showed that possums were attracted to baited areas while bait was present and continued to visit the baited area more than previously for up to 3 weeks after all of the prefeed had been consumed. The concern is that the major change in foraging behaviour might last for only a week or so after prefeeding, so we aimed to test in the Maruia trial whether cluster-sowing outcomes were poorer when there was a long interval between prefeeding and the application of toxic bait.

In addition, the Maruia and Cascade trials incorporated treatments in which prefeed and toxic bait were sown on the same day, as part of a separate but overlapping related project (R-10727: Better aerial baiting systems and strategies). The aim was to determine whether flying costs would be reduced by almost half by sowing the two bait types during a single helicopter pass. The logic suggesting that this might be feasible is as follows: With cluster sowing, only about 2–3% of the area is poisoned. If prefeed is distributed far more widely, in much larger numbers (250 baits/ha prefeed cf. 42 baits/ha toxic) of very small size (2 g), then there is a high likelihood (>97%, because the clusters occupy <3% of the area) that a possum will first encounter one of the prefeed baits and become familiar with it, yet, because of its small size, not be satiated by it. When they eventually encounter a larger toxic bait, the previous experience will have increased the likelihood that they will accept it and eat a lethal dose.

Finally, as part of a separate project (R-10729: Effect of rat interference on possum kill during aerial 1080 poisoning), the effect of rat abundance on possum kill was also investigated. The full results for the latter trial will be reported separately, but results relevant to the above comparisons are reported here.

3 Objectives

3.1 Overall (2008–2013)

To identify, from a series of discrete operational trials over 5 years, how the cost of aerial poisoning and the amount of toxin used can be reduced by >80% with little or no loss of efficacy.

3.2 2009–2010 trials

To develop, test, and refine new approaches for cluster and strip sowing during aerial 1080 baiting of possums (and also rodents), by:

- Comparing the control efficacy of cluster, strip and broadcast baiting
- Determining the effect of increased FPS on control efficacy
- Determining the effect of the interval between prefeed and toxic baiting on control efficacy, including (as part of a related study) an interval of zero.

4 Methods

4.1 Operational areas and overall approach

A range of different aerial baiting techniques were experimentally tested in small sub-areas nested within three large-scale poisoning operations, hereafter designated as the Whanganui, Cascade, and Maruia operations. The first two were undertaken by the Department of Conservation (DOC) for biodiversity reasons, and the third by the AHB as part its TB-management programme. All three 'main' operations were conducted using local best-practice broadcast baiting.

One or more sub-trials were undertaken within each area, each including a comparison between the 'standard' broadcast baiting approach and one or more alternative approaches using cluster or strip sowing to deliver toxic bait at a far lower sowing rate than in the standard approach. Trial outcomes were primarily expressed by measuring the effect of poisoning on indices of possum, rat, mouse, and stoat activity (specifically the rate at which each species bit chew cards, a multi-species detection device; Sweetapple & Nugent 2009). Chew card surveys were conducted before and after aerial baiting. A range of ancillary information was also gathered, varying between trials, but including any 'operational' monitoring conducted by the agency undertaking the operation. In all trials field staff recorded all incidental encounters (including animals heard and not seen) with selected native bird species, pigs and deer, both before and after poisoning, and also recorded all observations of dead animals.

All prefeeding and toxic baiting were conducted using helicopter-slung sowing buckets, with the helicopter using flight paths spaced 100–240 m apart for broadcast baiting, 100–150 m apart for cluster sowing, and 130–180 m apart for strip sowing. The main focus of these trials was to refine cluster sowing. The second and third trials were conducted using a new purpose-designed cluster-sowing bucket, so this report includes some notes on performance of that bucket (and of the buckets with which it was compared).

4.2 Whanganui trials

4.2.1 Study area and design

In late 2009, DOC aerially poisoned an area of 31 700 ha within the Whanganui National Park (Appendix 1). The area is steep hill country with mostly complete forest cover dominated by conifer–broadleaved forest at lower levels and mixed beech forest on the ridges. Two sub-trials were conducted in 10 study blocks of 625–975 ha embedded within this overall operation. The operational target was to reduce possums to below a Residual Trap-Catch Index (RTCI; NPCA 2008) of 5%.

Sub-trial 1: Cluster vs broadcast

This sub-trial comprised a 2 × 2 comparison of the efficacy of cluster and broadcast sowing, and was effectively a replicate of the Isolated Hill trial reported previously (Nugent &

Morriss 2010). The trial was conducted in the Kaiwhakauka Stream area (Appendix 1), which had been previously poisoned in 2005. All prefeeding and toxic baiting were conducted using helicopter-slung sowing buckets to deliver Wanganui #7 cinnamon-lured cereal bait (Animal Control Products, Whanganui).

- *Broadcast sowing (DOC standard practice):* A single prefeed of non-toxic 6-g bait was broadcast at 1 kg/ha with an FPS of 240 m. Prefeed was followed 6–7 days later by broadcast baiting using the same FPS to deliver 12-g baits containing 0.15% 1080 at 2 kg/ha, with no particular effort made to align the prefeed and toxic flightpaths. This treatment was also applied to all of the larger operational area not included in this trial.
- *Cluster sowing:* A single prefeed of non-toxic 2-g baits was sown in ~40-m-wide strips at 0.5 kg/ha along flight paths spaced 100 m apart, followed 7 days later by 6-g baits containing 0.15% 1080 sown in clusters at 0.25 kg/ha, with the prefeeding and toxic baiting flight paths aligned as closely as possible. The prefeed was sown using a spinner turning at a very slow speed so that bait was spread no more than ~20 m each side of the flight path and with the bulk of the prefeed close to or under the flight path. The clusters of toxic bait were spaced 50 m apart along the flight paths, with approximately 21 baits per cluster.

Sub trial 2: Strip vs broadcast

This trial comprised a 3 × 2 comparison of three sowing treatments, and was conducted in Blocks 5–10 alongside the Whanganui River (Appendix 1), which had been previously poisoned in 2007 (Block 5) or November 2002 (Blocks 6–10). In this trial, we compared prefed broadcast sowing (as above) with strip sowing at two different FPS as follows:

- *Strip sowing with 130-m FPS*: A single prefeed of non-toxic 2-g baits was sown at 0.6 kg/ha in ~40-m-wide strips, using a 130-m FPS. Subsequently 6-g baits containing 0.15% 1080 were sown in ~40-m-wide strips at 0.6 kg/ha along the same flight paths used for prefeeding so that the distributions of prefeed and toxic bait were as closely aligned as possible.
- *Strip sowing with 180-m FPS*: Baits were sown as above, except that a 180-m FPS was used, and the sowing rate was 0.45 kg/ha for both prefeed and toxic bait.

4.2.2 Poisoning operation

Prefeed was sown on 30–31 October and 1080 bait on 6–7 November 2009. Two Iroquois helicopters (Beck Helicopters) and 1400-kg-capacity sowing buckets fitted with large-diameter spinners were used for broadcast sowing of both prefeed and toxic bait (sowing speed 100 km/h, and FPS of 240 m). Where required, strip sowing of both prefeed and toxic bait was achieved by fitting one of the above buckets with a smaller, slower spinner. Cluster sowing of 1080 bait was conducted using the spinnerless 600-kg-capacity bucket used for the previous trials (Nugent & Morriss 2010). The bucket was fitted with a fixed-interval periodic-release mechanism to cluster-sow bait. A Squirrel helicopter (Amuri Helicopters) flown at ~65 km/h was used. All of the cluster baiting was conducted on 7 November 2009. No rain fell for 3 days after poisoning, with 6.8 mm falling on the fourth night, and then none for the next three nights. A total of 98.4 mm had fallen by the end of November. Uneaten baits observed during post-control monitoring (3–15 December 2009) were degraded and often mouldy.

4.2.3 Monitoring of effects on possums, rats, and other species

Two indices of pest activity were used to assess control, with chew cards (CCs) used primarily for possums and rats, and tracking tunnels for rats, mice and stoats.

Chew cards

About 2 months before poisoning (1–6 September 2009) nine CC transects were established in each block. Each line was subjectively placed so that bearings following ridgelines and avoided the many papa bluffs and gorges in the area. Lines were spaced at least 200 m apart and were 520 m long, taking 14 cards at 40-m intervals.

Chew cards were baited with a mixture of peanut butter, icing sugar and ground lucerne (5:1:0.6; Nugent et al. 2008). The cards were nailed to tree trunks 15–20 cm above the ground to allow easy access by rodents with the replacement cards being placed on different nearby trees. The cards were put out 1–6 September 2009 and checked and replaced 7 days later. Cards were again checked and replaced 86 days later (3–8 December 2009; 3 weeks after poisoning), and finally checked and removed 7 days later.

Tracking tunnels

Tracking tunnels were placed at each end and at the midpoint of each CC line at the same time that the CC lines were established. ‘Black Tracker’ tracking cards (Gotcha Traps, Warkworth) were placed in the tunnels, which were baited with rabbit meat and left for 7 nights before the tracking cards were removed and checked. The monitoring was repeated 3 weeks after poisoning. The tracking cards were deployed for the same 7-day periods as the chew cards, above.

Ancillary monitoring

In addition to the monitoring conducted as part of this project, DOC also conducted WaxTag and RTCI monitoring in parts of the operational area in or near the blocks used for sub-trial 1, as follows:

- A total of 20 lines (of 20 WaxTags spaced at 10-m intervals) were deployed for 7 nights in March 2010, with 14 of the lines within the study blocks.
- Seventeen 10-trap RTC lines were established, using 30-cm raised sets, in May–June 2010, about 7 months after poisoning. The midpoints for these were randomly positioned along some of the CC lines above, with a trap-line bearing of magnetic north.

4.3 Cascade trial

4.3.1 Study area and design

In mid-2010, DOC undertook aerial 1080 poisoning of possums (and rats and stoats) over an area of 29 397 ha between the Gorge and Cascade rivers, South Westland. Part of the area (~3000 ha) was used for this trial, and was divided into 11 blocks (Appendix 2). The site was predominantly steep north-facing slopes with mostly complete forest cover dominated by a mixture of silver beech (*Nothofagus menziesii*), hardwoods (particularly kamahi, *Weinmannia racemosa*) and podocarp species. The understorey below about 600-m altitude is dominated by dense waist-high crown fern (*Blechnum discolor*). At higher altitudes silver beech dominates most of the forest, but forest on less fertile sites includes a mix of podocarp species such as celery pine (*Phyllocladus alpinus*) and yellow silver pine (*Lepidothamnus intermedius*) (P. Knightbridge, DOC Hokitika, pers. comm.). The area had been aerially poisoned previously, in December 2005, after which a post-control RTCI of 1.7 ± 0.6% was recorded. Between May 2006 and June 2009, regular possum kill-trapping was undertaken along the ridge line that formed the southern, high-elevation, boundary of the study area.

The trial effectively comprised three sub-trials. It aimed firstly to compare cluster and broadcast sowing, secondly to determine the effect of increased FPS on the efficacy of cluster sowing, and thirdly to determine whether a prefeed interval (PFI) of zero (i.e. sowing prefeed and toxic bait on the same day) would reduce the efficacy of cluster sowing. The study area was divided into 11 blocks (6 high-altitude, 5 low-altitude) with one or two high-altitude and one low-altitude block assigned to each of the following aerial baiting treatments:

1. *Broadcast sowing (DOC standard practice) FPS =100 m, PFI = 9 days*: A single prefeed of non-toxic cereal bait (cinnamon-lured 6-g RS5 baits; Animal Control Products, Whanganui) was broadcast at 1 kg/ha followed 9 days later by 0.15% 1080 cereal bait (cinnamon-lured 6-g RS5 baits) broadcast at 2 kg/ha, with no particular effort made to align the prefeed and toxic flight paths.
2. *Cluster sowing, FPS =100 m, PFI = 9 days*: A single prefeed of non-toxic cereal baits (cinnamon-lured 2-g RS5 baits) was sown in ~40-m-wide strips at 0.5 kg/ha along flight paths spaced 100 m apart, followed 9 days later by 0.15% 1080 cereal baits (cinnamon-lured 6-g RS5 baits) sown in clusters of ~21 baits (125 g) every 50 m along flight paths spaced 100 m apart, with the prefeed and toxic baiting flight paths aligned as closely as possible. The prefeed was sown using a spinner turning at a very slow speed so that bait was spread no more than ~20 m each side of the flight path and with the bulk of the prefeed close to or under the flight path. The prefeed and toxic sowing rates were 500 g/ha and 250 g/ha respectively.
3. *Cluster sowing, FPS =150 m, PFI = 9 days*: As for 2 above, except a 150-m FPS was used reducing the prefeed and toxic sowing rates to 330 g/ha and 167 g/ha respectively.
4. *Cluster sowing, FPS =100 m, PFI = 0 days*: As for 2 above, but with both prefeed and toxic bait sown on the same day.
5. *Cluster sowing, FPS =150 m, PFI = 0 days*: As for 3 above, but with both prefeed and toxic bait sown on the same day.

4.3.2 Poisoning operation

For the main operation, and the broadcast trial blocks, prefeed was broadcast-sown on 9 May and the toxic bait on 18 May 2010, using six Jet Ranger helicopters (Helicopters Otago) flown at 100–110 km/h. On the same dates strip prefeeding was achieved in the trial blocks using a slow spinner speed and flying at 90–100 km/h, and cluster sowing of toxic bait was achieved using a new GPS-activated bucket (developed in Project R-10727 Better aerial baiting systems and strategies) flown at 90–100 km/h. There was no rainfall recorded for 4 days following application of toxic bait and only 9 mm up until 27 May 2010 (9 days following bait application).

4.3.3 Effects on possum, rat, mouse, and stoat abundance

Chew card surveys

About 2 months before poisoning, a chewcard grid (n = 36 cards per block; see Appendix 2 for grid locations) was established in 10 of the trial blocks. Cards were placed 100 m apart, so the grid covered an area of ~25 ha. This sampling design was developed in an effort to achieve greater statistical power than in the design used previously (e.g. the Whanganui trial above) in which the reduction in Chew Card Indices (CCIs) was determined on a per-line basis and sampling error on lines with very low pre-control CCIs has a disproportionately large impact on the variance about the mean reduction per lines.

The distance between cards was increased to 100 m to increase the independence of adjacent cards. Grids were placed within blocks in advance, without prior knowledge of ground conditions, using the same subjective rules as used in the Whanganui trial blocks to avoid the bluffs and steep-sided creeks that were likely to be unsafe to traverse. Each grid was sited at least 200 m inside the block boundary to avoid confounding effects from the neighbouring treatments.

For all but one block, 7-day CC surveys were conducted as above (section 4.2.3) before control (16–20 March 2010) and after control (21–27 June 2010), with cards also deployed and checked for the intervening 93–100 days. The 11th block was added after the pre-control survey failed to detect any possums in one of the 10 blocks initially defined. CCs were established in this grid on 5 May 2010 and collected and replaced 6 days later (a day earlier than planned, due to forecast bad weather) and it was resurveyed at the same time as the others.

Trap-catch surveys

About 6 weeks after poisoning (3–9 July 2010), six standard 10-trap RTCI traplines (NPCA 2008) were run in each of the five low-altitude blocks. Line locations were randomly selected within each block, with all trap sites >200 m from the block boundary.

4.4 Maruia trials

4.4.1 Study area and design

In mid-2010, the AHB undertook aerial 1080 baiting targeting possums in an area of 23 006 ha west of the Maruia River, Westland (Appendix 3). The area was steep, mostly east-facing forest dominated by beech (*Nothofagus* spp.), with a mostly open understorey. Before control, possum density was moderate to high with an RTCI of 27 ± 7% recorded in part of the area 8 months before the poisoning operation (R. Blankenstein, VCS, pers. comm.). The area had not been aerially poisoned previously.

A set of 20 study blocks, each of ~110 ha, were established on the eastern side of the operational area, with a buffer of 140 m between the eastern operational boundary and the eastern edge of each trial block (Appendix 3).

The trial comprised four sub-trials. It aimed firstly to compare cluster and broadcast sowing, secondly to determine the effect of increased FPS on the efficacy of cluster sowing, and thirdly to determine whether a prefeed interval (PFI) of zero (i.e. sowing prefeed and toxic bait on the same day) would reduce the efficacy of cluster sowing. The fourth sub-trial aimed to determine the effect of pre-control rat abundance on possum reduction during cluster sowing, as part of a related study.

Two sowing methods were used. As follows (and see Table 1):

- *Broadcast sowing FPS = 140 m, PFI = 26 days*: A single prefeed of non-toxic cereal bait (cinnamon-lured 6-g RS5 baits; Animal Control Products, Whanganui) was broadcast at 1 kg/ha followed 26 days later by 0.15% 1080 cereal bait (cinnamon-lured 12-g RS5 baits) broadcast at 2 kg/ha, with no particular effort made to align the prefeed and toxic flight paths.
- *Cluster sowing, with various FPS and PFI (Table 1)*: A single prefeed of non-toxic cereal baits (cinnamon-lured 2-g RS5 baits) was sown in ~40-m-wide strips at FPS of 100, 125, or 150 m, followed 0, 5, 14, or 30 days later by 0.15% 1080 cereal baits (cinnamon-lured 6-g RS5 baits) sown in clusters of ~21 baits (125 g) every 50 m along flight paths, with the prefeed and toxic baiting flight paths aligned as closely as possible.

4.4.2 Poisoning operation

The broadcast sowing and strip prefeeding in the trial areas were conducted using a Hughes 500F helicopter (Coastwide Helicopters) fitted with a conventional 500-kg-capacity broadcasting bucket, using a flying speed of ~100 km/h. Cluster sowing was achieved using the GPS-activated bucket used in the Cascade trials under a Raven R44 helicopter (Amuri Helicopters), flown at ~100 km/h. Most of the toxic bait in the trial blocks was sown on 4 June 2010, but the same-day trial blocks were sown 14 June 2010.

Some rain (20 mm) fell 2 days after (6 June 2010) most toxic bait had been sown. Some rain (8 mm) was recorded 5 days after the toxic bait was sown in the same-day trial blocks. A total of 135 mm of rain was recorded at Maruia for the month of June 2010.

Table 1 Treatments applied to trial blocks at Maruia, Westland

				Sowing rate	
Block no.	Sowing method	Flight path spacing FPS (m)	Prefeed interval PFI (days)	Prefeed (kg/ha)	Toxic (kg/ha)
'Cluster vs Broadcast' trial					
8	Broadcast	140	26	1.00	2.00
18	Broadcast	140	26	1.00	2.00
19	Broadcast	140	26	1.00	2.00
20	Broadcast	140	26	1.00	2.00
'FPS/PFI' trial					
2	Cluster	100	5	0.50	0.25
15	Cluster	100	14	0.50	0.25
4	Cluster	100	30	0.50	0.25
6	Cluster	125	5	0.40	0.20
7	Cluster	125	14	0.40	0.20
13	Cluster	125	30	0.40	0.20
10	Cluster	150	5	0.33	0.17
14	Cluster	150	14	0.33	0.17
16	Cluster	150	30	0.33	0.17
'Same-day' trial					
1	Cluster	100	0	0.50	0.25
5	Cluster	125	0	0.40	0.20
9	Cluster	150	0	0.33	0.17
'Rat Interference' trial					
3	Cluster	100	14	0.50	0.25
11	Cluster	100	14	0.50	0.25
12	Cluster	100	14	0.50	0.25
17	Cluster	100	14	0.50	0.25

4.4.3 Effects on possum, rat, mouse, and stoat abundance

Chew-card surveys

Chew card grids (*n* = 36 cards per grid) were established in each trial block, as at Cascade (section 4.3.3). This design was used so that the core of the whole block could be indexed and cards were placed 100 m apart so as to have some degree of independence. Each CC grid was at least 250 m from the block boundary.

The pre-control survey was conducted 16–22 March 2010 (2.5 months before poisoning) and cards were checked and replaced 6–8 days later. Cards were again checked and replaced 117–125 days later (12–14 June 2010) 4 weeks after poisoning, and finally checked and removed 7 days later. The replacement cards were placed on different nearby trees.

Ancillary monitoring

No other monitoring was undertaken as part of this project, but more intensive CC surveys were undertaken in the four ‘Rat interference’ trial blocks as part of that project, along with trap-catch monitoring before and after control. Sixty-six CCs were established in each block, with interference measured twice prior to aerial poisoning as well as once afterwards. Three standard 10-trap RTCI traplines (NPCA 2008) were established in each of the blocks and run for three nights prior to the poison operation (16–18 April 2010). Three weeks after poisoning (30 June – 2 July 2010), the same number of trap lines were established at different locations. Most of the possums captured during pre-control trapping were fitted with radio-collars, some of which had ‘time-since-death’ capability to identify (on recovery after poisoning) when the possum had died.

Bait acceptance

To aid interpretation of the same-day trial outcomes at Maruia, bait acceptance was assessed ~8 weeks after poisoning. Four 380-m-long bait acceptance lines were established in each of two same-day trial blocks in which surviving possums had been detected. Lines were spaced 100 m apart, and a baiting site was established every 20 m along them. At each site a chew card was placed 20–30 cm above ground, and four different non-toxic baits were nailed 5 cm apart above the chew card (i.e. so that the card was encountered first). The four bait types were cinnamon-lured 6–8-g RS5 bait (Animal Control Products, Whanganui), aniseed-lured 6–8-g RS5 bait (Pest Control Research, Christchurch), 10–20-g cut plain apple and 10–20-g cut plain carrot. The percentage of each bait eaten was subjectively assessed 2 days later and as far as possible the species responsible were identified.

4.5 Analysis and assumptions

Cards were checked for bite marks, using a magnifying glass where necessary, and the percentage of cards marked by each species was used as a Chew Card Index (CCI) of the relative abundance of that species. Because a high percentage of cards can be marked, the CCI is certain to be non-linearly related to pest abundance, in the same way (but more so) that the RTCI is (Forsyth et al. 2005). To partially reduce the effect of index saturation on understating high levels of pest abundance, the CCI were transformed assuming an underlying Poisson (random) distribution of card encounters. As animal distribution and habitat use are usually clustered rather than random, reductions in the transformed CCIs (tCCIs) are still likely to understate the true reduction in pest abundance.

The estimated changes in CCI activity should be viewed as relative indices (rather than absolute measures) of the true changes in pest activity (i.e. the difference in the change in CCI activity between treatments indicates a difference in activity levels), which we assume reflects some decrease (or increase) in pest abundance, at least for possums and rats, but may not accurately reflect the size of the difference.

For the Whanganui trials, the various treatments were compared (separately for each species) using the per-line reduction in Poisson-transformed CCIs as the dependent variable in a linear mixed-effect (LME) model-selection approach in which the aerial baiting treatment was treated as a fixed effect, block as a random effect, and (where there were sufficient data) the pre-control CCIs for possums, rats, and mice as potential covariates.

For the Cascade and Maruia trials, there were usually too few post-control data to warrant statistical testing of differences between treatments. Where possible, however, simple contingency tables were used, with the presence or absence of a bite on each card treated as an independent binary variable. This assumes that each individual card provided an independent indication of animals' activity.

Where appropriate, sampling error is presented as standard errors.

5 Results

5.1 Whanganui trial

5.1.1 Whanganui: Possums

Possum abundance indices varied considerably between blocks before control, with the mean of the 7-day-CCIs for each block being 74.8 ± 2.8% (SEM; range of block averages 30.2–98.4%). CCIs for possums were lower in the northern study area (53.6 ± 4.8%) than along the Whanganui River (88.9 ± 1.7%), consistent with the more recent control in the former.

Sub-trial 1: Broadcast vs cluster sowing

The average reduction in possum activity (tCCI per block, n = 2 blocks per treatment) was 55.6 ± 15.7% (SEM) for the broadcast treatment, and 97.1 ± 2.1% for the aligned cluster treatment (Fig. 1A). Despite the large difference in the mean reductions between treatments, however, an LME model indicated no significant difference between the treatments (t_2 = 1.82, P = 0.21). This reflected the high variance between lines in the broadcast blocks, with total reductions in tCCI on 10 lines, but substantial increases on two others.

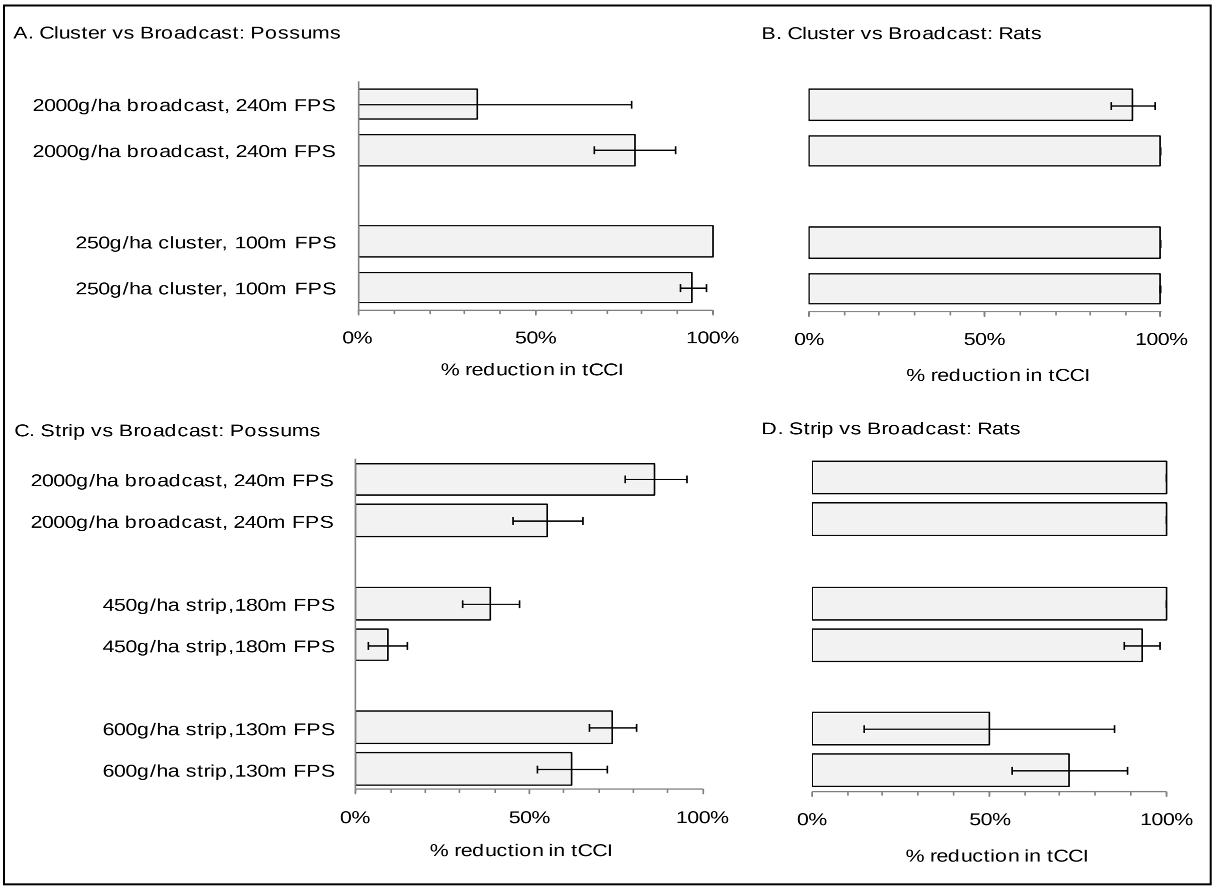

Figure 1 Reductions in possum (A, C) and rat (B, D) activity after aerial 1080 baiting in the Whanganui National Park, separately for the 'cluster vs broadcast sowing' sub-trial (A, B) and the 'strip vs broadcast sowing' sub-trial (C, D). Data are the % reduction in Poisson-transformed CCI per line averaged (±SEM) across the nine lines in each treatment block. FPS = flight path spacing; tCCI = Poisson-transformed Chew Card Index

Ignoring sowing treatment, the pre-control CCIs for possums and mice had no effect on the possum CCI reduction ($F_{1,26}$ = 0.0014, P = 0.97 and $F_{1,27}$ = 2.69, P = 0.11, respectively), but the possum reduction decreased with increasing rat abundance (slope = −0.03303, SE_{slope} = 0.1490, t_{28} = 2.12, P = 0.03). For cluster sowing, the only two lines on which 100% reduction in possum CCI was not achieved had high rat indices. For broadcast sowing, there were some poor reductions even at moderate rat CCIs.

Operational RTCI and WaxTag® monitoring conducted by DOC 6 months after the aerial 1080 baiting was consistent with the CCI evidence above that cluster and broadcast sowing had had a similar outcome. The 30-cm-raised-set RTCI for one of the cluster-sown blocks was 2 ± 2% (Block 1; n = 8 traplines), similar to the 3 ± 2% recorded in one of the broadcast-sown blocks (Block 2; n = 9). The WaxTag Bite Mark Index (BMI) for cluster-sown Block 4 (4 ± 3%; n = 4) was similar to that in broadcast-sown Block 4 (2 ± 2%, n = 10) and in the broadcast-sown main block north of our study sites (3 ± 2%, n = 6).

Sub-trial 2: Broadcast vs strip sowing

The average reduction in possum CCI per block was 70.6 ± 11.0% (SEM) for the broadcast treatment, 68.0 ± 4.2% for the 130-m-FPS treatment, and 23.8 ± 10.4% for the 180-m-FPS strip treatment (Fig. 1C). There was weak evidence that the difference between sowing treatments was real ($F_{2,3}$ = 7.74, P = 0.07). Comparison of the two strip-sown treatments provided weak evidence of a lesser reduction in possum activity at the wider 180-m FPS ($F_{1,2}$ = 15.33, P = 0.06).

There was no significant effect of the pre-control possum CCI when compared with the possum reduction across the treatments ($F_{1,45}$ = 0.83, P = 0.37) nor any effect with the pre-control mouse CCI ($F_{1,46}$ = 1.67, P = 0.20), but a significant combined effect of pre-control rat CCI ($F_{1,47}$ = 4.29, P = 0.04) and sowing treatment ($F_{2,3}$ = 16.51, P = 0.02). High rat interference on CCIs pre-control tended to result in lower possum reductions under all treatments.

5.1.2 Whanganui: Rats

Rat abundance varied considerably between blocks before control, with the mean of the 7-day-CCI for each block being 38.9 ± 9.2% (SEM; range of block averages 9.7–99.3%). CCIs were higher in the northern study area (66.9 ± 8.2%) than along the Whanganui River (20.2 ± 7.5%), the inverse of the pattern for possums.

Sub-trial 1: Broadcast vs cluster sowing

The overall reduction in rat CCIs was 97.9 ± 1.8% (SEM) (broadcast 95.9 ± 2.9%, cluster 99.9 ± 0.1%; Fig. 1B). There was no significant difference in the CCI reduction between sowing treatments (t_2 = 0.9503, P = 0.44), and too little variation in kill to explore covariance. Similarly, there was no difference in post-control tracking rates for rats (Table 2), with a 96% reduction in the percentage of tunnels tracked.

Table 2 Percentages of tracking tunnels tracked by rats, mice, and stoats before and after control, for each treatment and overall in Whanganui National Park, September–December 2009

Treatment	No. tunnels	Percentages of tunnels tracked					
		Rat		Mouse		Stoat	
		Pre-	Post-	Pre-	Post-	Pre-	Post-
Sub-trial 1							
Cluster	54	54	4	6	0	0	0
Broadcast	54	74	2	6	0	0	0
Sub-trial 2							
130-m strip-sown	54	28	2	20	15	0	0
180-m strip-sown	54	20	4	11	17	0	0
Broadcast	54	56	0	13	0	0	2
Overall	**270**	**46**	**2**	**11**	**6**	**0**	**0**

Sub-trial 2: Broadcast vs strip sowing

The overall tCCI reduction was 86.6 ± 7.7% (SEM) (broadcast 100.0 ± 0.0%; 130-m-FPS strip 61.3 ± 8.0%, 180-m-FPS strip 96.5 ± 2.4%; Fig. 1D). However, despite the large size of these differences, there was only weak evidence of a significant treatment effect ($F_{2,3} = 5.83$, $P = 0.09$), the lack of significance again reflecting large variation in the CCI reductions between lines. None of the pre-control indices for rats, possums or mice had any significant effect on the reduction in rat index. The post-control tracking rates for rats (Table 2) were consistent with total removal of rats in the broadcast treatment and large but not total reduction in the two strip-sown treatments.

5.1.3 Whanganui: Other species and ancillary sightings

Mice

The overall CCI for mice increased from 4.2% to 14.9% (Table 3), with increases recorded in most blocks. As the increase was too rapid to reflect reproductive increase, the increases were attributed to behavioural change in response to removal of rats and possums, and no attempt was made to analyse these increases in CCI in relation to the aerial 1080 baiting.

There was 43% overall decline in tunnel tracking rates, but with no mouse tracking recorded post-control in any of the broadcast- or cluster-sown blocks (Table 2). The reason for the disparity between post-control mouse tracking rates (0%) and CCIs (27%) for the cluster-sown blocks is not known.

Stoats

Stoat bite marks were recorded on three chew cards before 1080 baiting, but none afterwards. No tracking tunnels detected stoats before 1080 baiting, but one tunnel in a broadcast-sown block was tracked afterwards.

Table 3 Chew Card Indices (CCI) for mice before and after control, for each treatment and overall, in Whanganui National Park, September–December 2009

Treatment	No. cards	Mouse CCI (%)	
		Pre-	Post-
Sub-trial 1			
Cluster	252	3	27
Broadcast	252	5	18
Sub-trial 2			
130-m strip-sown	252	3	17
180-m strip-sown	252	4	11
Broadcast	252	7	1
Overall	**1260**	**4**	**15**

Ancillary sightings

After the aerial 1080 baiting, 79 possum and 9 rat carcasses were found during post-control monitoring (Appendix 4). No birds were found dead after poisoning. For the cluster- and broadcast-sown blocks similar numbers of robins and tomtits were observed before and after baiting (species combined totals of 72 and 69 respectively). For the strip-sown blocks, only half as many were sighted afterwards (species combined totals of 52 and 25 respectively).

5.2 Cascade trials

5.2.1 Cascade: Possums

Possum abundance was low before control, with a mean 7-day- CCI of 23.7 ± 6.7% (SEM; range of block averages 0.0–69.7%; Table 4). There were fewer possums at higher elevations (estimated 0–2% RTCI), but moderate densities at lower elevations (estimated 10–15% RTCI). As the 7-day pre-control indices were very low, the reductions in possum abundance were compared using the CCI recorded for the 45–100-day interval between the pre- and post-control surveys as the pre-control measure (Table 4).

Table 4 Possum Chew Card Indices (CCI) recorded in pre-, mid- and post-control surveys in 11 blocks at Cascade Valley, South Westland. The reductions in the Poisson-transformed 7-day CCI are shown, along with the relative reductions calculated similarly but using the mid-CCI recorded in the interval between the pre- and post-control surveys as the estimate of the pre-control abundance. High-elevation blocks are marked with (H) and low-elevation with (L). FPS = flight path spacing; PFI = prefeed interval

Sowing method	FPS / PFI	Pre- 7-day CCI (%)	Post- 7-day CCI (%)	Mid- 100-day CCI (%)	% Reduction in 7-day tCCI	Relative reduction (mid- to post-tCCI) (%)	RTCI (%)
'Same-day prefeed' trial							
Cluster	100 m / 0 day (H)	11.8	0.0	14.7	100.0	100.0	-
Cluster	150 m / 0 day (H)	8.3	0.0	22.9	100.0	100.0	-
Cluster	100 m / 0 day (L)	37.1	52.8	69.4	−61.6	36.7	2.2
Cluster	150 m / 0 day (L)	69.7	50.0	88.9	41.9	68.5	8.6
'Cluster vs broadcast' trial							
Cluster	100 m / 9 day (H)	8.3	0.0	28.6	100.0	100.0	-
Cluster	150 m / 9 day (H)	2.9	2.8	31.3	2.8	92.5	-
Cluster	100 m / 9 day (L)	31.4	5.6	76.5	84.9	96.0	3.4
Cluster	150 m / 9 day (L)	35.3	5.6	65.7	86.9	94.7	2.2
Broadcast	100 m / 9 day (H)	0.0	0.0	5.6		100.0	-
Broadcast	100 m / 9 day (H)	5.6	0.0	35.3	100.0	100.0	-
Broadcast	100 m / 9 day (L)	55.9	23.5	52.8	67.2	64.2	2.4
Overall		**23.7**	**12.7**	**44.9**	**49.7**	**77.2**	**-**

For the blocks with a 9-day PFI, there were similarly large reductions in possum interference on chew cards in all the cluster blocks, and in the two high-elevation broadcast blocks, but only a modest reduction in the low-elevation broadcast block. In the same-day trial, there were total reductions in the two high-elevation blocks, but only modest reductions in the two low-elevation blocks.

RTCI trapping of the low-elevation blocks 6 weeks after poisoning indicated similar residual abundance in four blocks (range 2.2–3.4% RTCI) but a substantially higher RTCI (8.6%) in the 150-m-FPS same-day block (which had the highest pre-control CCI).

Post-operational RTCI monitoring was also conducted in August–September 2010 by DOC in other parts of the larger 26 000-ha operational area outside of the trial blocks. An RTCI of zero was recorded on 27 10-trap traplines run for 2 nights.

5.2.2 Cascade: Other species and sightings

Rats

The rat 7-day CCIs were low before control (3.6 ± 1.8%), with rats detected in only four of the blocks (max. = 17.6%). Using the 'mid' CC data from between the pre-and post-control surveys, the mean 45–100-day CCI was 8.9 ± 4.0% (max. = 36.1%), with rats detected in five blocks.

After control, rats were detected in three blocks, but this included two blocks (with one detection in each) in which no rats had been detected before control. Of the five blocks with rats confirmed present before control, only one (one of the same-day trial blocks) had rats present after.

Mice

Mouse abundance was similar in all blocks (Table 5), and was markedly lower after poisoning, with a total reduction in the three broadcast blocks.

Table 5 Numbers of chew cards marked and mice Chew Card Indices (CCI) before and after control, for each treatment and overall. FPS = flight path spacing; PFI = prefeed interval

Treatment		No.	Mouse CCI (%)	
	FPS / PFI	cards	Before	After
Broadcast	100 m / 9 day	106	31.1	0.0
Cluster	100 m / 9 day	72	48.6	4.2
Cluster	150 m / 9 day	69	47.8	2.9
Cluster	100 m / 0 day	69	34.8	4.3
Cluster	150 m / 0 day	69	47.8	14.5
Overall		**385**	**41.0**	**4.7**

Stoats

Two stoat detections were recorded before control (one in each of two cluster blocks). One was recorded afterward, in a different cluster-sown block.

Ancillary sightings

During post-control monitoring nine possums, one rat, one stoat, and two deer were found dead, presumably poisoned (Appendix 5). Fewer sightings of live deer were recorded after control than before.

No native birds were found dead, but two introduced birds were (both blackbirds; Appendix 5). Similar numbers of kea were seen before and after control (14 vs 15 respectively), and more kākā were seen after (10 vs 19) but fewer tomtits were seen afterwards (65 vs 36).

5.3 Maruia trials

5.3.1 Maruia: Possums

Possum abundance indices varied widely between blocks before control, with the mean of the 7-day- CCIs being 58.4 ± 5.4% (SEM; range of block averages 8.3–97.2%). In the four 'rat interference' trial blocks, the mean CCI of 88.7% was correlated to a mean ground-set RTCI of 18.1%. An RTCI of 5% equates to a density of 1 possum/ha (Ramsey et al. 2005), which suggests that densities in the area were of the order of 3–4 possums/ha.

For all but one of the 17 blocks with an interval of at least 5 days between prefeeding and toxic baiting, no possums were detected after control, and only a single possum was detected in the exception (Table 6). Clearly total or near-total reductions were achieved regardless of sowing method, sowing rate, or prefeed interval, even when sowing rates as low as 167 g/ha of toxic bait were cluster sown.

All of the 31 radio-collared possums confirmed alive in the 'rat interference' trial blocks on the day toxic bait was cluster sown were found dead. All 18 of those fitted with radio-collars with 'time-of-death' recording capability appeared to have died within one day of the toxic bait being sown, with the first ceasing movement at 2105 hours, and the last at 1145 hours the next day. This equates to 3–18 h (average ~ 9 h) after sunset (1800 hours).

Where prefeed and 1080 bait were sown on the same days, outcomes varied widely. There was no apparent reduction in CCI at 150-m FPS, but a total reduction at 125-m FPS, and an 81% reduction with the 100-m FPS. The difference between FPS is statistically significant (Log Linear Analysis, $G^2 = 60.3$, d.f. = 2, $P < 0.001$).

5.3.2 Maruia: Rats

Rat abundance indices before control were moderate, with a mean 7-day-CCI of 43.5 ± 4.8% (SEM; range of block averages 11.1–90.9%).

As with possums, total or near-total reductions were achieved regardless of sowing method, sowing rate, or prefeed interval in the 17 blocks with an interval of at least 5 days between prefeeding and toxic baiting (Table 6). In the main trial, the only rat detection recorded after control was in the cluster-sown block with the widest FPS (150 m) and the longest PFI (30 days).

Also, as with possums, outcomes varied widely where prefeed and 1080 bait were sown on the same day, but in a converse pattern. There was only a modest reduction (24%) at the 100-m FPS (and highest sowing rates) but high reductions at the two lower sowing rates (100% and 98% for the 125-m and 150-m FPS respectively). The difference between FPS is significant (Log Linear Analysis, $G^2 = 75.6$, d.f. = 2, $P < 0.001$).

5.3.3 Maruia: Mice

Mouse abundance indices before control were similar to those for rats, with a mean 7-day-CCI of 49.9 ± 5.7% (SEM; range of block averages 9.1–91.7%). However, before control, mouse CCIs were negatively correlated with rat CCIs ($y = -0.86x + 0.87$, $r^2 = 0.53$, d.f. = 18, $P < 0.001$).

As with possums and rats, total or near-total reductions were achieved regardless of sowing method, sowing rate, or prefeed interval in the 13 main trial blocks with an interval of at least 5 days between prefeeding and toxic baiting (Table 6). The most post-control mouse detections per block (3) were recorded in the cluster-sown block with the closest FPS and highest cluster sowing rate, and one detection was recorded in a broadcast block.

In the ‘rat interference’ trial, pre-control mouse CCIs and the reductions in mouse tCCI varied widely (2–100%). The highest post-control mouse CCI and lowest tCCI reduction were recorded in the block with the highest rat index before control.

In the same-day trial, only moderate or low mouse reductions were achieved, with little or no reduction at the widest FPS (Table 6).

5.3.4 Maruia: Other species, ancillary sightings and bait acceptance

Stoats

In total, only seven stoat detections were recorded before control (CCI = 1.0%). None were detected afterward.

Ancillary sightings

During post-control monitoring in the main and same-day prefeed trials six possums, one rat, two pigs and four deer were found dead, presumably poisoned (Appendix 6). There were four sighting of live deer before poisoning, but none afterwards, whereas for pigs one was seen before, and 17 afterward. In the ‘rat interference’ trial (which was much more intensively worked) a further 11 possums, eight rats, one mouse, and one cat were found dead. No native birds were found dead but two blackbird carcasses were found in the rat interference blocks.

Table 6 Pre- and post-control 7-day chew-card indices (CCIs) of possum, rat, and mouse abundance, and the percentage reduction in Poisson-transformed CCIs, for each of 20 110-ha blocks at Maruia. The sowing method, flight path spacing (FPS), and the interval between prefeeding and toxic baiting (PFI) are shown with each sub-trial listed separately

		Possum			Rat			Mouse		
Sowing method	FPS / PFI	Pre-control CCI (%)	Post-control CCI (%)	% reduction	Pre-control (%) CCI	Post-control CCI (%)	% reduction	Pre-control CCI (%)	Post-control CCI (%)	% reduction
Main trial										
Cluster	100 m / 5 day	65.7	0.0	100	62.9	0.0	100	48.6	8.3	87
Cluster	125 m / 5 day	65.7	0.0	100	42.9	0.0	100	54.3	0.0	100
Cluster	150 m / 5 day	66.7	0.0	100	80.6	0.0	100	16.7	0.0	100
Cluster	100 m / 14 day	47.2	0.0	100	27.8	0.0	100	66.7	0.0	100
Cluster	125 m / 14 day	54.3	5.6	93	37.1	0.0	100	51.4	0.0	100
Cluster	150 m / 14 day	33.3	0.0	100	38.9	0.0	100	83.3	0.0	100
Cluster	100 m / 30 day	17.1	0.0	100	48.6	0.0	100	48.6	0.0	100
Cluster	125 m / 30 day	28.1	0.0	100	37.5	0.0	100	78.1	0.0	100
Cluster	150 m / 30 day	36.1	0.0	100	22.2	2.8	89	77.8	5.6	96
Broadcast	100 m / 26 day	67.6	0.0	100	41.2	0.0	100	58.8	0.0	100
Broadcast	100 m / 26 day	61.1	0.0	100	27.8	0.0	100	69.4	0.0	100
Broadcast	100 m / 26 day	77.8	0.0	100	19.4	0.0	100	47.2	0.0	100
Broadcast	100 m / 26 day	8.3	0.0	100	11.1	0.0	100	91.7	2.9	99
'Rat- interference' trial'										
Cluster	100 m / 14 day	94.3	0.0	100	40.0	0.0	100	3.2	0.0	100
Cluster	100 m / 14 day	97.2	0.0	100	36.1	0.0	100	12.5	1.5	89
Cluster	100 m / 14 day	84.4	0.0	100	53.1	1.6	98	6.9	1.6	77
Cluster	100 m / 14 day	78.8	0.0	100	90.9	0.0	100	6.2	6.1	2
'Same-day-prefeed' trial										
Cluster	100 m / 0 day	47.1	11.1	81	41.2	33.3	24	55.9	25.0	65
Cluster	125 m / 0 day	69.4	0.0	100	27.8	0.0	100	66.7	30.6	67
Cluster	150 m / 0 day	66.7	66.7	0	90.9	5.6	98	9.1	8.3	9
Overall average		**58**	**4**	**94**	**44**	**2**	**95**	**48**	**5**	**85**

More tomtits were seen before control than after (64 vs 15 respectively), and more robins were seen before control than after (196 vs 77). Although not recorded in detail, there were numerous observations of kākāriki and fantails after poisoning.

Bait acceptance

At least some cereal, carrot or apple bait was eaten at 41% of the 160 baited sites. Animals were also detected by chew cards at some sites where no bait was eaten (two possums, 12 rats, nine mice). There was only one (2%) of 49 sites where baits had been eaten but where there was no CC detection.

Possums were strongly averse to cereal bait, as there was very little consumption of either cereal bait type at sites where possums were detected by chew cards (Table 7). In contrast, all of the apple bait was consumed at most possum detection sites in both blocks and likewise for carrot in one of blocks (Table 7). The reason for the contrasting take of carrot and apple in one block is not known. There is some suggestion that the aversion to cereal was lower in one of the blocks where an aniseed lure was used rather than the cinnamon lure used in the poisoning operation.

Table 7 Maruia, in August 2010. Data are the mean percent take of each bait type, separately for each, and for sites with and without a chew card (CC) detection of possums

FPS / PFI	No. sites	Cinnamon-lured RS5	Aniseed-lured RS5	Apple	Carrot
No possum CC detection at site					
100 m / 0 day	53	2	5	2	2
150 m / 0 day	59	0	0	2	2
Possum CC detection at site					
100 m / 0 day	27	7	26	90	2
150 m / 0 day	21	0	0	90	90

5.4 Sowing buckets

In the Whanganui trial, cluster sowing was conducted using the sowing bucket used in previous trials. It did not have GPS control of cluster release, so the spacing of clusters was achieved by flying at, or close to a designated speed.

In the Maruia and Cascade operations, a purpose-designed cluster bucket was used (for the first time) with GPS control of cluster release. This enables a constant sowing rate regardless of helicopter speed. As previous research (Nugent et al. 2011) had shown that use of a broadcasting spinner increased bait fragmentation rates, we presumed there would be far less bait fragmentation with the cluster buckets. However, video footage of cluster releases at Cascade indicated that large numbers of fragments were still being sown in some clusters, specifically the first few clusters sown after the bucket had been refilled (Fig. 2A).

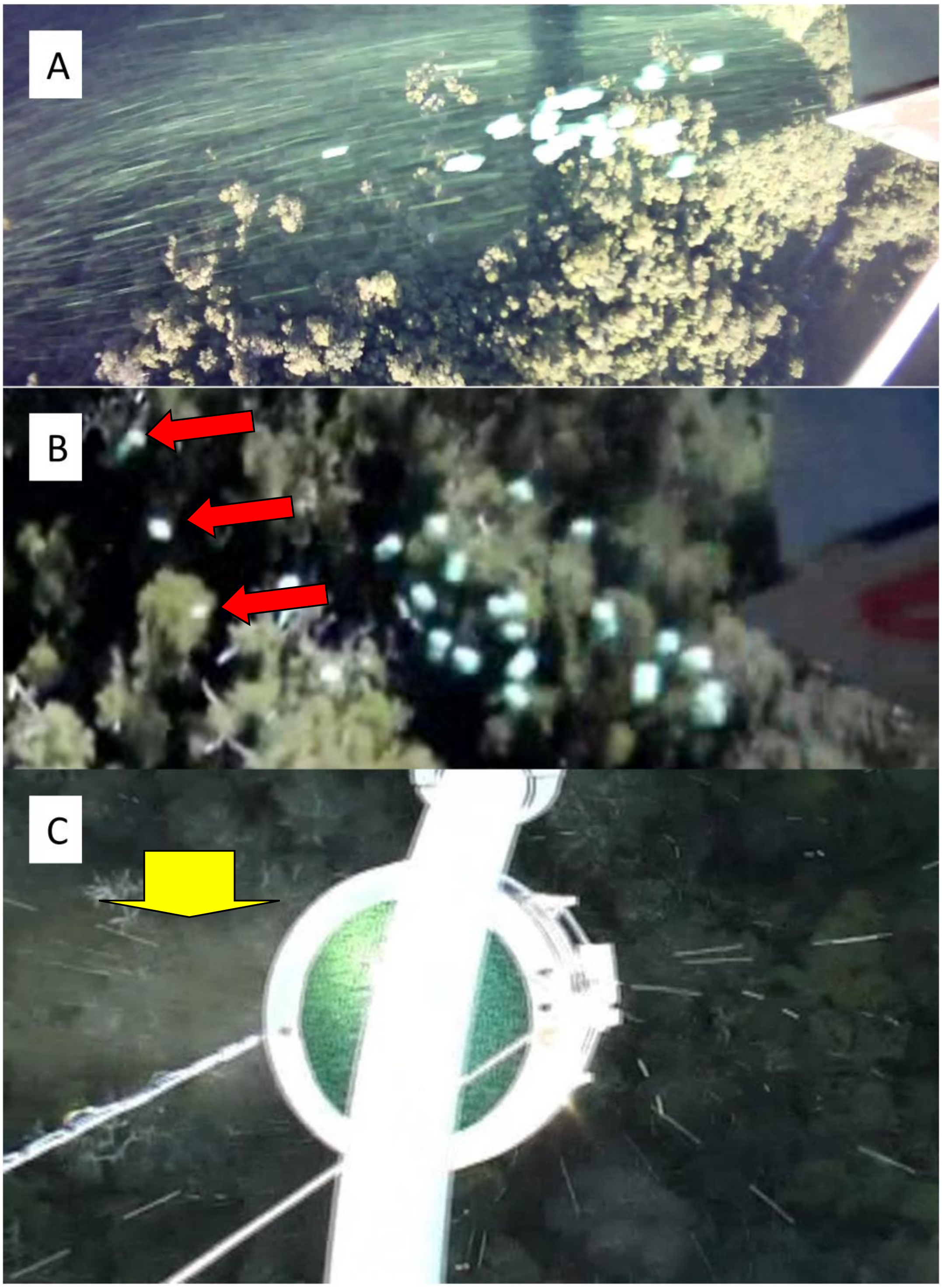

Figure 2 Frame-capture images from video footage of aerial baiting during the Cascade operation, May 2010, showing: (A) the large number of bait fragments/dust released with the first 3–5 clusters sown at the start of a new sowing run after bucket reloading; (B) Small baits (red arrows) becoming separated from the main group of baits within a cluster; and (C) the dust cloud of very fine fragments (yellow arrow) produced during broadcast baiting.

In subsequent clusters (the great majority of each sowing run) there were far fewer, or no very small fragments, but there were indications that medium-sized baits were being separated from larger bait by the slipstream (Fig. 2B). With broadcast sowing, there was a more or less continuous dust cloud produced during sowing (Fig. 2C).

6 Conclusions

6.1 Cluster vs broadcast sowing

Overall the broadcasting treatments for the three operations within which our trials were embedded had varied possum-control outcomes ranging from moderate (Whanganui) to very good (Maruia). Including previous trials (Table 8), aerial cluster sowing has matched or bettered broadcast sowing in five of the six trials completed by 2010, and hand-sown clusters were as effective as broadcast sowing in an initial trial in 2007.

The results confirm that the number of baits sown is not, within reason, a crucial determinant of control success. At Maruia, in the main trial, we recorded 100% reduction in CCI for possums, rats, and mice using just 167 g/ha of toxic bait (150-m-FPS treatment) when the PFI was 5 days or 14 days, and only slightly smaller reductions of rats and mice when the PFI was 30 days. That sowing rate equates to about 28 toxic baits per hectare. As we are confident (from trapping) that some parts of these study areas would have had more than 5 possums/ha at commencement of operations, and CCIs for rats and mice were moderately high, these very good reductions were achieved despite there being as few as two or three baits available per animal. That indicates that the current best-practice sowing rates of 2–3 kg/ha (167–500 baits/ha depending on bait size) deliver a far greater number of baits per animal than is acutally required to kill them, if they were able to find them. We infer (as previously) that local bait density is what is important; i.e. that, for possums in particular, a percentage of animals need to encounter and consume more than a single bait within a period of an hour or so. That therefore requires a high local density of bait. At Maruia, the conventional (12-g baits) broadcast sowing treatment delivered 0.02 baits/m^2 over the whole area, whereas cluster sowing (6–8-g baits) delivered higher densities of 0.08–0.12 baits/m^2 but into only 3% of the area. The outcomes indicate that possums, rats and mice were all able to easily find the small cluster-baited areas, facilitated, we believe, by the open nature of the understorey. It seems clear from the radio-telemetry data that possums in this area were ranging widely (the radio collared possum carcasses recovered were found, on average, 132 m from where the possum was captured) and that all of them encountered a bait cluster within a few hours of nightfall on the day bait was sown.

Extending that inference to the Cascade trial, the more variable reductions (with both broadcast and cluster sowing) achieved there could be attributed to the large areas of dense waist-high crown fern. Intuitively, near-total coverage of an area with dense ground cover would increase the time required to find a first bait by reducing the proportion of the ground area useable by possums, increasing the likelihood that baits might be hidden under foliage even in possum-accessible areas, and perhaps also substantially reducing the percentage of time possums spend at ground level. The effect of those factors on the time required to find a second bait (where the first bait contained only a sublethal dose of 1080) is likely to be even greater. A key point is that the time required to find a first bait is not likely to greatly affect the lethality of first encounters (unless the period is extended to multiple days and increases the chance of a rain event affecting bait toxicity), but for the subset of encounters that are sublethal the effect of a reduced encounter rate (because of bait density or ground cover or other influence on foraging behaviour) appears likely to be substantial. If that logic is correct, the implication is that efforts should be made to ensure the lethality to possums of first encounters where ground cover is particularly dense. Simplistically that suggests use of larger baits (e.g. 12 g cf. 6–8 g) should be favoured in areas with dense ground cover, but if 6–8-g baits are adequately lethal the issue becomes one of the fragmentation rate. Nugent et al. (2011) show that broadcast sowing can sometimes produce large numbers of small bait fragments (< 2 g) in size. If the *percentage* of baits that produce small fragment is the same regardless of whether baits are 6–8 g or 12 g, then for any given sowing rate, the density of individually lethal doses will be lower for the larger baits. Possums that first encounter a sublethal fragment will then take longer to find a subsequent lethal dose. Thus, although counter-intuitive, it is possible that use of baits far larger than the minimum lethal size may be counterproductive when the same sowing rates (by weight) are used.

Ground cover in the Whanganui trial areas was intermediate, with open ridge and ridge tops but sometimes dense fern cover on the steep valley sides. It is therefore unlikely that the moderate possum reductions achieved with broadcast sowing in both sub-trial areas (Fig. 1) compared to the other trials (Table 8) are attributable to a ground-cover effect. Adding to that, cluster sowing was more effective against possums but both were equally highly effective against rats (Fig. 1). We speculate that these outcomes could be a consequence of bait fragmentation, possibly through use of a large-diameter spinner to achieve wide lateral bait distribution enabling use of a 240-m FPS for the broadcast sowing treatment, or simply through the bulk-handling procedures used by this operator. Such fragmentation would have little effect on lethality to rats (lethal dose = 0.1 g of 0.15% 1080 bait; Innes et al. 1995) but would affect possum kill for the reasons outlined above.

Overall, the three trials reported here provide further evidence that cluster sowing can achieve good possum and rat kills using ~90% less bait than conventional broadcast baiting. A meta-analysis of the data presented in Table 8 indicates similar or higher efficacy of cluster sowing across the 7 reported studies compared to broadcast sowing (Figure 3), when compared as side-by-side methods for controlling possums (NB: all operations achieved > 85% reduction in possum relative abundance, with the exception of broadcast sowing in the Whanganui study and cluster sowing in the Isolated Hill study). That lends weight to our working hypothesis that bait fragmentation is a major contributor to possum survival, and that both prefeeding and overbaiting in conventional broadcasting function primarily to overcome this problem by increasing the encounter rate. Video footage of broadcast sowing (Fig. 2C) clearly showed production of very small fragments (dust) but lacked the resolution needed to identify medium-sized fragments in the 1–3 g range. From cluster-sowing video footage, it was clear that some fragmentation occurred during transport and the loading of the bucket (Fig. 2A) but also that any small baits were likely to become separated from the main bait cluster. The cluster baiting reduces but does not eliminate fragmentation.

6.2 Strip vs broadcast sowing

In the Whanganui trial, strip sowing resulted in only modest reductions in possum CCIs. At 130-m FPS, the outcomes were similar to those achieved by broadcast sowing, but at 180-m FPS the reductions did not appear to be as good. Assuming that the strips of bait were ~40 m this suggests that unbaited strips 140 m wide are too wide, with some possums living entirely within those unbaited strips and not ranging widely enough to encounter bait. However, that did not appear to be the case for rats.

The density of bait within the baited strips (baits of 6–8 g; 0.28–0.39 baits/m^2) was much higher than the average density of bait (12 g) delivered by broadcasting (0.02 baits/m^2), and the rate of bait fragmentation should have been lower given the slow spinner speed used. The poorer (or at best equal) performance against possums is therefore puzzling. However, given that broadcast sowing was also poor against possums in both sub-trials, it is possible that some unquantified factor (such as easily fragmented bait) had a far greater influence on possum survival than sowing method. We therefore suggest the trial be repeated.

6.3 Same-day sowing

The results of the same-day trials at Maruia and Cascade will be reported in full elsewhere. However, some key points are relevant.

At Maruia, total reductions in possum and rat CCI were achieved at 125-m FPS. That indicates that the underlying concept has merit. In that particular block, most possums and rats will have encountered prefeed first and then gone on to eat a fully lethal dose when they encountered toxic bait. The much poorer reduction in possums at 150-m FPS at Maruia is therefore puzzling. One possible explanation is that at such spacing many more possums were only encountering toxic bait at the extreme edges of their home range rather than well within it, and this somehow affected their foraging behaviour – where clusters fell at the edge of a possum's home range, it may have been more inclined to search back within its home range for bait (and found more prefeed) than to search further afield. For rats, which we argue seldom require multiple encounters to eat a lethal dose but which do require familiarisation with bait, the poorest reduction was at the closest spacing (100-m FPS), with near-total reductions at wider FPSs. A possible explanation is that at the closest spacing rats encountered toxic bait 'too soon' after first encountering prefeed, so that they had not had sufficient time to become familiarised with cereal bait as a desirable food.

At Cascade, there were total reductions in possum CCI in both the 100-m and 150-m FPS blocks at high elevation, where pre-control possum numbers were low. At low elevation the reductions were moderate, possibly reflecting denser ground cover there.

The bait acceptance monitoring at Maruia indicates that in the two same-day blocks where there were surviving possums, all of those possums had encountered and eaten bait, but not enough to kill them. In the third block, however, all detectable possums had found enough bait to kill them. As the physical and size distributions of prefeed and toxin should have been identical apart from the size of unbaited area between bait clusters, and it seems unlikely that possums in adjacent blocks would differ greatly in their willingness to eat bait, the difference between blocks appears to reflect some difference in encounter rate. That implies that even with cluster sowing some possums are still having sublethal first encounters. That in turn implies that bait fragments are still a problem with cluster sowing, as illustrated in Fig. 2.

Whatever the explanations, and despite the highly variable outcomes, we consider that the trial challenges accepted wisdom about how prefeeding works. Specifically, it demonstrates clearly that extended familiarisation with non-toxic bait is not essential in achieving near total kills of possums or rats.

Table 8 Summary of possum control outcomes achieved in the seven trials comparing cluster and broadcast sowing that were completed between 2007 and 2010. All toxic baiting was conducted using 0.15% 1080 cereal baits. Experimental treatments not included in the table are (i) non-aligned prefeed (Landsborough 2009); (ii) strip sowing vs cluster sowing (Whanganui 2010); (iii) same-day prefeed and toxic sowing (Maruia and Cascade 2010). FPS = Flight Path Spacing, PFI = Pre Feed Interval, AS = Aligned Strip prefeeding, BC = Broadcast. The CCI Redn Index is the percent reduction in Poisson-transformed Chew Card Index. The RTCI Index (Residual Trap-Catch Index) is a measure of post-control abundance

Operation, year (Source)	Broadcast	Cluster	Index	Broadcast (%)	Cluster (%)
Whirinaki, 2007 (Nugent et al. 2008)	1.0 kg/ha 2-g W#7 prefeed (BC) 2.0 kg/ha 12-g W#7 toxic 100-m FPS, 5-day PFI	1.0 kg/ha 2-g W#7 prefeed (BC) 0.4 kg/ha 12-g W#7 toxic hand laid 100-m FPS, 5-day PFI	CCI Redn RTCI Redn	99 89	97 89
Molesworth, 2008 (Nugent et al. 2009)	No prefeed 2.5 kg/ha, 6–8-g RS5 toxic 130-m FPS	No prefeed 1.0 kg/ha, 6–8-g RS5 toxic 130-m FPS	CCI Redn RTCI	96 0.9	96 1.1
Landsborough, 2009 (Nugent & Morriss 2010)	1.0 kg/ha 6–8-g W#7 prefeed (BC) 3.0 kg/ha 12-g W#7 toxic 100-m FPS, 5-day PFI	0.5 kg/ha 6–8-g W#7 prefeed (AS) 0.25 kg/ha 12-g W#7 toxic 100-m FPS, 6-day PFI	CCI Redn RTCI	90 1.4	87 2.0
Isolated Hill, 2009 (Nugent & Morriss 2010)	1.0 kg/ha 6–8-g RS5 prefeed (BC) 3.0 kg/ha 6–8-g RS5 toxic 140-m FPS, 12–13-day PFI	0.5 kg/ha 2-g RS5 prefeed (AS) 0.25 kg/ha 6–8-g RS5 toxic 100-m FPS, 12-day PFI	CCI Redn RTCI	88 0.9	73 4.2
Whanganui, 2010 (This report)	1.0 kg/ha 6–8-g W#7 prefeed (BC) 2.0 kg/ha 12-g W#7 toxic 240-m FPS, 6-day PFI	0.5 kg/ha 2-g W#7 prefeed (AS) 0.25 kg/ha 6–8-g W#7 toxic 100-m FPS, 7-day PFI	CCI Redn	56	97
Cascade (excl. PFI = 0), 2010 (This report)	1.0 kg/ha 6–8-g RS5 prefeed (BC) 2.0 kg/ha 6–8-g RS5 toxic 100-m FPS, 9-day PFI	0.5 kg/ha 2-g RS5 prefeed (AS) 0.25 kg/ha 6–8-g RS5 toxic 100–150-m FPS, 9-day PFI	CCI Redn RTCI	88 2.4	96 2.2–3.4
Maruia (excl. PFI = 0), 2010 (This report)	1.0 kg/ha 6–8-g RS5 prefeed (BC) 2.0 kg/ha 12-g W#7 0.15% 1080 140-m FPS, 26-day PFI	0.5 kg/ha 2-g W#7 prefeed (AS) 0.17–0.25 kg/ha 6–8-g W#7 toxic 100–150-m FPS, 5–30-day PFI	CCI Redn	100	99

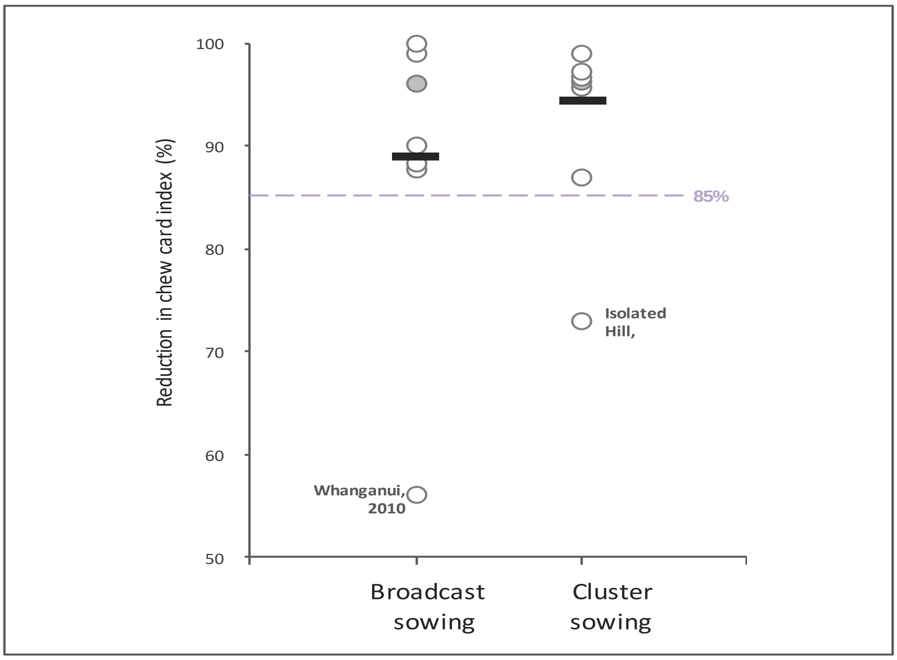

Figure 3 Meta-analysis comparison of reduction in possum relative abundance following 1080 operations (2007-2010), using either broadcast or cluster sowing bait dispersal. Key: Circular symbols represent individual 1080 operations (open symbols; operations with pre-feeding; shaded symbols, single operation without pre-feeding [Molesworth, 2008]). Horizontal bars represent group median values.

6.4 Impact of rat abundance on possum kill

The results of the formal 'rat interference' trial at Maruia will be reported in full elsewhere, but it is clear that pre-control rat abundance had no impact on possum kill in that trial. That contrasts with the Whanganui trial, where in both trials there was statistical evidence of a small rat effect on possum kill regardless of sowing treatment. That result in turn contrasts with the previously reported Isolated Hill trial where there was a negative correlation between pre-control rat abundance and possum reduction under cluster sowing but not with broadcast sowing (Nugent & Morriss 2010).

This difference between trials suggests that there can sometimes be an effect of rat abundance on possum kill, but the effect is idiosyncratic. The Maruia trial suggests the hypothesis that any rat influence will be minimal where possums are ranging widely on the ground and there is little ground cover (making it easy to find multiple baits quickly before they are reduced in size or depleted in number by rats). Conversely, the rat influence would be greater where possums make little use of the ground and baits are hard to find.

6.5 Other species

6.5.1 Rodents and stoats

Over these three trials, rat reductions achieved by cluster sowing were high and matched those for broadcast sowing. At Maruia, the only rat detected after control in the main trial was in the 30-day PFI so may well have been recruited to the population after prefeeding. The similarity of the cluster and broadcasting results suggest that bait fragmentation is a much less important issue for rats than for possums, presumably because even fragments are individually lethal to rats given their small body size.

Indices of mouse abundance are typically suppressed when rat numbers are high, and can therefore increase after aerial poisoning where poisoning removes most rats but few mice, as occurred at Whanganui (Table 3). That makes interpretation of changes in mouse CCIs difficult except where mouse reductions are also high, as occurred at Maruia (Table 6). Nonetheless it is clear that efficacy against mice is highly variable. At Whanganui, a spring operation, large numbers of mice survived. At Maruia, an early-winter operation, few mice survived under conventional (PFI > 0) treatments, with some indication from the rat interference trial that high pre-control rat abundance might result in poor mouse reductions. At Cascade, another early-winter operation, there were large reductions, with broadcast sowing possibly the most effective.

Within each trial, there were too few chew card data to usefully compare the effect of the different treatments on stoats. Overall, across the three trials, there were 12 chew card detections of stoats before control and two afterward suggesting that poisoning had reduced stoat densities. Tracking tunnels were used at Whanganui specifically to obtain pre-poison stoat data, but detected none before control and one afterwards, whereas there were three chew card detections before and none after.

6.5.2 By-kill

Over the three trials, 139 animals were found dead during post-control monitoring, mostly possums (105) and rats (19).

No native birds were found dead, but four blackbirds were. Assuming the density of native birds is of roughly the same magnitude as that of all of the other small vertebrates combined (blackbirds, rats, mice and stoats) and assuming that all of the latter were killed, we would expect native birds to comprise up to half of the small vertebrates found dead if significant numbers of them were killed. Since many of the rats and mice are likely to die underground (in a ship rat pen study using 1080 cereal baits, 74% of rats died in their nests or under cover; Morriss et al. in prep), there was probably a greater chance of finding dead native birds than finding dead rats or mice, yet we found none. There is therefore no indication from these trials that either cluster or broadcast aerial 1080 baiting kills a large proportion of native birds.

The number of tomtits and/or robins seen alive occasionally decreased substantially after poisoning, but without unpoisoned blocks to compare these data with, it is not possible to assess whether the change reflects a change in seasonal observability, change in observer skill, a real but natural reduction in bird numbers, or a poisoning-induced reduction.

However, given no native birds were found dead, we suspect the reductions were seasonal effects in observability as they were most marked at Maruia and Cascade where the post-control monitoring was done in winter. We note that nowhere were the numbers seen afterward reduced to zero. There was no clear evidence of a greater reduction with cluster sowing that with broadcast sowing.

Six deer were found dead in these trials, four in the 27 cluster-sown blocks and two in the 11 broadcast blocks. As the number found dead per block is lowest for cluster sowing there is no indication cluster sowing increases the number of deer killed. That contrasts with the indication from the Molesworth study (Nugent et al. 2009), possibly reflecting the reduced sowing rate used in these trials (250 g/ha cf. 1000 g/ha).

7 Recommendations

Given that, in favourable circumstances, good possum and rat reduction can be achieved with as little as 167 g/ha of 1080 bait, the AHB should begin to use cluster sowing operationally in a sufficient number of areas to test the reliability of the method under a wide range of contexts. Initially, we recommend focussing on areas where possum numbers have already been reduced to low levels by previous control operations. This testing should include:

- Assessing bait fragmentation rates, pre-control possum and rat abundance, and ground cover density as potential determinants of cluster poisoning success
- Exploring further the effect of flight path spacing on the efficacy of cluster sowing in controlling possums and rats.

In addition, we recommend further research to:

- Determine the effect of bait screening on aerial poisoning efficacy (cluster and broadcast) and, in conjunction with this, explore the efficacy of same-day poisoning when every bait is lethal to possums (i.e. well-screened)
- Determine the efficacy of ultra-low cluster sowing for high frequency control of possums and rodents, for both TB and conservation purposes.

8 Acknowledgements

This study was contracted research, carried out for the Animal Health Board. Thanks to the DOC staff who assisted greatly in running these trials, namely Rod Smillie, Daniel Hurley, Miles Gembitsky (DOC Wanganui), Terry Farrell, Mark Martini (DOC Hokitika), Gary Scott, and Pat Dennehy (DOC South Westland). Thanks to Bushwork Contracting (Chris Brausch, Charlie Lim, Natalie Curnow, Ben Peckham, Marcus Bridge, and Nyree Fea), Vector Control Services (Randal Beal, Robbie Blankenstein, and staff) and Landcare staff (Roger Carran, Mike Perry) who carried out the monitoring. Thanks also to Bruce Warburton, Andrew Gormley and Andrea Byrom for reviews of this report, and Christine Bezar and Frank Cross for editing.

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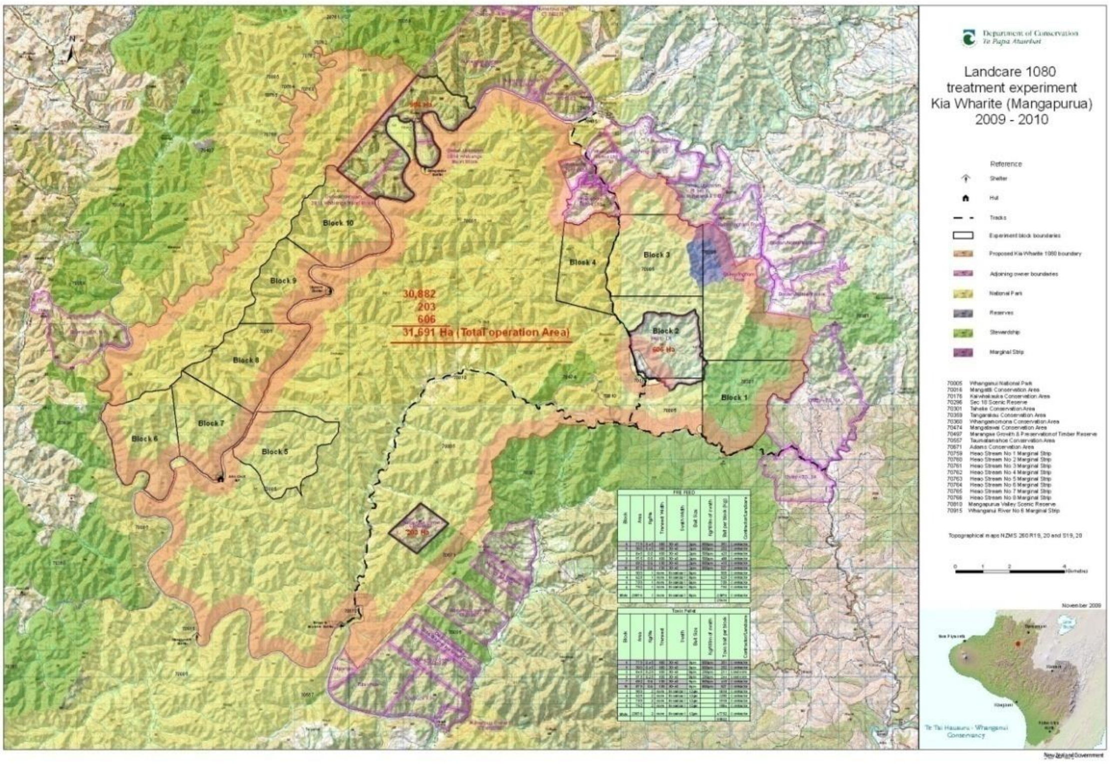
Appendix 1 – Whanganui trial study areas

Whanganui trial study areas, showing: (A) the whole area aerially poisoned by DOC (thick orange line); (B) the Kaiwhaukau Stream blocks used for sub-trial 1; and (C) the Whanganui River blocks used for sub-trial 2.

A.



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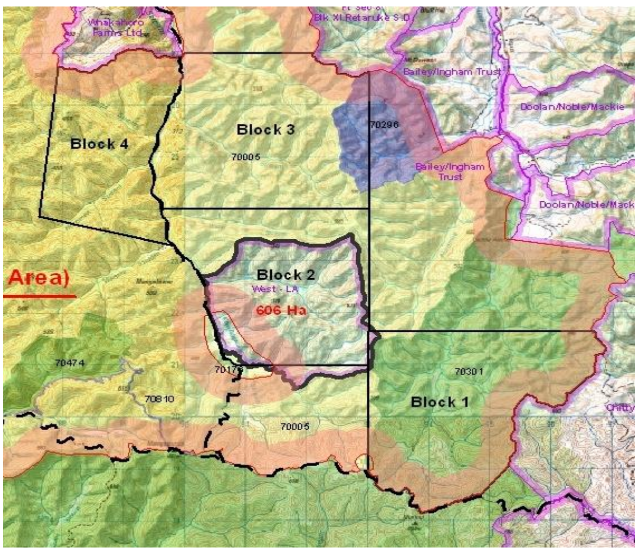

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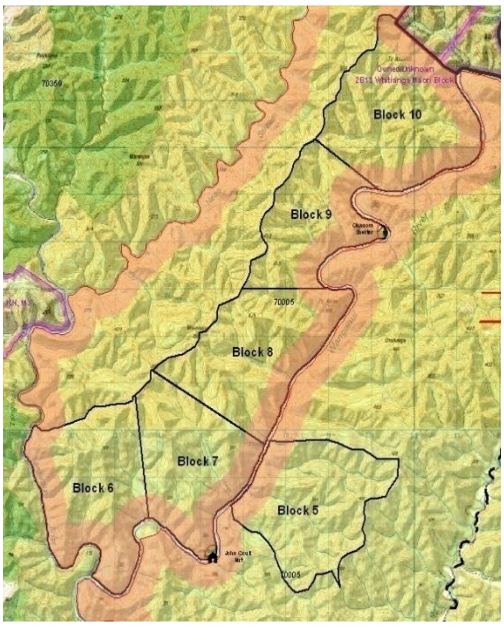
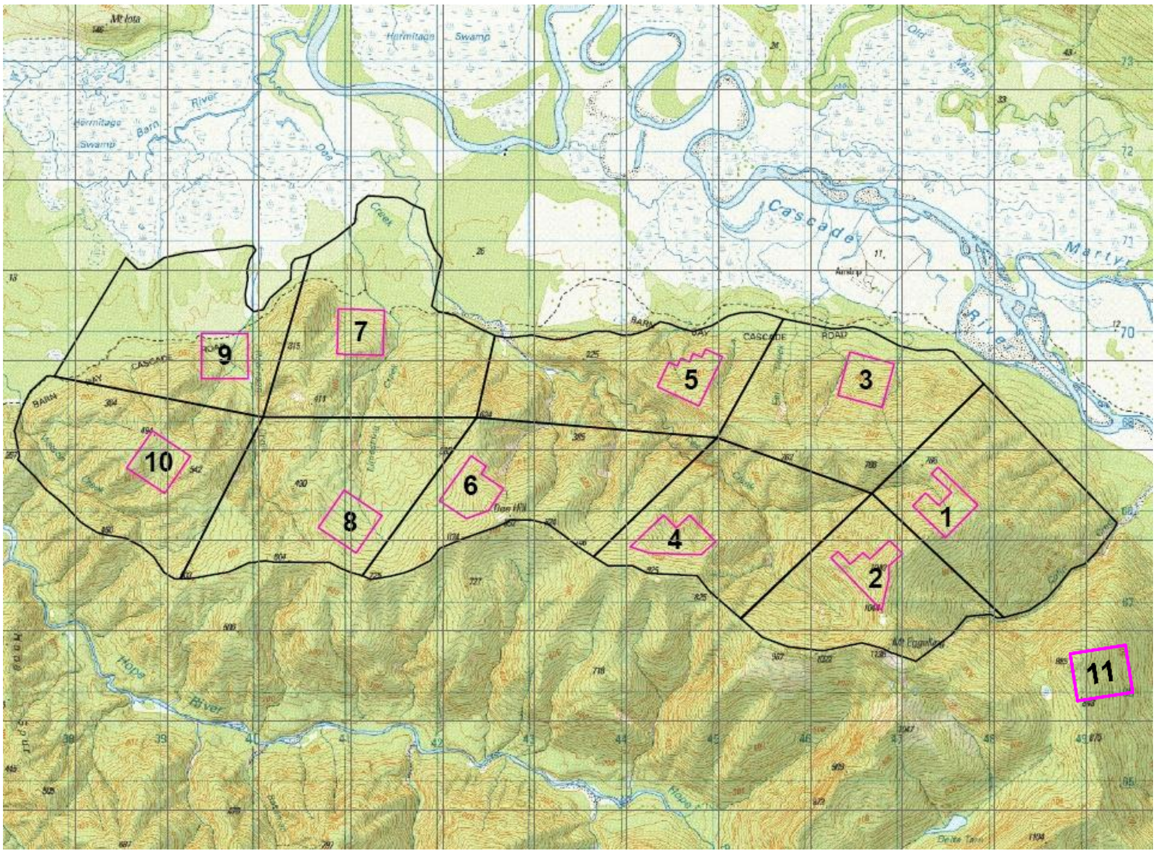


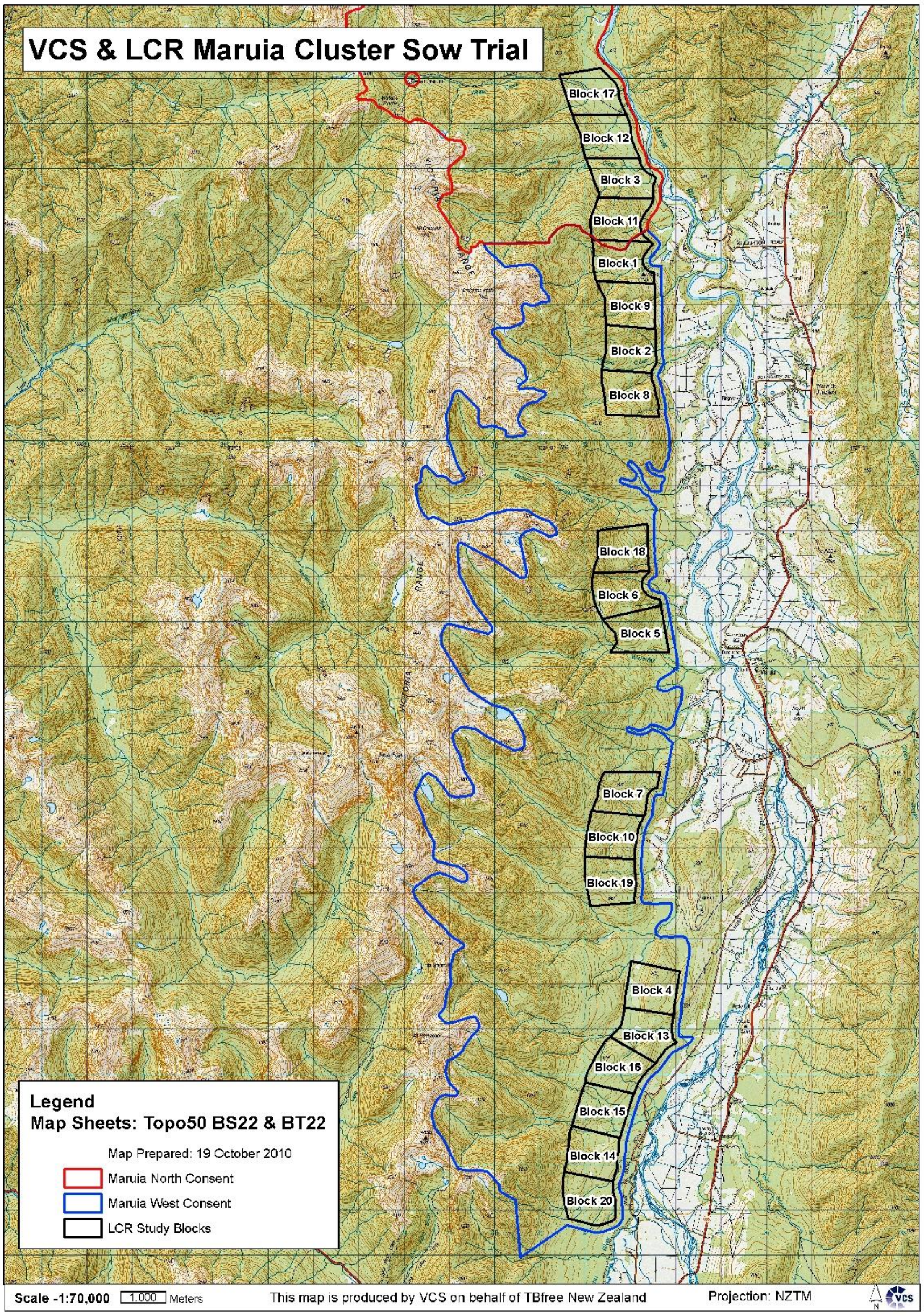
Appendix 2 – Study blocks in the Cascade Valley, South Westland

The pink outlines show the location of the monitoring grids in each block. Broadcast sowing was used in Blocks 5 and 8, and also in the main operational area including where grid 11 was established. For the cluster-sown blocks, FPS = 100 m and PFI = 9 days were used in Blocks 1 and 4, FPS = 100 m and PFI = 0 days in Blocks 6 and 9, FPS = 150 m and PFI = 9 days in Blocks 2 and 7, and FPS = 150 m and PFI = 0 days in Blocks 3 and 10.



Appendix 3 – Operational area at Maruia, Westland

The map shows the location of the trial blocks including the four northern blocks used in Project R-10729: Effect of rat interference on possum kill during aerial 1080 poisoning.



Appendix 4 – Animals observed in Whanganui National Park

Incidental observations of animals seen alive or found dead during monitoring in the Whanganui National Park, before (pre-) and after (post-) aerial 1080 poisoning in November 2009. In addition to the species listed, whitehead, tūī, falcon, grey warbler, bellbird, fantail and bats were observed after poisoning, and a kiwi was also heard (and fresh kiwi probe marks sighted). FPS = flight path spacing

			240-m FPS Broadcast	130-m FPS Strip-sown	180-m FPS Strip-sown	100-m FPS Cluster
Possum	No. found dead	Post-	46	15	14	4
Rat	No. found dead	Post-	7	0	1	1
Deer	No. seen alive	Pre-	0	0	0	2
	No. seen alive	Post-	2	0	0	1
	No. found dead	Post-	0	0	0	0
Pigs	No. seen alive	Pre-	3	2	0	0
	No. seen alive	Post-	0	0	0	0
	No. found dead	Post-	0	0	0	0
Tomtit	No. seen alive	Pre-	22	14	18	16
	No. seen alive	Post-	19	9	8	18
	No. found dead	Post-	0	0	0	0
Robin	No. seen alive	Pre-	19	9	11	15
	No. seen alive	Post-	18	6	2	14
	No. found dead	Post-	0	0	0	0

Appendix 5 – Animals observed in the Cascade Valley, Westland

Incidental observations of animals seen alive or found dead during monitoring in the Cascade Valley, Westland, before (pre-) and after (post-) aerial 1080 poisoning in May 2010. Sightings of species other than those listed were not recorded. PFI = prefeed interval

			Broadcast 9-day PFI	Cluster 0-day PFI	Cluster 9-day PFI
Possum	No. found dead	Post-	2	5	2
Rat	No. found dead	Post-	0	1	0
Stoat	No. found dead	Post-	0	0	1
Deer	No. seen alive	Pre-	2	21	10
	No. seen alive	Post-	2	6	3
	No. found dead	Post-	1	0	1
Tomtit	No. seen alive	Pre-	4	21	40
	No. seen alive	Post-	5	16	15
	No. found dead	Post-	0	0	0
Kea	No. seen alive	Pre-	5	3	6
	No. seen alive	Post-	2	8	5
	No. found dead	Post-	0	0	0
Kaka	No. seen alive	Pre-	2	8	0
	No. seen alive	Post-	6	7	6
	No. found dead	Post-	0	0	0
Blackbird	No. found dead	Post-	1	0	1

Appendix 6 – Animals observed in the Maruia Valley, Westland

Incidental observations of animals seen alive or found dead during monitoring in the Maruia Valley, Westland, before (pre-) and after (post-) aerial 1080 baiting in June 2010. Sightings of species other than those listed were not recorded. Data are pooled for groups of 4–8 blocks (each ~ 110 ha) subject to the same sowing technique and with the same sowing rate of 1080 bait. The animals found dead in the 'Rat Interference' trial (Cluster (RI)) are show separately as a greater amount of fieldwork was conducted in these blocks. NR = not recorded.

			Broadcast 2000 g/ha	Cluster (RI) 250 g/ha	Cluster 250 g/ha	Cluster 200 g/ha	Cluster 167 g/ha
N blocks			4	4	8	4	4
Possum	No. found dead	Post-	0	11	2	2	2
Rat	No. found dead	Post-	1	8	0	0	0
Cat	No. found dead	Post-	0	1	0	0	0
Mouse	No. found dead	Post-	0	1	0	0	0
Deer	No. seen alive	Pre-	1	0	1	2	0
	No. seen alive	Post-	0	0	0	0	0
	No. found dead	Post-	1	0	1	2	0
Pig	No. seen alive	Pre-	1	0	0	0	0
	No. seen alive	Post-	0	0	1	0	16
	No. found dead	Post-	0	0	0	2	0
Tomtit	No. seen alive	Pre-	13	NR	6	20	25
	No. seen alive	Post-	4	NR	1	6	4
	No. found dead	Post-	0	0	0	0	0
Robin	No. seen alive	Pre-	74	NR	37	24	61
	No. seen alive	Post-	13	NR	21	10	32
	No. found dead	Post-	0	0	0	0	0
Blackbird	No. found dead	Post-	0	2	0	0	0