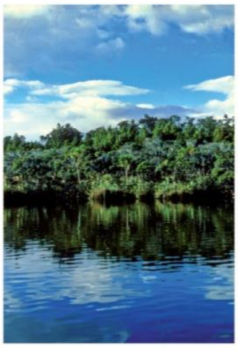

Low-cost aerial poisoning: Comparing the efficacy of clustered and broadcast baiting in two 2009 field trials

Animal Health Board R-10710

Landcare Research
Manaaki Whenua

Low-cost aerial poisoning: Comparing the efficacy of clustered and broadcast baiting in two 2009 field trials

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Summary

Project and Client

- In 2009, Landcare Research conducted two 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 trials were conducted between January and December 2009.

Objectives

To determine and improve the cost-effectiveness of aerial 1080 baiting in controlling possums (and also rodents) when a much smaller quantity of 1080 cereal bait than usual is aerially sown in clusters rather than broadcast, by:

- Comparing, for three experimental treatments (standard broadcast baiting, cluster baiting without prefeed alignment, and cluster baiting with prefeed alignment) applied in the Landsborough Valley, Westland, (1) the reduction in possum, rat, mouse and stoat interference rates on ChewTrack cards and tracking tunnels; and (2) the Residual Trap Catch Indices of possum abundance;
- Comparing, for two experimental treatments (standard broadcast baiting, and cluster baiting with prefeed alignment) applied at Isolated Hill, Marlborough, (1) the reduction in possum, rat, mouse and stoat interference rates on ChewTrack cards; and (2) the Residual Trap Catch Indices of possum abundance.

Methods

- Six blocks were delineated in the Landsborough Valley, S. Westland. Of these, four were aerially broadcast sown with 1 kg/ha prefeed and two were strip-sown with 1 kg/ha prefeed. After 5–6 days, 3 kg/ha 0.15% 1080 cereal bait was broadcast over two of the broadcast prefed blocks, and 0.25 kg/ha of 0.15% 1080 cereal bait was cluster-sown directly over the prefeed flight path in the two blocks with strip-sown prefeed, and with no attempt made to align with the prefeed flight path in the remaining two.
- Four blocks were delineated at Isolated Hill, Marlborough. In two, aerial broadcast was used to apply 1 kg/ha prefeed followed by 3 kg/ha 0.15% 1080 cereal baits. In the other two, 0.5 kg/ha of pre feed was sown in strips, and then 0.25 kg/ha of 0.15% 1080 cereal bait was cluster-sown directly over the prefeed swaths.
- The effect on the abundance of pests were assessed using Chew-Track cards (possums and rodents), trap-catch rates (possums only) and tracking tunnels (rodents and stoats; Landsborough only), and we recorded incidental sighting of selected live animal species and of dead vertebrates. In the Landsborough, we assessed bait shyness in survivor.

Results

- In the Landsborough, the average CTCI reduction per block was 89.6% ± 1.6% for the DOC standard treatment, 86.7% ± 2.0% for the aligned cluster treatment, and 41.9% ± 20.5% for the non-aligned cluster treatment. The respective post-control RTCI were 1.4% ± 0.6%, 1.9% ± 1.0%, and 3.3% ± 0.4%, and did not differ significantly between treatments ($F_{2,3} = 1.0$, $P = 0.46$). Surviving possums appeared to be shy of cereal bait in all the poisoned blocks but not apple or carrot. There were too few data to usefully compare the effect of the different treatments on rats and stoats. Few if any mice were killed. Tomtit sightings were higher after poisoning, while robin, kea, and deer were rarely seen or heard before or after. No birds were found dead after poisoning, but 13 possum and two deer carcasses were found.
- At Isolated Hill the DOC standard treatment produced 96.6% ± 3.0% and 77.8% ± 12.1% CTCI reductions, resulting in RTCIs below 2%. The aligned cluster treatment produced reductions of 84.1% ± 6.0% and 62.4% ± 9.5%, resulting in RTCIs close to 4% RTCI. In the aligned cluster treatment blocks the reduction in possum CTCIs was negatively correlated to a pre-control measure of rat activity ($r^2 = 0.73$, d.f. = 6, $P = 0.007$), but not in the DOC standard broadcast blocks ($r^2 = 0.21$, d.f. = 6, $P = 0.25$). The DOC standard treatment reduced rat CTCIs to low levels, but the aligned cluster treatment was less effective. Mouse CTCIs increased after poisoning in all blocks. A total of 59 animals were found dead after poisoning (30 possums, 1 rat, 1 mouse, 2 hedgehogs, 11 deer, 11 blackbirds, 2 chaffinches, and 1 silvereye).

Conclusions

- The cluster sowing strategy used in these two trials produced moderate kills that in some places matched those obtained with current standard practice. The Landsborough Valley trial indicates that good kills can sometimes be achieved with as few as 20 baits/ha even in areas where dense ground cover makes bait difficult to find, at least where alignment of prefeeding is used to ‘teach’ possums where to look for toxic bait.
- The negative correlation between the reduction in possum activity and pre-control rat activity at Isolated Hill, both suggest that bait depletion by rodents may increase the risk of poorer kills when a low toxic sowing rate is used. An alternative or complementary hypothesis is that bait depletion by rodents may be crucial where possums are not actively looking in the right place for bait clusters.
- In these trials, neither cluster baiting nor conventional broadcasting appeared to have any significant impact on mouse populations, and in both trials the removal of most possums (and probably also rats and stoats) resulted in a rapid increase in the detectability of mice.
- The incidental observations of non-target mammals and birds must be treated with caution because the data were not collected in a rigorous survey design, but these data at least provide no indication of that cluster baiting has any greater effect on non-target species than conventional broadcast baiting.

Recommendations

The series of trials planned for this project should continue, but with some redirection. We propose that the next 2–4 trials focus on (i) Determining how few clusters are needed to put all possums and rats at risk using an aligned prefeed sowing strategy; and (ii) determining how long the change in foraging behaviour of possums persists after prefeeding with a small amount of prefeed.

- The AHB should consider developing or refining guidelines for aerial baiting that take into account the finding of this and previous ‘low-sow’ research, and this should include revisiting the trade-offs between bait size, toxic loading, and individual lethality of baits. For example, increasing toxic loading from 0.15% to 0.25% but reducing bait size proportionately from 12g to 7.2g would enable the same number of individually lethal baits to be delivered in a 40% smaller payload, with a commensurate reduction in sowing costs.

1 Introduction

In 2009, Landcare Research conducted two 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 trials were conducted between January and December 2009.

2 Background

There is increasing evidence that very little toxic bait is actually needed to obtain acceptable possum and rat kills with aerial 1080 poisoning, provided the bait is aggregated in space to ensure that any possums (in particular) that encounter first a sub-lethal bait can quickly then find an additional bait and be killed rather than survive and develop bait aversion (Nugent et al. 2008). At present, that high encounter rate is achieved by broadcast sowing many more baits than is needed to kill all of the pests present – an approach that delivers a high density of bait throughout the whole operational area. However, there are indications that broadcast sowing can cause additional bait fragmentation that exacerbates the sub-lethal dosing problem (Nugent et al. 2008), so in essence the solution contributes to the problem.

The alternative solution that we explore here is to reduce fragmentation by removing the high-speed spinners used to fling bait laterally from helicopter-slung sowing buckets, and instead sow a much smaller amount of bait in tight clusters that cover only a small percentage of the area. The benefits that could potentially arise from use of much smaller amounts of bait than is currently the norm include not only much reduced cost but also reduced risk to non-target bird and invertebrate species and a lower risk of water contamination. Intuitively, however, using very few toxic baits during aerial poisoning could increase the likelihood of poisoning failures as a result of complete bait depletion in the areas with the highest density of pests.

This 4-year project was initiated in 2008 to explore how much the amount of 1080 bait sown during aerial poisoning can be reduced without adversely affecting efficacy and reliability in killing possums and rodents. The first steps in this project comprised two operational field trials conducted in 2009 in which we compared an experimental sowing strategy applied to a part of the operational area against the standard practice that was applied to the remainder of the area.

The first trial was conducted in early 2009 in the Landsborough Valley, South Westland, as part of an operation conducted by the Department of Conservation (DOC). It aimed to: (1) assess, for the first time, whether it was practically feasible to aerially sow as little as 250 g/ha of toxic bait with the efficacy of that sowing rate compared with that of the nine-times-higher sowing rate that is DOC standard practice for the region, and (2) whether prefeed could be used not only to familiarise possums and rats with the bait but also to increase the likelihood that they would encounter bait when it was sown in isolated clusters. The latter aim was based on evidence that prefeeding can have a substantial effect on space use by possums (Warburton et al. 2009).

The second trial was conducted in spring 2009 at Isolated Hill, Marlborough, and aimed to refine the best experimental sowing strategy identified from the first trial using smaller baits and less prefeed.

Although the AHB's primary interest in using aerial 1080 poisoning is to control possums, the tool is increasingly used by DOC to also control rodents and secondarily stoats, so we aimed to monitor efficacy against these species as well.

3 Objectives

To determine and improve the cost-effectiveness of aerial 1080 baiting in controlling possums (and also rodents) when a much smaller quantity of 1080 cereal bait than usual is aerially sown in clusters rather than broadcast, by:

- Comparing, for three experimental treatments (standard broadcast baiting, cluster baiting without prefeed alignment, and cluster baiting with prefeed alignment) applied in the Landsborough Valley, Westland, (1) the reduction in possum, rat, mouse and stoat interference rates on ChewTrack cards and tracking tunnels; and (2) the Residual Trap Catch Indices of possum abundance
- Comparing, for two experimental treatments (standard broadcast baiting, and cluster baiting with prefeed alignment) applied at Isolated Hill, Marlborough, (1) the reduction in possum, rat, mouse and stoat interference rates on ChewTrack cards; and (2) the Residual Trap Catch Indices of possum abundance.

4 Methods

4.1 Trial 1: Efficacy of clustered baiting with and without aligned prefeed, Landsborough Valley

Study area and aerial baiting treatments

In early 2009, aerial poisoning of possums (and rats and stoats) over a 3685-ha area in the Landsborough Valley was undertaken by DOC to protect indigenous biodiversity (Fig. 1). The site was steep north-west-facing valley side with mostly complete forest cover dominated by a mixture of silver beech (*Nothofagus menziesii*) and podocarp species, with an understorey comprised largely of dense waist-high crown fern (*Blechnum discolor*). Before control, possum density was only moderate as a Residual Trap Catch Index (RTCI) of 7.5 ± 4.2% was recorded 15 months prior to the operation (G. Scott, DOC South Westland, pers. comm.). The lower slopes of the operational area lying below ~700 m a.s.l. were divided into six experimental blocks, each of 301–455 ha. A randomly selected pair of these blocks was assigned to one of three aerial baiting treatments (DOC standard practice; clustered baiting with no alignment of prefeed and toxic bait, and clustered baiting with aligned prefeed and toxic baiting). All prefeeding and toxic baiting were conducted using helicopter-slung sowing buckets, with the helicopter using flight paths spaced 100 m apart. Flight path spacing was set slightly lower than the usual spacing used by DOC (120 m) to reduce the perceived risk of major operational failure. The treatments were as follows:

- *DOC standard practice:* A single prefeed of non-toxic cereal bait (cinnamon-lured 6-g Wanganui #7 baits) was broadcast at 1 kg/ha followed 5 days later by 0.15% 1080 cereal bait (cinnamon-lured 12-g Wanganui #7 baits) broadcast at 3 kg/ha, with no particular effort made to align the prefeed and toxic flight paths.
- *Non-aligned ultra-low cluster baiting:* A single prefeed of non-toxic cereal bait (cinnamon-lured 6-g Wanganui #7 baits) was broadcast at 1 kg/ha, followed as above by 0.15% 1080 cereal bait (cinnamon-lured 12-g Wanganui #7 baits) sown in clusters at 0.25 kg/ha, with no particular effort made to align the prefeed and toxic flight paths. The clustering of bait was achieved using the same Landcare Research – Amuri Helicopters sowing bucket used to deliver bait clusters in a 2008 poisoning operation on Molesworth Station, where bait was applied at ~ 1 kg/ha (Nugent et al. 2009).
- *Aligned ultra-low cluster baiting:* A single prefeed of non-toxic cereal bait (cinnamon-lured 6-g Wanganui #7 baits) was sown (1 kg/ha) in broad strips by using a very slow spinner speed to spread bait only 15–20 m either side of the flight path, leaving the majority of the central area between flight paths unbaited. Subsequently 0.15% 1080 cereal bait (cinnamon-lured 12-g Wanganui #7 baits) was sown in clusters at 0.25 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.

Poisoning operation

The prefeed was sown 28 January 2009 by Heli-Otago using Bell Jet Ranger and Hughes 500 MD Notar helicopters, and a flying speed of 100 kph. After five fine nights toxic bait was sown on 2–3 February 2009 by Amuri Helicopters using a Squirrel helicopter. A ‘standard’ sowing bucket (700-kg capacity) with a broadcasting spinner was used for the ‘DOC standard’ treatment, while a modified bucket (600-kg capacity) with a gated periodic-release mechanism was used to sow bait in clusters. Windy conditions later in the day made it difficult to deliver bait clusters on the first day of toxic baiting, so most cluster baiting was conducted on the second day. The rate of bait application was checked twice to confirm that the bucket was sowing at the desired rate of 0.25 kg/ha. Some rain (15 mm) fell on the night of 3 February but DOC staff who checked a sample of baits the following day considered it had little effect on bait quality. A stoat found dying by these staff during the bait check had mouse remains in its stomach, and latter analysis of the stoat confirmed the presence of 1080 (0.1 mg/kg). Little rain fell during the next two weeks and monitoring staff reported that the bait found during fieldwork on 18–19 February was still in good condition. Heavy rain then fell on 20–23 February after which most baits found were badly degraded.

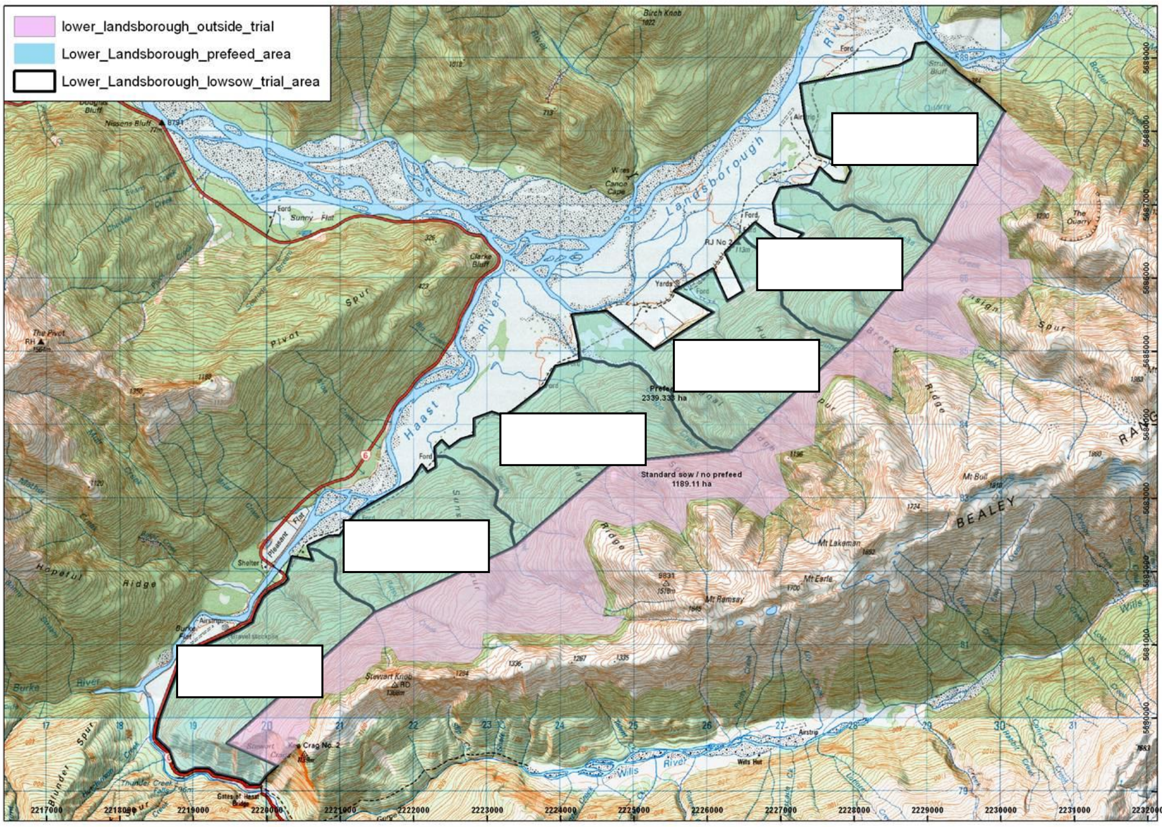

Figure 1 Study blocks in the Landsborough Valley, South Westland. The area shaded purple was part of the overall DOC operation but was not part of this trial. DOC standard practice (1 kg/ha prefeed, 3 kg/ha 0.15% 1080 baits) was applied to Blocks 3 & 6, the non-aligned prefeed treatment to Blocks 1 & 5 (1 kg/ha prefeed, 0.25 kg/ha 0.15% 1080 baits), and the aligned prefeed treatment to Blocks 2 & 4 (1 kg/ha prefeed, 0.25 kg/ha 0.15% 1080 baits).

Effects on possum, rat, mouse, and stoat abundance

We expected that all three treatments might be highly effective and therefore leave too few survivors of some species to allow us to affordably and usefully compare their relative efficacy. We therefore adopted a multiple-index approach to assessing poisoning outcomes under each treatment, and used three different indices of pest abundance or activity (ChewTrack Cards (CTCs) for possum, rat and mouse abundance, RTCI trapping for possums, and tracking tunnels (TTs) for rats, mice and stoats).

ChewTrack Cards: ChewTrack Cards (CTCs) have been developed recently for assessing the distribution and relative abundance of the suite of small mammals that are ubiquitous in New Zealand forest (Nugent et al. 2007; Sweetapple & Nugent 2009), but there is as yet no well-tried protocol for their use in assessing percentage kill and/or residual pest abundance. For this trial, four 1-km-long CTC transects were established in each block running uphill with 26 cards placed at 40-m intervals along each. Lines were spaced at least 200 m apart. Two of the CTC lines in each block covered the same ground as the tracking tunnel lines above.

CTCs were baited with a mixture of peanut butter, icing sugar and ground lucerne (5:1:0.6; Nugent et al. 2008) and 'Black Track' ink (Pest Control Research, Christchurch) was painted along the inner edge of the bent card (Fig. 2). The cards were nailed to tree trunks 15–20 cm above the ground to allow easy access by rodents and were left in place for 35–36 days. The CTCs were collected, read and replaced with new cards 17–21 days after poisoning (20–23 February 2009) and collected and read 16–24 days later (10–17 March 2009). The replacement cards were nailed to a different tree within 10 m of the original site to minimise the possibility that pests had habituated to ignoring the cards.

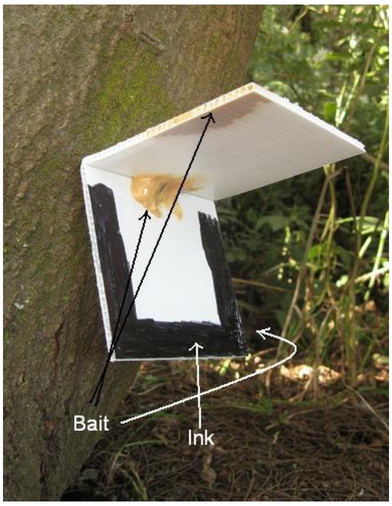

Figure 2 A baited and inked ChewTrack card.

Residual trap catch: To provide a more established and widely used measure of possum control effectiveness, we also used the Residual Trap Catch Index (RTCI; NPCA 2008) to assess post-control possum abundance relative to the 5% RTCI performance target set by DOC. The RTCI monitoring was conducted using NPCA-certified staff about 5–6 weeks after the poison operation (11–18 March 2009), with six trap lines established in each block, four of them randomly placed along one of the CTC lines and the other two randomly located elsewhere in the block. CTC cards were removed before traps were put in place.

Tracking tunnels: In each block two 500-m lines of tunnels were established running vertically upslope, with 10 tunnels spaced 50 m apart on each line. The steepness and deeply incised nature of the numerous gullies in the area made it impractical to orient lines randomly. Tunnels were established during 19–21 November 2008 and left unbaited so that rodents and stoats could acclimatise to their presence. On 13 January 2009 'Black Tracker' tracking cards (Gotcha Traps, Warkworth) were placed in the tunnels baited with peanut butter and removed after one night (following DOC standard operating guidelines for rodent monitoring). Then the 1st, 5th and 10th tunnel on each line was reset with a fresh tracking card and rebaited with rabbit meat and left 4–5 nights before the tracking card was collected. Using the same approach, monitoring was repeated 15 days after poisoning (18–23 February 2009). Rodent and stoat tracking activity levels before and after poisoning were compared using the percentage of cards per line tracked for rodents and the percentage of lines tracked for stoats following the DOC tracking tunnel protocol, differing only in that the stoat baits were left out for 4–5 nights instead of the recommended three.

Incidental bird and mammal sightings

Field staff recorded all encounters (including animals heard and not seen) with live deer, kea, robins and tomtits, both before and after poisoning. After poisoning field staff also recorded all animals found dead during the course of their fieldwork.

Bait acceptance post-poisoning

Approximately 11 weeks following poisoning bait acceptance lines were established (April 2009) in the blocks across the treatments where RTCI trap catch and CTC interference suggested the highest number of surviving possums. Eight 1-km-long lines were established (two each in the standard DOC treatment, non-aligned cluster sown, and aligned cluster-sown treatments) along the same route where chew-card lines had formerly been in place, and a further two new lines were established in an uncontrolled area 5 km away on the true left of the Haast River. Fifty or fifty-one ‘triplets’ of bait were placed every 20 m along the lines (as determined by GPS). The three bait types were non-toxic cinnamon-lured green-dyed 12-g Wanganui #7 bait, 10–20-g cut plain apple and 10–20-g cut plain carrot. These baits were nailed side by side (5–10 cm apart) approximately 15–20 cm above the ground. Baits were left in place for two fine nights before remaining bait was collected and bait take and species responsible were assessed.

4.2 Trial 2; Efficacy of clustered baiting with aligned prefeed, Isolated Hill

Study area and aerial baiting treatments

In late October 2009, DOC and AHB jointly undertook the aerial 1080 poisoning of a 2597-ha area at Isolated Hill, Marlborough, for biodiversity protection and TB management (Fig. 3). The nominal performance target for biodiversity protection was 5% RTCI, but as the work was conducted as an ‘input-contract’ no TB management target was set. The site comprises steep limestone country with vegetation predominantly consisting of mixed beech–seral forest. The operational area was divided into four blocks of 483–736 ha. Two different experimental treatments were applied, each to two of the blocks. One was again the DOC standard practice, and the other was a modified form of the ‘aligned ultra-low cluster baiting’ regime used in the Landsborough Valley. The modifications in the latter were use of a smaller toxic bait, a much smaller prefed bait, and a reduced prefeeding rate. The treatments were as follows:

- *DOC standard practice:* A single prefeed of non-toxic cereal bait (cinnamon-lured 6-g RS5 baits) was broadcast at 1 kg/ha from flight paths spaced 140 m apart, followed 12–13 days later by 0.15% 1080 cereal bait (cinnamon-lured 6-g RS5 baits) broadcast at 3 kg/ha from flight paths spaced 140 m apart, with no particular effort made to align the prefeeding and toxic baiting flight paths.
- *Aligned ultra-low cluster baiting:* A single prefeed of very small 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 12 days later by 0.15% 1080 cereal baits (cinnamon-lured 6-g RS5 baits) sown in clusters at 0.25 kg/ha from flight paths spaced

100 m apart, 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.

Poisoning operation

Prefeed was sown 12 October 2009 by Amuri Helicopters using a Squirrel flying at ~100 kph. Toxic bait was sown 12–13 days later (24–25 October 2009), using a Robinson R44 to broadcast bait at 100 kph and the Squirrel to sow in clusters at ~65 kph. The slower speed used for cluster baiting was intended to reduce bait spread, in the belief that that would increase the density of bait within clusters and therefore the likelihood that pests would encounter multiple baits before the onset of toxicosis. All of the cluster baiting was conducted on 24 October, along with 80% of the standard baiting, with the final 20% completed the following day. Light rain (4 mm recorded at nearby Bluff Station) fell on 26 October, and more (10 mm) fell on 3 November. After that, little or no rain fell before the completion of monitoring 4 weeks after poison baiting.

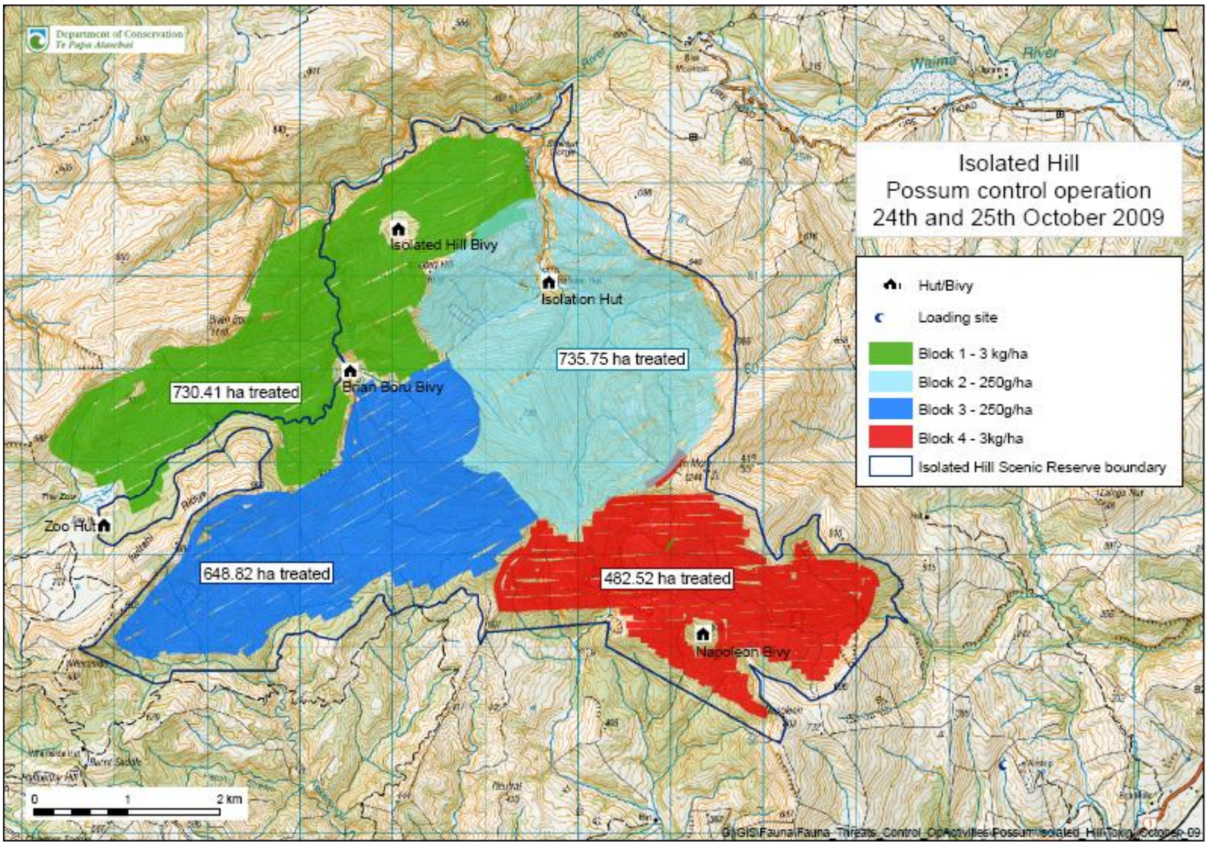

Figure 3 Study blocks at Isolated Hill, Marlborough. The map shows the flight lines (140 m and 100 m between flight paths with the 3 kg/ha and 0.25 kg/ha blocks respectively) where toxic bait was laid. Buffers around the huts and block boundary were not treated.

Effects on possum, rat, mouse, and stoat abundance

Tracking tunnels were not used at Isolated Hill, but otherwise the monitoring approach was similar to that used in the Landsborough Valley (see above).

ChewTrack Cards: About five months before poisoning (18–27 May 2009) four 1-km-long CTC transects were established in each block as above, but on random bearings. Lines were subjectively placed to avoid the numerous areas of difficult or impassable terrain. Tracking ink was not used as it had produced little useful information in Trial 1. Cards were checked and replaced after 7 days (26 May – 3 June 2009). Delays in the poisoning operation resulted in those cards not being checked and replaced until 2 weeks after poisoning (157–162 days later; 4–7 November 2009). The replacement cards were placed on different nearby trees, and were collected 7 days after placement (11–14 November 2009).

Residual trap catch: Ten 10-trap RTC lines were established in each blocks 14–27 days after poisoning, as above.

Incidental bird and mammal sightings

Field staff recorded all encounters (including animals heard and not seen) with live deer, pigs, goats, robins and tomtits, both before and after poisoning. After poisoning field staff also recorded all animals found dead during the course of their fieldwork.

4.3 Analytical assumptions

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

The transformed CTCIs were used to estimate the changes in activity levels before and after poisoning. For the Landsborough trial we assumed that almost all of the activity initially recorded reflected pre-control activity over the 3-week period immediately before control and that, in the 2-week interval between poisoning and checking those cards, surviving possums did not mark any cards that had not previously been encountered and bitten. We therefore also assumed that the pre- and post-control indices were more or less equivalent in the time they were available, so did not correct for differences in the numbers of days the cards were exposed. As-yet-unpublished data show that at moderate or low densities about 80% of card interference occurs within the first week of exposure, so the small differences in effective exposure time between the pre- and post-control CTCIs for the Landsborough (effective exposure periods of 2–3 weeks) should not greatly reduce the comparability. Nonetheless, the estimated changes in CTCI activity should be viewed as relative indices (rather than absolute measures) of the true changes in pest activity (i.e. difference in the change in CTCI activity between treatments indicates a difference in activity levels – which we assume reflects some change in pest abundance, at least for possums and rats – but may not accurately reflect the size of the difference).

Statistical comparison of differences in reductions in tCTCIs and in RTCIs was using linear mixed-effects mod ("lme" procedure; Pinheiro et al. 2009) in the R statistical computing environment (version 2.9.2). In all cases area was used as a random effect with trap type as a fixed effect.

5 Results

5.1 Efficacy of clustered baiting with and without aligned prefeed, Landsborough trial

Possums

Possum densities appeared to be low before control, with the mean 2–3-week CTCI for each block being 65.6% ± 5.2% (SE) (range of block averages 42.9–85.1%). Based on a regression of the transformed residual CTCI against the RTCIs for each block ($y = 12.0x + 1.0$, $r^2 = 0.63$, d.f. = 4, $P = 0.059$) this range equates to a pre-control range of 5–15% RTCI.

The average CTCI reduction per block ($n = 2$ blocks per treatment) was 89.6% ± 1.6% for the DOC standard treatment, 86.7% ± 2.0% for the aligned cluster treatment, and 41.9% ± 20.5% for the non-aligned cluster treatment (Fig. 4). The low mean value and high standard error for the latter treatment reflected increased (rather than decreased) CTCI activity on one line in Block 5. In the other block treated the same way the reduction was 70% (Fig. 4). Linear mixed-effects (LME) modelling of the reduction in tCTCI per line within each treatment indicates the difference between the three treatments was not significant (modelled means; reduction in tCTCI for DOC standard of 89.6 ± 16.9%, aligned cluster of 86.7 ± 16.9%, and non-aligned cluster of 41.9 ± 16.9%; $F_{2,3} = 2.508$, $P = 0.23$).

The average post-control RTCI per block ($n = 2$ blocks per treatment) was 1.4% ± 0.6% for the DOC standard treatment, 1.9% ± 1.0% for the aligned cluster treatment, and 3.3% ± 0.4% for the non-aligned cluster treatment (Fig. 5). LME modelling indicated the difference between the treatments was not significant (modelled means; RTCI DOC standard of 1.4 ± 1.0%, aligned cluster of 1.9 ± 1.0% non-aligned cluster of 3.3 ± 1.0%; $F_{2,3} = 1.0$, $P = 0.46$). Despite the marked differences in the reductions in CTCI between the two non-aligned cluster blocks (Fig. 4), the observed RTCIs in these two blocks were similar (Fig. 5).

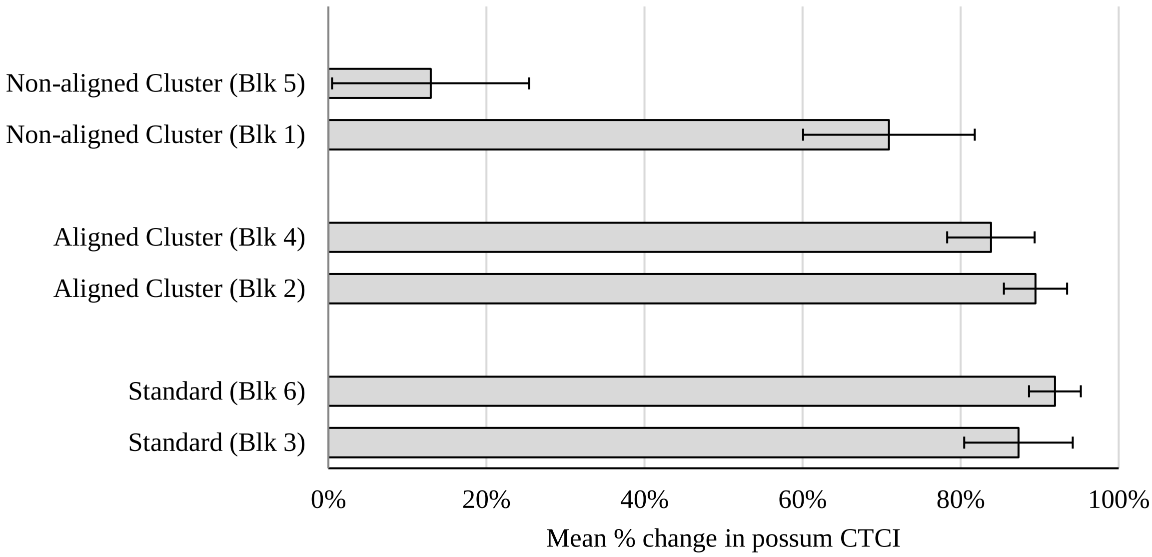

Figure 4 Changes in possum ChewTrack Card activity after aerial 1080 poisoning in the Landsborough Valley, South Westland, by treatment. Data are the % reduction in Poisson-transformed CTCI per line averaged (±SE) across the four lines in each treatment block. The treatments are described in full in Section 4.1.

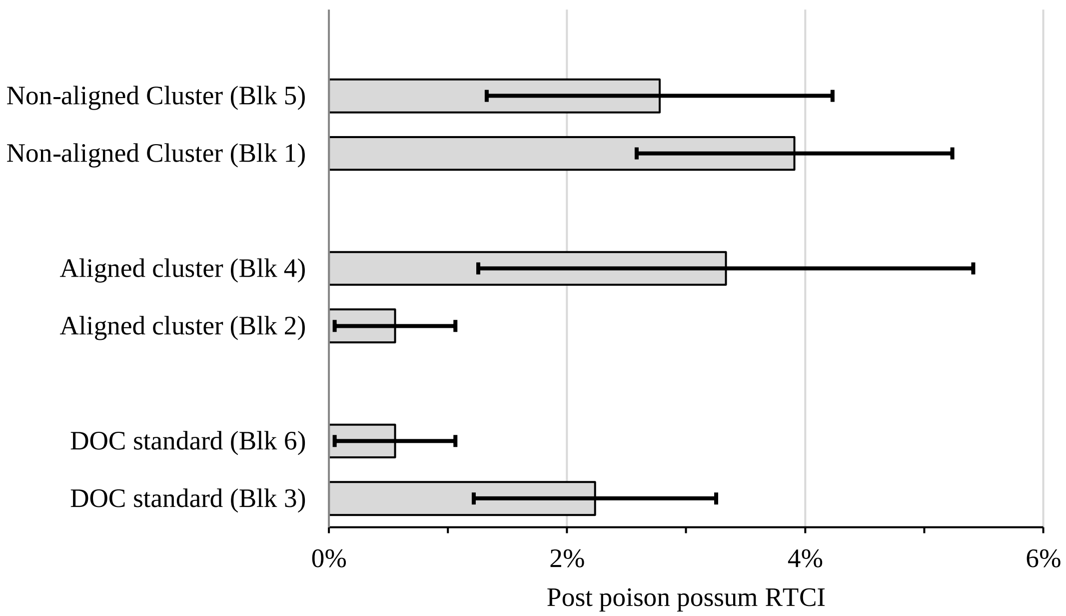

Figure 5 Possum RTC indices after aerial 1080 poisoning in the Landsborough Valley, South Westland, separately for each block. Data are the means (±SE) of the six trap lines per block.

Incidental bird and mammal sightings: Observers averaged more than one tomtit sighting per individual field day, and the numbers seen increased fourfold over the 8 weeks of

CTC monitoring (Table 1). Robin, kea, and deer were rarely seen or heard. No birds were found dead after poisoning, but 13 possum and two deer carcasses were found. One of the deer was in a DOC standard block, the other in an aligned cluster block.

Table 1 Average number of selected live native birds and red deer in the Landsborough Valley seen or heard incidentally each observer field day during monitoring sessions before and after control. Three observers were present in the first three sessions, and two in the last.

	3 weeks before	2 weeks after	4 weeks after	12 weeks after
N field days	18	18	24	8
Tomtit	1.6	3.1	6.7	6.6
Kea[1]	0.7	0.3	0.1	0
Robin	0.1	0.1	0	0
Deer	0	0.1	0	0.4

[1]All but one of the kea observations were heard but not seen, and so the bird may not have been in the actual study areas.

Post-control bait acceptance

At least some cereal, carrot or apple bait was eaten at 70% of the 404 baited sites, with this figure varying from 57% in the unpoisoned area to 83% in the aligned cluster block. In the poisoned blocks, mouse bite marks were recorded at almost all the sites at which bait take occurred, but at only a few in the unpoisoned area, with the reverse being the case for possums (Table 2).

Table 2 Main consumers of bait identified as present at a bait site from bite marks and sign on at least one bait type in and near the Landsborough Valley, South Westland, in April 2009. Data are the total number of sites in each treatment, the number of sites at which at least some of the bait was eaten, and the number of sites at which takes by each consumer was identified. More than one consumer was identified at some sites, while at other sites total consumption of all three baits precluded identification of the species responsible.

	N sites	Sites with bait eaten	N Mouse takes ID'd	N Possum takes ID'd	N Rat takes ID'd	Consumer not ID'd
DOC standard	100	66	58	7	2	6
Aligned cluster	102	83	70	6	0	8
Non-aligned cluster	102	77	67	6	0	5
Unpoisoned	100	57	9	48	0	0
Total	**404**	**283**	**204**	**67**	**2**	**19**

Mice appeared to strongly favour cereal bait over carrot or apple. At 155 sites at which mouse take was identified (and where there was also no indication of possum consumption from bite marks or from complete consumption of whole baits) the average amounts of the carrot and apple baits consumed was only 0.3% and 0.4% respectively, with zero take on 90% and 85% of these 155 baits respectively. In contrast, only 1.5% of the 155 cereal baits had zero take, and, on average, 22% of each mouse-encountered bait was consumed even though only 6% of these baits were consumed completely.

Assuming from the above that possums were by far the most likely consumer at sites at which all of the carrot or all of the apple bait was consumed, there was clear evidence that possums were reluctant to consume cereal in the poisoned blocks but not in the unpoisoned areas (Fig. 6A). For sites at which all of the apple bait was eaten, usually all of the carrot was also eaten and, in the unpoisoned area only, all of the cereal as well (Fig. 6B). In the poisoned areas, however, only parts of most cereal baits were eaten at those sites, in quantities similar to those consumed by mice at sites with no evidence of possum presence (Fig. 6B).

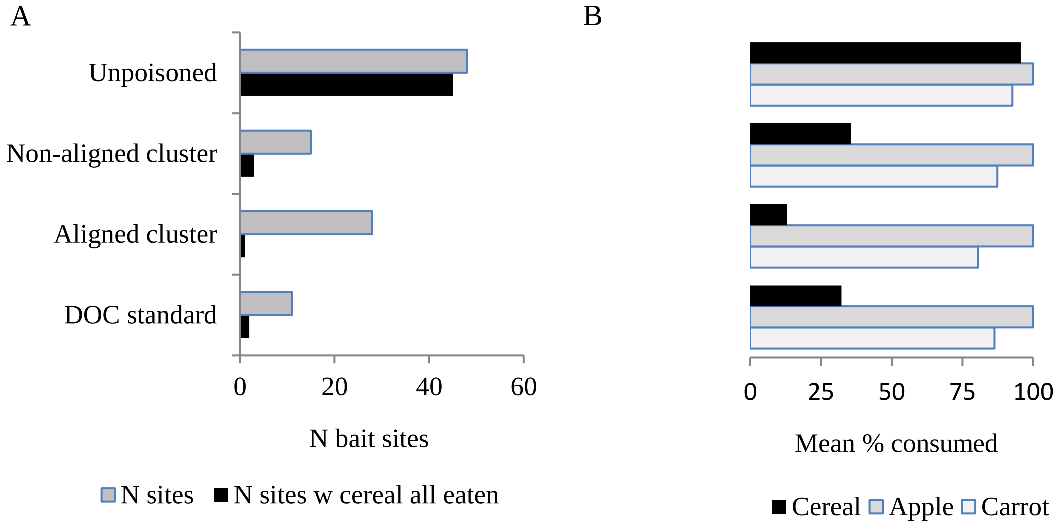

Figure 6 Outcomes of a post-control bait acceptance trial conducted in and near the Landsborough Valley, South Westland, in April 2009, separately for treatment. (A) Number of sites at which all of the apple bait was eaten, and the number of those at which all of the cereal was also eaten. (B) Mean percentage of each bait type consumed at sites at which all of the apple bait was eaten.

Other species

Rats and stoats: There were too few CTC data obtained on rat and stoat abundance to usefully compare the effect of the different treatments on these species (Table 3). A few stoats were detected before control, and none afterward. Rats were detected in two blocks before control but not in those blocks afterward. Three rats were detected in the non-aligned cluster block after control, where there had been none detected before.

Mice: There were twice as many CTC detections of mice after control than before (Table 3), indicating few if any were killed.

Table 3 Numbers of CTCs marked by rats, stoats and mice before and after control, overall, and for each treatment.

Treatment	N	Number of detection (cards marked)					
		Rat		Stoat		Mouse	
	CTCs	Before	After	Before	After	Before	After
DOC standard	198	14	0	6	0	40	101
Aligned cluster	201	5	0	0	0	35	97
Non-aligned cluster	199	0	3	1	0	70	96
Total	598	19	3	7	0	145	294

Tracking tunnel indices were 5.0% ± 3.4% (SE) mean tracking per line for rats and 25.0% ± 12.5% of lines tracked by stoats before control, and zero for both species afterward.

5.2 Efficacy of clustered baiting with aligned prefeed, Isolated Hill trial

Possums

Possum densities appeared to be moderate before control, with the mean of the one-week CTCIs for each block being 74.5% ± 5.7% (SE) (range of block averages 57.7–88.5%; Fig. 7A). Based on a non-significant regression of the post-control RTCI on the transformed residual CTCIs for the four blocks ($y = 9.7x + 0.1$, $r^2 = 0.26$, d.f. = 2, $P = 0.46$) this range equates to a pre-control range of 9–22% RTCI.

The CTCIs for the two DOC standard blocks were by chance both lower than those recorded in the aligned cluster blocks (Fig. 7A). The DOC standard treatment produced a near-complete reduction (96.6% ± 3.0%) in one block, but a more modest reduction (77.8% ± 12.1%) in the other, whereas the aligned cluster treatment produced one modest reduction (84.1% ± 6.0%) and one poor reduction (62.4% ± 9.5%) (Fig. 7B). LME modelling of the reduction in tCTCI per line within each treatment indicates the difference between the two treatments was not significant (modelled means; reduction in tCTCI for DOC standard of 87.2 ± 10.1% and for aligned cluster of 73.3 ± 10.1%; $F_{1,2} = 0.941$, $P = 0.43$).

The trap catch indices showed a slightly different pattern than the residual CTCIs, with both the DOC standard blocks below 2% RTCI while the aligned cluster blocks were both close to 4% RTCI (Fig. 8). In operational terms, the DOC standard treatment was a success, but the aligned cluster treatment did not meet the 2% RTCI widely used as a performance target in TB management. LME modelling provided weak evidence that the difference is significant (modelled means; RTCI DOC standard of 0.8% ± 0.6%, aligned cluster of 4.2 ± 0.6%; $F_{1,2}$ = 15.0, P = 0.06)).

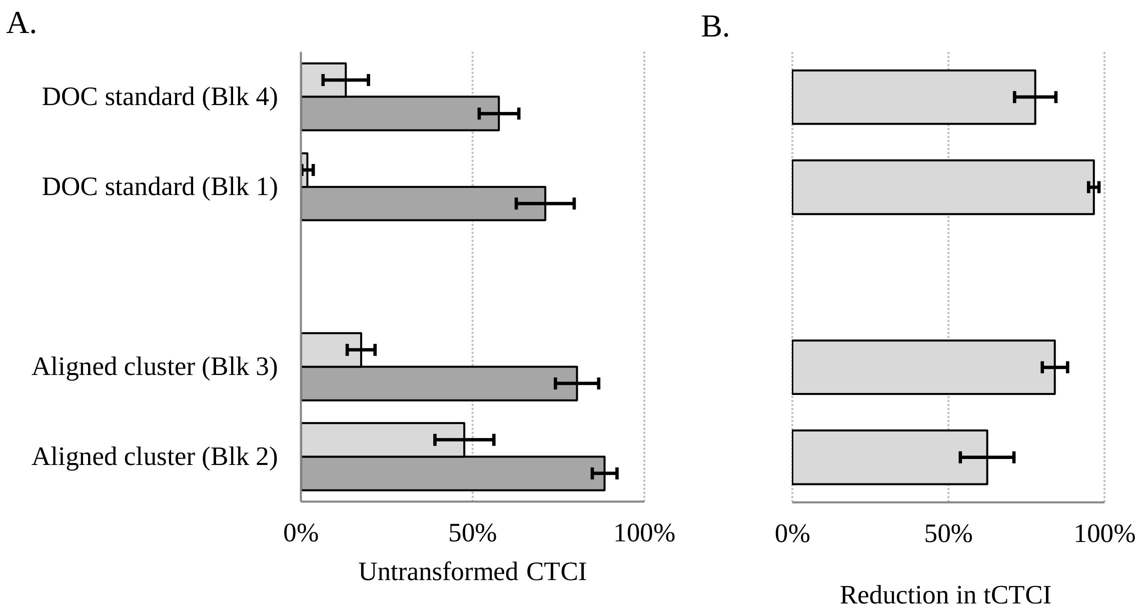

Figure 7 Mean possum CTCIs before and after control for each block, by treatment, following aerial 1080 poisoning at Isolated Hill, Marlborough. A. Raw (untransformed) CTCIs (dark grey = before, light grey = after). B. Reductions in Poisson-transformed CTCIs.

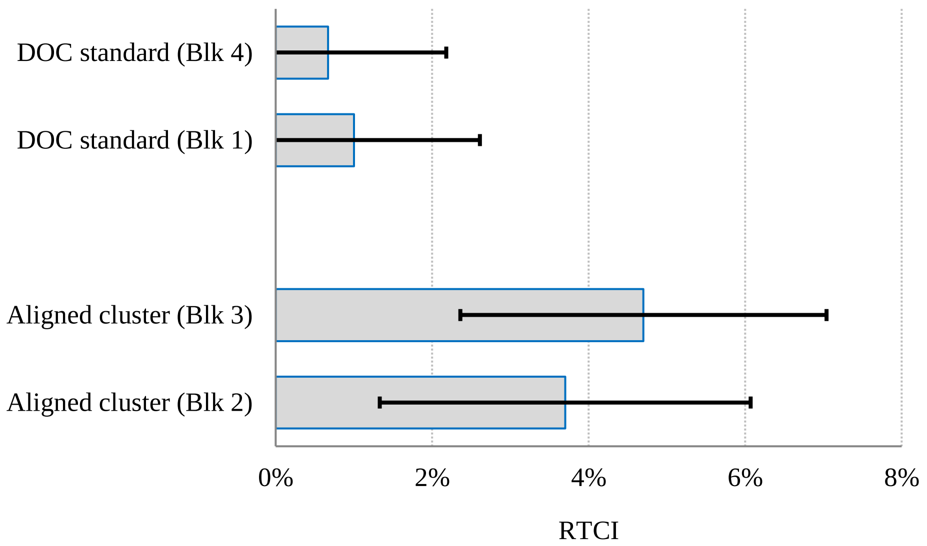

Figure 8 Mean RTCIs (±SE) for each block, by treatment, after aerial 1080 poisoning at Isolated Hill, Marlborough.

For the aligned cluster treatment, the reductions in CTC activity on each line were negatively correlated to the pre-control measures of rat activity, particularly the long-interval CTCIs recorded over the 5 months prior to poisoning (Fig. 9A, $r^2 = 0.73$, d.f. = 6, $P = 0.007$), but there was no evidence of any such correlation where toxic bait was broadcast (Fig. 9B, $r^2 = 0.21$, d.f. = 6, $P = 0.25$).

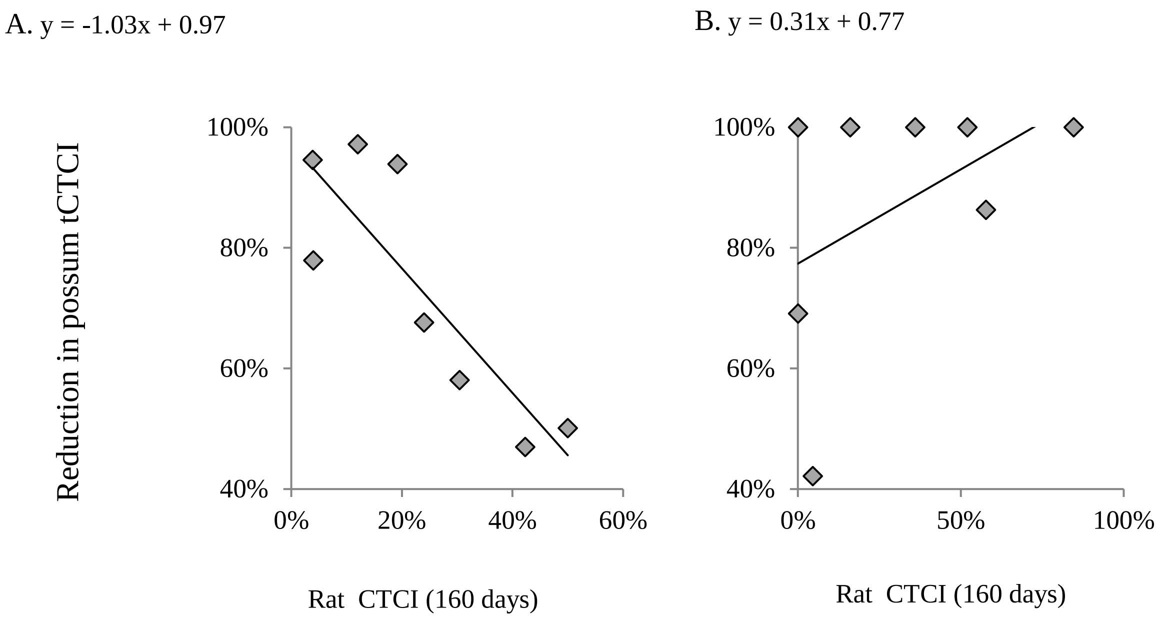

Figure 9 Relationships between the rat CTCIs recorded over ~160 days before poisoning and the reduction in Poisson-transformed CTCIs for possums, for (A) the aligned cluster treatment area (both blocks combined); and (B) the DOC standard broadcast treatment areas (both blocks combined). Data points are the values for each CTC line.

As with possums, the DOC standard treatment reduced rat CTCIs to low levels (Fig. 10A, but the aligned cluster treatment was less effective (Fig. 10B).

As in the Landsborough trial, mouse CTCIs increased overall from 10% before poisoning to 29% afterward. The increase was most marked in the aligned cluster blocks (Table 4). Some of the increase reflected the removal of possums, as mouse marking was observed on only 4.5% of the 309 pre-control CTCs marked by possums, but on 27% of the 106 that were not marked by possums. Excluding the former cards, mouse CTCIs still increased by 50% in the aligned cluster block, but were little changed in the DOC standard blocks (Table 4).

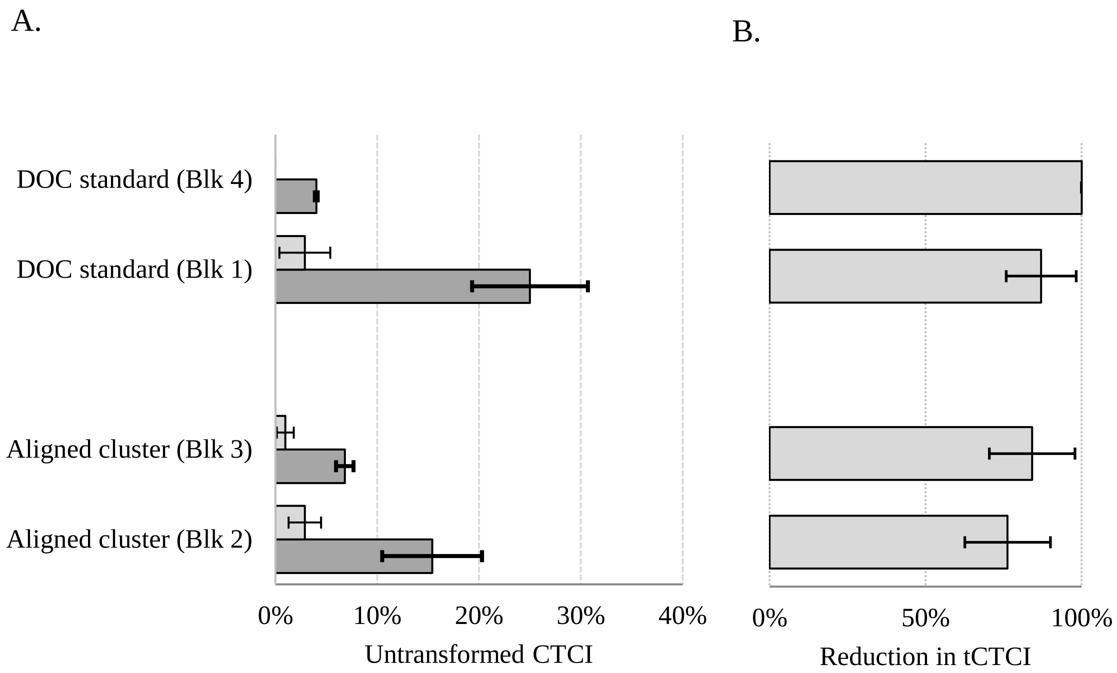

Figure 10 Mean rat CTCIs before and after control for each block in the Isolated Hill study area, by treatment. (A) Raw (untransformed) CTCIs (dark grey = before, light grey = after). (B) Reductions in Poisson-transformed CTCIs.

Table 4 Mouse CTCI (one- week assessment period) before and after control by treatment and block.

	Aligned cluster			DOC standard		
	Blk 2	Blk 3	Total	Blk 1	Blk 4	Total
All cards						
N CTCs	104	104	208	104	104	208
Pre CTCI	1.9%	8.7%	5.3%	26.0%	4.8%	15.4%
Post CTCI	20.2%	51.0%	35.6%	18.3%	26.9%	22.6%
Cards possum-free before control						
N CTCI	12	21	33	30	44	74
Pre CTCI	8.3%	38.1%	27.3%	60.0%	4.5%	27.0%
Post CTCI	25.0%	57.1%	45.5%	10.0%	36.4%	25.7%

No stoats were detected in any of the monitoring periods.

Incidental observations: There was roughly similar incidental search effort in each block as the same amount of RTC & CTC monitoring was conducted in each. The same numbers of deer (10) were seen alive before and after poisoning. Eighteen pigs were seen in the block before poisoning but none afterward (despite fresh pig sign being seen), but a group of c. 10 was observed east of the treatment area near the block boundary during RTCI monitoring. Falcons and kakariki were sighted alive after poisoning but not before.

A total of 59 animals were found dead after poisoning (Table 5). These included 45 mammals (30 possums, 1 rat, 1 mouse, 2 hedgehogs, and 11 deer). All but one of the 14 birds found dead were introduced species, predominantly blackbirds. The native bird found was a silvereye. Fewer deer, blackbirds, and possums were found dead in the aligned cluster blocks (Table 5). The lower number of possums is consistent with the lower kill there.

Table 5 Incidental observations of animals seen alive or found dead during monitoring at Isolated Hill, Marlborough, after aerial 1080 poisoning in October 2009. Sightings of species other than those listed were not recorded.

	Animals sighted alive before and after poisoning				Animals found dead after poisoning	
Species	DOC standard Before	DOC standard After	Aligned cluster Before	Aligned cluster After	DOC standard	Aligned cluster
Possum	nr	nr	nr	nr	21	9
Rat	nr	nr	nr	nr	0	1
Mouse	nr	nr	nr	nr	1	0
Hedgehog	nr	nr	nr	nr	1	1
Deer	7	7	3	3	8	3
Pigs	15	0	0	0	0	0
Goats	21	2	10	0	0	0
Blackbird	nr	nr	nr	nr	8	3
Silvereye	nr	nr	nr	nr	0	1
Chaffinch	nr	nr	nr	nr	2	0
Tomtit	10	8	14	5	0	0
Robin	2	2	1	2	0	0

6 Conclusions

The cluster-sowing strategy used in these two trials produced moderately good kills that in some places matched (but did not exceed) those obtained with current standard practice. Statistically, there was little evidence of difference in efficacy between treatments in either trial, despite some quite marked differences in block and treatment means. The lack of significance appears to reflect high within-block variability in all treatments, both for the reductions in tCTCI and for RTCI. Nonetheless the trials confirmed previous trials in which much lower than usual sowing rates can produce outcomes that almost match those achieved at more than twice the cost (Nugent et al. 2008, 2009). Crucially, the Landsborough Valley trial indicates that good kills can sometimes be achieved with as few as 20 baits/ha even in areas where dense ground cover makes bait difficult to find (Fig. 11). While the same trial suggests that that may only be achievable where alignment of prefeeding is used to 'teach' possums where to look for toxic bait, the lack of statistical significance for the difference between treatments does not allow us to state that with any confidence.

Figure 11 Dense ground cover in the Landsborough Valley, South Westland.

These results are now supported by preliminary analysis of the third trial in the series planned for this project. At Whanganui, in November 2009, a 98.9% reduction in possum CTCIs and a 99.6% reduction in rat CTCIs was achieved with an aligned prefeed of 0.5 kg/ha of 2-g cereal pellets followed 6 days later by clustered 0.25 kg/ha of 6–8-g cereal 0.15% 1080 baits. In contrast a simultaneous conventional broadcast operation delivered a 77.5% reduction for possums and a 95.6% reduction for rats.

Aligned cluster baiting appears to also be effective in killing rats and stoats, although there were too few rats and stoats in the Landsborough trial for that trial to provide robust inference. As stoats are mostly or entirely killed by secondary poisoning, it seems reasonable to presume that wherever there is a good kill of possums and rats we can assume a good kill of stoats, The non-significant but negative correlation between the apparent effect of poisoning on mouse abundance and the reduction in possum activity in the non-aligned cluster block in the Landsborough trial, and the significant negative effect of rat abundance on possum kill in the aligned cluster treatment at Isolated Hill, both suggest that bait depletion by rodents may increase the risk of poorer kills when a low toxic sowing rate is used.

An alternative or complementary hypothesis is that bait depletion by rodents may be crucial where possums are not actively looking in the right place for bait clusters. This is consistent with the possibly (but not statistically significant) poorer measured outcomes with non-aligned prefeed in the Landsborough trial. It may also be consistent with the poor outcome of the aligned prefeed treatment at Isolated Hill if that was caused by the 12-day delay between prefeeding and toxic baiting there compared with the 6-day interval at Whanganui; i.e. the hypothesis is that by 12 days most of the effect of prefeeding on possum foraging behaviour (Warburton et al. 2009) had dissipated, so possums took a long time to find bait by which time much of it had been cached or eaten entirely by rats, or had been partially consumed by mice leaving sub-lethal doses for possums. Although Warburton et al. (2009) indicate that the change in possum behaviour lasted for about three week in their trial, inspection of their data indicates most of the effect had dissipated well before then, and they used a much large quantity of bait (2kg/ha) placed by hand in larger clumps rather the broadcast over a 30-40m swath, so we suggest in these trials the smaller amount of bait is likely to have been consumed more quickly, and provided a much weaker spatial focus to the change in behaviour.

In these two trials, neither cluster baiting nor conventional broadcasting appeared to have any significant impact on mouse populations, and in both trials the removal of most possums (and probably also rats and stoats) resulted in a rapid increase in the detectability of mice. That increase may be partly an artefact of the CTC monitoring technique, with possums and rats either making the cards less attractive to mice by removing the bait or by obliterating the marks left by mice. That would tend to bias the pre-control mouse indices low. However, we also observed increased use of tracking tunnels so at least some of the increase represents an increase in mouse activity around monitoring devices.

The incidental observations of non-target mammals and birds must be treated with caution because the data are not collected using a rigorous survey design, but at least provide no indication that cluster baiting has any greater effect on non-target species than conventional broadcast baiting.

Overall, sowing small amounts of bait in clusters is reasonably effective in controlling possums provided prefeeding is used to teach the possums where to look for patches of bait. By using 92% less toxic bait than normal sowing (i.e. 0.25 kg/ha instead of 3 kg/ha), this opens up new strategic possibilities, such as increasing the affordability of the more frequent repeat control needed to reduce numbers of rats and stoats. The results add weight to our working hypothesis that fragmentation of bait is potentially a major contributor to the problem of sub-lethal poisoning of possums, and that one way to overcome the problem is by aggregation of baits in strips or clusters (thus reducing bait fragmentation). This provides an alternative to the current approach of 'broadcast overbaiting with excess lethal doses' as it requires less toxic bait to be sown.

7 Recommendations

- The series of trials planned for this project should continue, but with some redirection in response to the results of these two trials, and the result of the two further trials at Whanganui for which the fieldwork has now been completed. We propose that the next 2–4 trials focus on:
    - Determining how few clusters are needed to put all possums and rats at risk using an aligned prefeed sowing strategy with 0.20 kg/ha of small (6–8 g) toxic baits and 0.40 kg/ha of very small (2 g) prefeed baits. The aim would be determine the optimal trade-off between increased flight-path spacing, increased spacing between clusters along flight paths, and the number of baits per cluster.
    - Determining how long the change in foraging behaviour of possums persists after prefeeding with a small amount of prefeed. The aim would be to test the effect of a range of intervals (including zero) between prefeed and toxic baiting on the efficacy of the aligned prefeed sowing strategy.
- The AHB should consider developing or refining guidelines for aerial baiting, taking into account the need to reduce spinner-induced fragmentation, and the potential to achieve adequate kills with very little toxic bait (at least when possum and rat numbers are low).
- The AHB should consider revisiting the trade-offs between bait size, toxic loading, and individual lethality of baits, at least initially within the ERMA constraint of 0.25% maximum 1080 concentration. For example, increasing toxic loading from 0.15% to 0.25% but reducing bait size proportionately from 12g to 7.2g would enable the same number of individually lethal baits to be delivered in a 40% smaller payload, with a commensurate reduction in sowing costs.

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