Bait aggregation and deer repellent effects on efficacy, and non-target impacts on deer and birds, during aerial 1080 baiting: Hauhungaroa 2011

Animal Health Board

R-10710 & R-10743

Landcare Research
Manaaki Whenua

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Summary

Project and Client

- Landcare Research conducted a multi-faceted field trial for the Animal Health Board to compare the relative efficacy against possums and rats of strip- and broadcast-sowing methods (with and without Epro deer repellent [EDR]) for aerial 1080 baiting, and assessed non-target impacts by measuring deer by-kill and bird abundance. The fieldwork was conducted between April 2011 and March 2012.

Objective

- Determine, in a first replicate, the effect of bait aggregation (through the use of strip-sowing at various sowing rates and flight-path spacings (FPS)) and deer repellent (EDR) on the efficacy of aerial 1080 baiting against possums and rats, and its impacts on non-target deer and birds.

Results

- Overall, possum abundance 6–8 months after control was below 2.5% Residual Trap Catch Index (RTCI) in all blocks, and to below 1% RTCI in most.
- For possums, 7-day Chewcard Indices (7dCCI) recorded immediately after control were well below 10% in all but one of the eight blocks studied. With broadcast sowing, the reductions recorded with and without EDR were similar (Relative Change in Activity Indices (RCAI) of 0.94 and 0.92 respectively). Very low pre-control possum abundance in the two EDR strip-sown blocks precluded such a comparison for strip sowing. At 100-m FPS, strip sowing matched broadcast sowing in efficacy despite lower sowing rates. At 150-m FPS, however, the RCAIs calculated were lower in the two strip sown blocks than the broadcast sown blocks.
- For rats, there were large (>90%) reductions in rat indices in both broadcast blocks and in three strip-sown blocks, and lesser reductions in the other three strip-sown blocks. The residual 7dCCI for one of the 150-m FPS strip sowing treatments was markedly higher (46%) than for any other block (all <7%). In all blocks, rat 7dCCIs increased rapidly over the 6–8 months after control to higher levels than before control.
- No dead deer were found during systematic searches of the four grids in which EDR was used, but 15 were found in the four grids where no repellent was used. A further 27 deer were found dead during the course of other project work, all in blocks in which no repellent was used. The deer sighting rate across all blocks declined from 0.37 per day before control to 0.27 immediately afterward, but was 0.40 after 6 months.
- Eleven birds were found dead (1 fantail, 4 kererū, 6 blackbirds), but 1080 was detected in only five of them (all blackbirds).
- Pre-control bird counts were conducted in May. Silvereye and tūī were the most commonly recorded species. Lower counts of these two species were recorded after control in some blocks, specifically the strip-sown blocks on the western side resurveyed in August or September. However, the tūī count recorded in an unpoisoned block in September was also much lower than in May. For the 14 less-common-but-widespread species, there was no evidence of a consistent and large (>50% change)

effect of aerial 1080 baiting. Reduced counts for a species after poison baiting were usually matched with a low count in the unpoisoned area, suggesting a seasonal effect on bird detectability, with only one exception for a native species (tomtits in the broadcast-sown EDR block).

Conclusions

- Possum survivors were most abundant in tow north-western blocks (AS2 and AS3), reflecting both moderate efficacy and higher than average possum abundance before control. The RTCIs, however, appear low enough to ensure that TB levels in possums will continue to decline for at least 2–3 years (if not already zero).
- Broadcast baiting reduced possum abundance (>90%) and EDR did not appear to affect efficacy. At 100-m FPS, strip sowing had similar efficacy against possums, but at 150-m FPS efficacy may have been lower. Further trials of strip sowing at 100-m FPS are warranted given the potential for cost reduction through use of fixed-winged aircraft.
- For rats, strip sowing appeared less reliable than broadcasting, especially at 150-m FPS. However, rat numbers in all blocks increased within 6 months to higher than before control, so differences in efficacy were inconsequential. None of the sowing methods would have protected native animals from rat predation for more than a few months.
- EDR was highly effective in reducing deer by-kill, and aggregating bait in strips did not reduce repellency. In blocks where no repellent was used, the widespread presence of fresh tracks after control, and the higher number of deer seen 6–8 months after control, than before, leads us to suggest that about a third of the deer in those blocks was killed.
- Although post-control a few introduced birds were found dead with 1080 residues, changes observed in the counts of the most commonly recorded bird species on areas not aerially baited suggest changes in baited areas were more likely to be seasonal effects than a result of 1080 baiting. Coupled with the lack of any consistent reductions in bird counts across all treatments, this indicates that aerial 1080 baiting or use of EDR and/or strip sowing either has little effect on common bird species, or that any effect is either small and/or highly inconsistent.

Recommendations

- To ensure on-going reduction in TB levels, the AS2 and AS3 blocks should be a priority for repeat control, given the higher than average RTCIs recorded there. Repeat control could be delayed until Winter 2014 without negating the downward pressure on TB levels in possums.
- Further operational trials should be conducted to test the efficacy of strip-sowing at 100-m FPS and with varying intervals between prefeeding and toxic baiting. These should be conducted using fixed-wing aircraft to maximise cost saving and should also include exploration of dual strip-sown prefeeding.
- EDR should be considered for use with both broadcast and strip sowing on areas where AHB wishes to avoid a substantial impact on deer abundance.
- The planned replication of the investigation of the effect of bait aggregation on EDR efficacy in protecting deer is desirable but higher priority should be given to replication of the effect of EDR and bait aggregation effects on non-target bird numbers.

1 Introduction

Landcare Research conducted a multi-faceted field trial for the Animal Health Board to compare the relative efficacy against possums and rats of strip- and broadcast-sowing methods (with and without deer repellent) for aerial 1080 baiting, and, at the same time, assessed non-target impacts by measuring deer by-kill and bird abundance. The fieldwork was conducted between April 2011 and March 2012.

2 Background

This report summarises results of an integrated set of investigations of the efficacy and non-target effects of aerial 1080 baiting operations for possums (and rats) conducted in the Hauhungaroa Range in winter, 2011. These investigations spanned two on-going AHB-funded projects, R-10710 and R-10743.

The first project, R-10710 *Low-cost aerial poisoning*, is a 5-year research programme that began in late 2008. Its aim is to test and refine new methods for aerial sowing of 1080 bait for possum (and rat) control by delivering bait in a highly aggregated manner. The concept aims to achieve a high density of bait where bait is present (in order to maximise the ease with which possums can find multiple baits) without having to apply that high bait density to the whole landscape (Nugent et al. 2012). Previous research in this project (Nugent & Morriss 2010, 2011) has focussed on the use of cluster sowing, but in these trials we focus instead on strip sowing.

With strip sowing, bait is sown continuously along an aircraft flight path, but with no effort made to spread bait laterally, so most of the area between the parallel and widely spaced flight paths typically used is left unbaited. With cluster sowing, bait is sown in the same way but discontinuously along the flight path, creating gaps in bait coverage along the flight path as well as between them. The latter potentially enables even greater reduction in the amount of bait required, but does (at least at present) require use of helicopters, whereas strip sowing can be achieved using fixed-wing aircraft, which have lower operating costs. Our original aim for this project in 2011 was to compare both strip and cluster sowing against conventional broadcasting, in two replicates. One replicate was successfully completed at Whanganui and showed no difference in possum and rat reductions between the three sowing methods (Nugent et al 2012a). However, for the Hauhungaroa Range replicate reported here, mechanical failure of the cluster sowing bucket within the first hour of use during this operation resulted in all cluster-sowing treatments being converted to strip-sowing treatments (see Methods section). This reduced the trial to a comparison of strip and broadcast sowing.

With both strip and cluster sowing, it is crucial that the distance between the baited areas (which is determined by the flight-path spacing (FPS)) is smaller than the smallest home range width of possum and rats, otherwise some targeted pests would not encounter bait. In initial trials, we recorded high possum and rat kills with a FPS of 100 m (Nugent et al 2009, 2011a; Nugent & Morriss 2010). In 2010, we also recorded near total kills of possums and rats using an FPS of 150 m (Nugent & Morriss 2011). As a wider FPS results in reduced bait costs if bait is sown at the same rate per kilometre of flight path and reduced flying costs, we aimed to conduct a further comparison of FPSs of 100 m and 150 m.

The second project, R-10743 *Deer repellent and cluster sowing effect on non-target species during aerial 1080 poisoning*, is a 3–4-year project aimed at assessing, in two different areas, whether sowing bait in a highly aggregated manner results in an increased by-kill of deer and birds, and whether the efficacy of the proprietary deer repellent (Epro Deer Repellent [EDR]), now registered for use on aerially-delivered 1080 baits, was affected by aggregating bait. We have shown previously that EDR is effective in reducing deer by-kill from conventional broadcast baiting (Nugent et al. 2004; Morriss et al. 2005; Morriss 2007; Morriss & Nugent 2008) but aggregation of bait could decrease or (more plausibly) increase its efficacy. There is no previous research into whether or not the use of EDR changes the impact of aerial 1080 poisoning on bird populations.

The combined aims for the overall study were therefore (1) to compare the target efficacy of strip sowing (at reduced sowing rates and two different FPSs) against conventional broadcast sowing; (2) to assess whether the efficacy of EDR in reducing deer deaths was affected by use of strip sowing; and (3) to determine whether use of strip sowing and/or EDR resulted in a major increase in non-target bird deaths.

3 Objectives

- Determine, in a first replicate, the effect of bait aggregation (through the use of strip-sowing at various sowing rates and flight path spacings) and deer repellent on the efficacy of aerial 1080 baiting against possum and rats, and its impacts on non-target deer and birds, by:
    - Comparing the relative changes in, and residual levels of, rat and possum abundance between broadcast aerial baiting and three variants of strip sowing, with and without EDR
    - Comparing the numbers of deer killed with strip and broadcast baiting, with and without EDR
    - Comparing changes in bird counts with strip and broadcast baiting, with and without EDR.

4 Methods

4.1 Overall approach

To compare the efficacy of strip and broadcast sowing, eight trial areas (six strip, two broadcast) were established in the Hauhungaroa Ranges (Appendix 1) with the various experimental poisoning treatments being applied in Winter 2011 within a larger conventional broadcast-sowing operation covering most of the ranges. The strip-sowing treatment included two FPS treatments (100 m and 150 m), and two different sowing rates. EDR was used in one of the broadcast blocks and two of the strip-sown blocks (Appendix 1).

The efficacy of each of the eight treatments against target pests was assessed using indices of possum and rat abundance (tracking tunnels and/or chewcards), with assessments immediately before poisoning, immediately afterwards, and 6–8 months afterwards (chewcards but not tracking tunnels). Residual Trap-Catch (RTC) monitoring of possums was conducted at the same time as the 6–8-month chewcard assessment.

To compare the efficacy of EDR in reducing deer deaths, systematic searches for deer carcasses were carried out in parts of four of the trial areas (two broadcast, two strip) following poisoning (Appendix 2).

To assess the effect of both EDR and bait aggregation on bird deaths, indices of bird abundance were recorded before and immediately after poisoning in six of the trial areas (two broadcast (one EDR) and four strip (two EDR)) and two adjacent areas that had not been poisoned (Appendix 2).

4.2 Strip versus broadcast aerial 1080 baiting

4.2.1 Study areas and design

Study areas

In Winter 2011, the AHB undertook aerial 1080 baiting targeting possums in an area of 70 116 ha in the Hauhungaroa Ranges, Central North Island (Appendix 1; Table 1). The area comprised mostly mixed podocarp–broadleaved forest. East of the main range, the podocarps rimu (*Dacrydium cupressinum*), mataī (*Prumnopitys taxifolia*), miro (*P. ferruginea*) and tōtara (*Podocarpus cunninghamii* and *P. totara*) were common over a broadleaved canopy dominated by kāmahi (*Weinmannia racemosa*), black maire (*Nestegis cunninghamii*), and *Elaeocarpus* species. The western catchments had scattered rimu and mataī over broadleaved canopies dominated by tawa (*Beilschmiedia tawa*). The main range is dominated by a canopy of kāmahi, broadleaf (*Griselinia littoralis*) and tāwheowheo (*Quintinia serrata*), with occasional emergent tōtara (Sweetapple & Nugent 2009). In many places there is a dense understorey tier dominated by horopito (*Pseudowintera colorata*) that sometimes forms a low canopy in gully heads and at higher elevations.

Parts of the range were first aerially-poisoned in the mid-1970s. In 1994/95, most of the eastern flank and the western- and southern-most parts of the western flank were poisoned again (Fraser et al. 1995), and in 2000/01 the whole range was treated for the first time. However, there were indications of suboptimal control in part of the area (the central western section of the area, designated AS3 in Appendix 1) in that operation (Nugent & Whitford 2006), with TB-infected possums identified there in 2005 (Coleman & de Lisle 2007). The whole range was then aerially poisoned again that winter (2005). That operation was particularly intensive, with two non-toxic prefeeds applied over most of the area (other than AS3 where only one prefeed was used), and with toxic 1080 baiting rates of 3–5 kg/ha. Intensive RTC monitoring using the standardised National Pest Control Agencies (NPCA 2011) protocol conducted immediately after control captured just eight possums on 539 trap lines (RTCI = 0.05%, *n* = 15 358 trap-nights; Coleman & de Lisle 2007). Large parts of the eastern area, and the AS3 block, were subsequently resurveyed 4–9 months after control, using the Chewcard Index (CCI) method (Sweetapple & Nugent 2011), and a 1.5% CCI was recorded, with almost 5 times as many possum detections per kilometre of survey transect than detected in the immediate post-control RTC survey (Nugent et al. 2008, p. 99). In a further survey 30 months after control, the possum CCI had doubled to about 3% (Nugent et al. 2008, fig. 47).

In 2009, an overall CCI of 18.4% was recorded in the AS3 block (Sweetapple et al. 2010), and there was some removal of detected possums at that time. Despite that, ‘trend’ monitoring conducted by the AHB in May–June 2010 in the seven vector control zones (VCZs) covering the western side of the ranges found an overall RTCI of 0.32% (n = 1846 trap-nights) and with RTCI for individual VCZ ranging from 0% to a maximum 0.67% (in AS1, north-west of AS2; Table 2).

We selected eight study blocks for this project assessing the efficacy of various aerial baiting protocols. The different protocols were mostly applied to whole VCZs but the AS2 VCZ was divided into western and eastern blocks, AS6 into northern and southern blocks, and our study block comprised only the western part of the AS7 VCZ. Treatments were allocated to blocks depending, in part, on the constraints imposed by land managers and owners (e.g. the part of AS7 in private ownership was used as the EDR broadcast treatment because the landowners requested use of EDR bait in that block). The size of the blocks varied from 1580 to 13 811 ha (Table 1).

Three sowing protocols were applied (and see Table 1):

- *Broadcast sowing FPS = 180 m*: In two blocks, a single prefeed of non-toxic cereal bait (orange-lured 6–8-g Wanganui No. 7 baits; Animal Control Products, Wanganui) was broadcast at 1.5 kg/ha followed 19–29 days later by 0.15% 1080 cereal bait (orange-lured 12-g Wanganui No. 7 baits) broadcast at 1.5 kg/ha, with no alignment the prefeed and toxic bait flight paths. EDR was applied to both prefeed and the toxic bait sown in AS7.
- *Strip sowing variant 1, FPS = 100 and 150 m.*: In the two halves of AS2, a single prefeed of non-toxic cereal baits (orange-lured 2-g Wanganui No. 7 baits) was sown in ~60-m-wide strips at the baiting rate of 5 kg per kilometre of flight path. In AS2 West, a 100-m FPS was used, resulting in a sowing rate of 0.5 kg/ha, while in AS2 East a 150-m FPS was applied (sowing rate of 0.33 kg/ha). In an effort to maximise efficacy of strip baiting against both possums and rats, AHB specified use of 6–8-g baits containing 0.15% 1080 (orange-lured) to deliver a high bait density within swaths for this trial, with these baits sown in 30-m-wide strips along the same flight paths as the prefeed, at the baiting rate of 10 kg/km, resulting in toxic bait sowing rates of 1.0 kg/ha and 0.67 kg/ha for the 100- and 150-m FPS blocks respectively.
- *Strip sowing variant 2, FPS = 100 and 150 m.*: In AS3, AS4 and AS6 North and South, the original intention was to use cluster sowing based on the AHB’s newly developed specification for that. Prefeed was applied in strips as above, but for the toxic baiting the sowing strip width was increased to 60 m and a larger bait size was used (orange-lured 0.15% 1080 12-g Wanganui No. 7 baits), with a baiting rate of 7 kg/km. In AS3 and AS6 N, a 100-m FPS was used resulting in a sowing rate of 0.7 kg/ha, while in AS4 and AS6 S the 150-m FPS used resulted in a sowing rate of 0.47 kg/ha

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Table 1 Study blocks used in the Hauhungaroa Ranges for the Winter 2011 trials, showing the AHB acronym for the Vector Control Zone (VCZ) designation for the block (see Appendix 1 for locations), area, treatment details, sowing dates, and whether or not systematic deer carcass searches and/or 5-minute bird counts were conducted in the particular block. Possum and rat monitoring was conducted in all but the two unpoisoned blocks.

Study block	Area (ha)	Sowing method	Flight path spacing (m)	Prefeed swath (m)	Toxin swath (m)	Deer repellent (EDR)	Prefeed sowing rate (kg/ha)	Toxin sowing rate (kg/ha)	Prefeed sowing date (2011)	Toxin sowing date (2011)	Prefeed interval (days)	Carcass grid Search	Five-minute bird counts
AS2 E	5420	Strip	150	60	30	-	0.33	0.67	23/5	30/5–1/6[1]	9–11	-	-
AS2 W	5303	Strip	100	60	30	-	0.5	1.0	20–21/5	30–31/5[1]	10–11	-	-
AS3	2982	Strip	100	60	60	-	0.5	0.7[2]	30/6	4/8	35	Yes	Yes
AS4	3052	Strip	150	60	60	-	0.33	0.47	30/6	4/8	35	-	Yes
AS6 N	1580	Strip	100	60	60	Yes	0.5	0.7	30/6	3/8	34	Yes	Yes
AS6 S	1820	Strip	150	60	60	Yes	0.33	0.47	30/6	3/8	34	-	Yes
AS7 W[3]	5308	Broadcast	180	180	180	Yes	1.5	1.5	2/6	1/7	29	Yes	Yes
Tihoi 3B (T3B)	13811	Broadcast	180	180	180	-	1.5	1.5	29/4	18/5	19	Yes	Yes
Tihoi 3A (T3A)	4530	Unpoisoned	-	-	-	-	-	-	-	-	-	-	Yes
Waipari (WP)	2997	Unpoisoned	-	-	-	-	-	-	-	-	-	-	Yes

[1] Low cloud prevented the whole block being sown in one day. [2] 28 min of sowing (100 kg) on 3 August with cluster bucket not performing properly; switched to strip sowing on 4 August. [3] Only the area where the monitoring grids were located was treated with 1.5 kg/ha prefeed and 1.5 kg/ha toxic bait (972 ha). The balance of AS7 was treated with 1 kg/ha prefeed and 2 kg/ha toxic bait. Poisoning operation

The poisoning operation was carried out progressively during the winter of 2011 as suitable weather windows occurred. The intervals between pre-feed and toxic bait application varied from 9-10 days in the AS2 blocks up to 34-35 days for the other four strip-sown blocks. For all blocks, there were at least three, and up to five nights of fine weather before rain fell. Baiting was conducted using Iroquois, Robinson 44 and Squirrel helicopters (Lakeland and Lakeview Helicopters). The overall poisoning operation was managed by Epro Ltd.

4.2.2 Effects on possum and rat abundance indices

Short-term (1–8 week) effects

Chewcards (Sweetapple & Nugent 2011) and tracking tunnels (King & Edgar 1977; NPCA 2007) were used to assess operational efficacy in reducing possum and rat abundance. Within each of the eight blocks, four sets of four monitoring lines were established. Each line comprised 10 chewcards alternating with 10 tracking tunnels with a spacing of 25 m between each device (total line length ~500 m). For logistic convenience, each set of four lines was arranged in a square ~700 × 700 m (e.g. Figure 1), with one line positioned in the middle of each side of the square and with the ends of each line at least 200 m from other lines within the set.

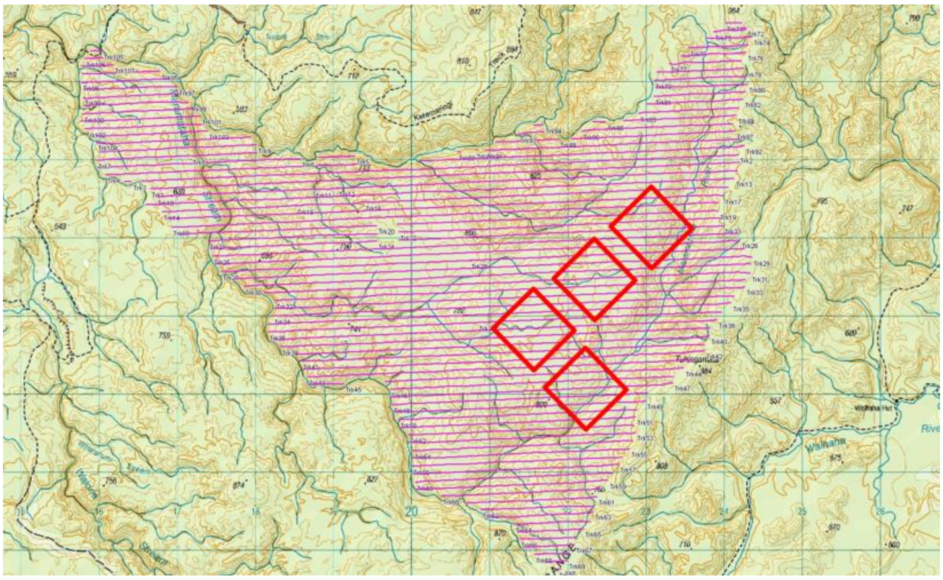


Figure 1 Trial block AS3 west of the Hauhungaroa Ranges. The horizontal pink lines show the flight lines where toxic bait was sown in August 2011. The red squares show the approximate location of the four chewcard and tracking tunnel monitoring squares located within the block. Each side of the squares represents a ~500-m-long line comprising 10 chewcards and 10 tracking tunnels. The orientation of each monitoring line was at an angle to the flight lines so that it crossed several flight lines. AS3 was strip-sown (0.5 kg/ha 2-g prefeed, 0.7 kg/ha 12-g 0.15% 1080 baits, FPS 100 m) in June–August 2011.

Chewcards were baited with a mixture of peanut butter, icing sugar and ground lucerne (5:1:0.6; Sweetapple & Nugent 2008). The cards were nailed to tree trunks, 15–20 cm above the ground to allow easy access by rodents, with replacement cards subsequently being placed on different nearby trees.

Tracking tunnels were established at the same time as chewcards. Peanut butter was smeared on the wooden blocks at each end of the tunnels to 'prefeed' the tunnels, which were then re-baited one week later with peanut butter and set with 'Black Tracker' tracking cards (Gotcha Traps, Warkworth).

Cards and tunnels were first deployed 27 April – 1 May 2011. The chewcards were checked and replaced ~7 days later (to provide a 7-day CC index [7dCCI]), and the tracking cards placed in the tracking tunnels at that time, The tracking cards were then collected one day later to provide a standard one-night Tracking Tunnel Index (1nTTI) of rodent abundance.

Post-poison monitoring was carried out progressively as blocks were baited. The post-poison monitoring in AS2, AS7, and Tihoi 3B was carried out 12–23 July 2011 (1–8 weeks after baiting). AS3, AS4 and AS6 were monitored 11–22 August (1–2 weeks after baiting).

Chewcards were checked and replaced 65–108 days after the pre-monitor and checked and removed 7 days later, with 65–108-day data being used to calculate a 'long-run' pre-control CCI [80dCCI]). Tracking tunnel cards were reinstalled and checked a day later to provide a post-control 1nTTI.

Medium-term (6–8 month) effects

Because indices of possum abundance recorded immediately after control may be much lower than indices measured some months later (Nugent et al. 2010), and because the AHB required some estimate of possum control outcomes based on conventional trap-catch indices, conventional RTCIs (NPCA 2011) were measured 6–8 months after the 1080 operation.

The RTC survey provided the opportunity to explore whether CCIs recorded immediately after control were also much lower than those recorded a few months later. It also proved an opportunity to explore the relationship between the two indices (RTCI and CCI) in more depth than has previously been possible.

In addition, further RTCI lines were assessed for operational purposes in a number of blocks that were not part of this trial. In total we surveyed 214 RTCI lines throughout eleven VCZs in the Hauhungaroa Ranges.

For our eight study blocks, chewcards were deployed for 7 days, as above, and then collected and read, with leg-hold traps being deployed after the cards had been collected. The 200-m-long trap lines began at randomly selected points along each chewcard line, and followed the lines back toward (and sometimes past) the middle of the chewcard line. This ensured that the four individual trap lines within each cluster were always more than 200 m apart and therefore could be expected to provide more or less independent possum abundance indices.

For the three blocks not included in our trial, we used a layout of lines similar to that in the trial blocks with trap lines distributed in clusters of four, with 5–6 clusters (20–24 lines) per VCZ. No chewcard monitoring was conducted in these three blocks. In addition, 18 individual trap lines were randomly located in AS2 East to increase the precision of the RTCI because the CCI detection rate recorded there immediately after control (28%) was considered higher than desirable (see below).

All of the leg-hold traps used in the RTCI monitoring were set on the ground.

4.2.3 Ancillary investigations

Bait acceptance

In response to the relatively high post-control CCI recorded in AS2 East, a bait acceptance trial was conducted in that block to help assess what bait type might be best suited for early follow-up control if AHB operational staff considered that that was necessary, and to help interpret the greater than expected survival of possums in AS2E.

Bait acceptance was assessed 7 months after poisoning. Two 1.2-km-long bait acceptance lines were established in areas where surviving possums had been detected. A total of 120 baiting sites were established, with ~20 m between sites along the lines. At each site a chewcard was placed 20–30 cm above ground, and three different non-toxic baits were nailed 5 cm apart above the chewcard (i.e. so that the card was encountered first). The three bait types were cinnamon-lured 6–8-g RS5 bait, orange-lured 6–8-g Wanganui No. 7 bait, which was the type of bait used in the poisoning operation (both cereal baits from Animal Control Products, Whanganui), 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.

Possum and rat survival within riparian buffers

During the broadcast 1080 baiting in the Tihoi 3B VCZ, an effort was made to eliminate the risk of toxic bait being sown into a major waterway, the Waihaha River. A ‘riparian buffer’ was defined with the nearest flight path 150 m from the river. At the request of AHB, Hamilton, chewcard monitoring was carried out in this unbaited buffer immediately downstream from the Waihaha Hut, with the survey conducted 2 months after poisoning. The aim was to determine if a substantial number of possums remained in the unbaited area.

Eight lines separated by at least 150 m were established on the north side of the river, from start points on the toxic bait flight path nearest the water, and running directly toward the river. Chewcards were spaced at 25 m and lines varied in length from 200–325 m (9–14 cards per line). The three chewcards closest to the toxic bait flight path were deemed to have been within the 50–60-m swath that would have been baited along each side of that flight path. Chewcards were collected and read after 7 nights.

Incidental mammal sightings

Field staff recorded all encounters (including animals heard but not seen) with live deer, pigs, and goats, both before and after poisoning. After the poisoning, field staff also recorded all animals found dead during the course of their fieldwork, to complement work carried out in Section 4.3.

4.2.4 Data analyses

The relationships between the various indices used to assess possum and/or rat density were explored using simple linear correlation.

Indices measured over a week are designated as 7dCCIs, while those recorded over the varying long interval between pre-and post-control monitoring are designated (for convenience) as 80dCCIs. As the 80dCCI measurement interval included several weeks of exposure to pre-control pest abundance, these are presumed to largely reflect pre-control activity levels. For tracking tunnels, the indices were measured over a single night, so are designated as 1nTTIs.

Because a high percentage of cards or tunnels can be marked, the CCI or TTI indices are certain to be related non-linearly to pest abundance, in the same way (but more so because these indices are more prone to saturation [i.e.; approaching 100% at moderate pest densities) that the RTCI is (Forsyth et al. 2005). To partially reduce the effect of index saturation on estimates of understating high levels of pest abundance, these indices were usually transformed assuming an underlying Poisson (random) distribution of card encounters. As animal distribution and habitat use are usually clustered rather than random, however, reductions in the transformed indices are still likely to understate the true reduction in pest abundance.

As in previously reported trials conducted in this or related projects, the CCIs on some transects increased rather than decreased, resulting in spurious estimates of ‘negative’ kills for those individual transects. In some instances, a very low or zero pre-control CCI coupled with a low post-control CCI may result in very large (even infinite) negative ‘kills’; whereas where CCIs are lower after control kill estimates can only lie between 0 and 100%. The negative kills therefore often have a disproportionate influence on the mean. A modified index of <u>relative</u> change was therefore calculated for each transect by expressing the post-control Poisson-transformed 7dCCI as a percentage of the Poisson-transformed index-based numbers of chewcards that were bitten either before <u>and/or</u> after control (see Nugent et al. 2011a). This effectively expresses the post-control index as a percentage of the overall ‘occupancy’ recorded in both pre- and post-control surveys. In other words, of all the places where an animal was detected at any time, what percent were recorded after control? This ‘relative change in activity’ index (RCAI) is likely to overstate the actual reductions, but the upward bias will be very small whenever the reductions are very large and we consider it enables more robust comparison between treatments than the unmodified index.

The various treatments were compared (separately for each species) using the per-grid reduction in RCAIs as the dependent variable in a linear mixed-effect (LME) modelling approach (Pinheiro et al. 2012) in the R statistical computing environment (version 2.15.0) in which the bait sowing treatment was treated as a fixed effect, and block and transect as random effects.

Where appropriate, sampling error is presented as standard errors or, for binomially-based percentages, as 95% confidence intervals (95% CIs) calculated using the algorithms in Collet (1991).

4.3 Effect of strip sowing on deer repellent efficacy during aerial 1080 baiting

4.3.1 Study areas and design

This component of project R-10743 aimed to determine whether aggregating bait during aerial delivery of 1080 cereal pellets substantially increased non-target poisoning of deer, and whether the use of a deer repellent (EDR) was still effective when bait was aggregated. We therefore conducted an unreplicated two-way (strip vs broadcast; repellent vs non-repellent) trial using four blocks (Tihoi 3B, AS7W, AS6N, AS3; Table 1), with the intention of a second replicate being conducted elsewhere in future. Red deer are the predominant, if not the only, deer species present in the Hauhungaroa Range.

In each of these four blocks, we systematically searched for deer carcasses in two sub-areas, and used a simple mark–recapture technique to estimate the total number of deer carcasses within the searched areas, as in previous trials (Nugent et al. 2004; Morriss et al. 2005). For this, each area was searched twice, and an estimated search efficiency was derived by deploying deer-sized objects (paper sacks simulating deer carcasses; Morriss et al. 2005) during the first search and counting how many of those were found in the second search.

In an effort to account for differences in deer density between blocks and obtain some indication of the effect of deer by-kill on deer density, we also measured two indices of deer abundance while searching for carcasses. We measured deer faecal pellet abundance and the abundance of fresh deer tracks about 2–8 weeks after poisoning. Because faecal pellets take several months to disappear (Nugent 1990), most of the pellets recorded were probably deposited before poisoning, and so provided a measure of pre-poisoning deer abundance. In contrast, fresh tracks can only be a few days old, so reflect only post-poisoning deer abundance. Although the different indices cannot be directly compared (because they measure different things) we assumed that each is correlated to deer abundance (i.e. that the index can be used to predict deer abundance by some constant but unknown regression equation). If so, and all else being equal, a lower than average ratio of tracks to pellets in a block suggests deer densities may have been reduced there.

4.3.2 Field protocol

In each block, two 163-ha search grids were established (Appendix 2). The grids were centrally located within the blocks to minimise the chances of finding carcasses of deer that had moved between areas subjected to different baiting regimes. Each grid was searched twice 2–8 weeks after poisoning, using 2–4 observers for each search travelling along more-or-less parallel fixed-bearing transects. The transects used for the second search were at right angles to those used for the first search. During the first search of each grid, individually-numbered litter-filled deer-sized brown paper bags were placed at 100-m intervals along transects, to simulate deer carcasses.

Observers recorded the details (age class, sex, and location) of each deer found dead, collected jawbones for ageing, and took muscle samples (~50 g). In addition, the location and number of any dead possums, rats, mice and birds found was recorded. The bird carcasses were identified by species, and retained (see section 4.4.1). The deer muscle samples and bird carcasses were frozen as soon as possible, and subsequently analysed by the Landcare Research Toxicology Laboratory for 1080, using Method TLM 005 (with a method detection limit of 0.001 mg/kg).

While traversing the carcass-search transects, observers recorded the presence or absence of fresh tracking by deer on every 100-m segment along each transect. A total of 1725 100-m-long segments were assessed. Observers also searched two 1.14-m-diameter plots (centred 2.5 m on either side of the transect) at 100-m intervals along these transects, and recorded the presence or absence of intact faecal pellets of deer, pigs, and possums. A total of 3450 plots were searched. This presence/absence method was chosen simply because it has been more widely used historically than other measures of faecal pellet abundance (e.g. see fig. 1 in Nugent & Fraser 1993). Observers also recorded the number and location of live deer and pigs seen or heard.

4.3.3 Data analyses

As we expected to find few dead deer, we used our ability to find sacks to estimate dead deer detection probabilities. We assumed that the probability of detecting a deer carcass in the first search (D_1) was the same as in the second search (D_2), and used the proportion of the sacks found during the second as a proxy for both probabilities (i.e. $D_1 = D_2 = S_2/S_1$, where S_1 is the number of sacks deployed during the first search, and S_2 is the number of those found during the second search). If so, the joint probability of a deer carcass being found in any of the searches (D_{Total}) can be calculated as: $D_{Total} = 1 - [(1 - S_2/S_1)^2$. The total number of deer carcasses in each block was then calculated as follows: Total number of carcasses = Number of carcasses found / D_{Total}.

Confidence limits for the deer carcass estimates were estimated by combining the appropriate binomial confidence intervals for the proportion of sacks *not* found in the respective searches.

4.4 Monitoring forest birds during aerial 1080 baiting

4.4.1 Study approach and design

As for deer deaths, we aimed to assess whether aggregated sowing of 1080 cereal bait in strips resulted in a marked increase in non-target bird deaths, and whether that was affected by use of EDR. We used two approaches: (1) comparison of indices of bird abundance before and immediately after poisoning as evidence of major declines potentially attributable to poisoning; and (2) searches for bird (and small mammal) carcasses both during the systematic grid searches above (section 4.3.2) and during the course of all other immediate-post-poisoning fieldwork, to provide direct evidence of bird deaths.

The widely used Five-minute Bird Count technique (5mbc; Dawson & Bull 1975) was chosen as both suitable for our purposes and practically feasible and affordable in the dense forests of the Hauhungaroa Range. It was selected after a preliminary field visit in February

2011, and discussion between Landcare Research (J. Innes) and DOC staff (T. Greene) with expertise in assessing changes in bird abundance.

As for deer deaths, an unreplicated 3 × 2 design was used, with the expectation that partial or full replication would be conducted in future. We compared three of our sowing protocols (broadcast, 100-m-FPS strip, and 150-m-FPS strip) and two repellent treatments (with and without EDR) (Table 1). In addition, we accounted for seasonal changes in bird detectability not related to poisoning (i.e. changes in calling behaviour or visibility, and/or natural changes in abundance) by collecting 5mbc data from two nearby unpoisoned areas (Table 1), but we note that these were more similar to some poisoned blocks than others.

4.4.2 Field protocol

In each of the eight '5mbc' blocks (see Table 1 & Appendix 2), a series of parallel transects spaced 200 m apart was established, and five-minute counts were made at count stations spaced at 200-m intervals along those transects. During each five-minute count, all birds seen or heard within 100 m of the stationary observer were recorded. As far as practicable, the same observers conducted both the pre- and post-control counts in each block.

A count was conducted once at each station between 4 May and 16 June 2011 (2−10 weeks before poisoning depending on the block), and again between16 June and 29 September 2011, 3−8 weeks after poisoning depending on the block. The variation in the duration of the intervals before and after poisoning reflects the progressive coverage of the area by aerial baiting as windows of fine weather occurred.

As far as possible, poisoned blocks were paired with non-treatment areas with similar topography and vegetation (Tihoi 3B with Tihoi 3A non-treatment, and all other blocks with the Waipari non-treatment). The Waipari non-treatment site was counted twice post-poisoning so that it could be paired with the blocks that were poisoned, and therefore counted, at different times.

5 Results

5.1 Overall operational outcomes and ancillary findings

5.1.1 Overall operational outcomes

Although completed last, the operational RTCI monitoring-and-index-calibration results are presented first to provide context for interpreting the more detailed results below.

A total of 214 RTCI trap lines was surveyed (6262 trap-night). An overall RTCI of 0.7 ± 0.1% was recorded. RTCIs were below 1% in seven of the nine VCZs monitored, 1.3% in AS3, and 2.0% in AS2 overall (eastern and western blocks combined) (Table 2). Within AS2, the RTCI recorded in the eastern study block (AS2 E) was 2.5%, with captures of up to four possums on a single trap line in this block.

Table 2 Possum monitoring outcomes in the Hauhungaroa Ranges 2011–12. Data shown are the VCZ codes and the treatments applied (EDR or not; FPS; toxic bait sowing rate) within them (refer to Table 1 for greater detail), the Chewcard Indices recorded immediately and 6–8 months after control, and the number of trap lines and RTCI indices recorded 6–8 months after control. The RTCIs recorded in western VCZs during an AHB trend monitor in 2010 are also shown. The bracketed figures in the No. trap lines colum indicate the number of additonal 'operational' trap lines surveyed over and above those surveyed as part of this project.

Block and treatment	Immed. post 7dCCI	6–8 m post 7dCCI	No. trap lines	2012 RTCI 6–8 m post	2010 RTCI trend
AS1 Broadcast EDR, 180 m, 1000 g/ha	-	-	20 (20)	0.3% (± 0.5%)	0.7%
AS2 E Strip NR, 150 m, 666 g/ha	28%	22%	34 (18)	2.5% (± 1.4%)	}0.0%
AS2 W Strip NR, 100 m, 1000 g/ha	1%	0%	16	1.3% (± 1.1%)	
AS3 Strip NR, 100 m, 700 g/ha	8%	8%	16	1.7% (± 1.2%)	0.4%
AS4 Strip NR, 150 m, 462 g/ha	9%	1%	16	0.00%	0.0%
AS5 Broadcast NR + EDR, 180 m, 2000 g/ha	-	-	24 (24)	0.1% (± 0.3%)	0.4%
AS6 N Strip EDR, 100 m, 700 g/ha	3%	1%	16	0.2% (± 0.5%)	}0.4%
AS6 S Strip EDR, 150 m, 462 g/ha	0%	0%	16	0.00%	
AS7 W Broadcast EDR, 180 m, 1500 g/ha	4%	7%	16	0.9% (± 1.1%)	0.3%
T3B Broadcast NR, 180 m, 1500 g/ha	1%	2%	20 (4)	0.3% (± 0.5%)	-
T4 Broadcast NR + EDR, 180 m, 1500 g/ha	-	-	20 (20)	0.3% (± 0.5%)	-

5.1.2 TB prevalence in deer and pigs

During the course of this and related projects, a total of 37 deer and 9 pigs were necropsied, mostly from AS2 (16 deer, 7 pigs) or AS3 (21 deer). These were either killed by hunters or found dead but still in a necropsiable state. None had lesions typical of TB, and no *Mycobacterium bovis* bacilli have been detected in any of the 31 deer and 2 pigs for which the final results from culture (of retropharyngeal or submaxillary lymph node tissue samples) are so far available.

5.1.3 RTC and CC Index calibration

For the eight study blocks in which four grids of paired chewcard-and-trap transects (total n = 128) were surveyed, there was a significant but weak positive correlation between the 7dCCIs and the RTCIs recorded on individual lines ($r^2 = 0.28$, d.f. = 126, $P < 0.001$). The weakness of the correlation appears to result from the high frequency of detection with no capture, or capture with no detection on individual lines. For any one line, for example, a single possum might be responsible for biting three successive chewcards (30% 7dCCI) but not be captured (0% RTCI). Possums were detected and/or trapped on 40 lines (31% of the total of 128) but, while they were detected on 30 lines, they were trapped on just 14 of those, while on 10 lines possums were trapped but not detected (i.e. possums were trapped on 24 lines). Half (5) of the capture-but-no-detection lines were in AS2 W, where six possums were captured, but there were no detections at all (even though possums had been detected on three lines immediately after control).

There was a much stronger correlation between the indices at block level (i.e.; with data pooled for the four grids (16 lines) per block) ($r^2 = 0.80$, d.f. = 6, $P = 0.002$) (Figure 2a). The correlation was even stronger with the anomalous AS2 W outlier removed ($r^2 = 0.96$, d.f. = 5, $P < 0.001$l; Figure 2b). Assuming a zero intercept, the slope of the regression of 7dCCI on RTCI varied from a multiplier of 5.5 when all blocks and all cards were included to 7.2 when the AS2 W block was excluded and only chewcards not bitten by rats were included (Figure 2d). These results indicate that for groups of 16 lines, 7dCCIs in the Hauhungaroa Range are likely to be about 6–7 times higher than RTCIs.

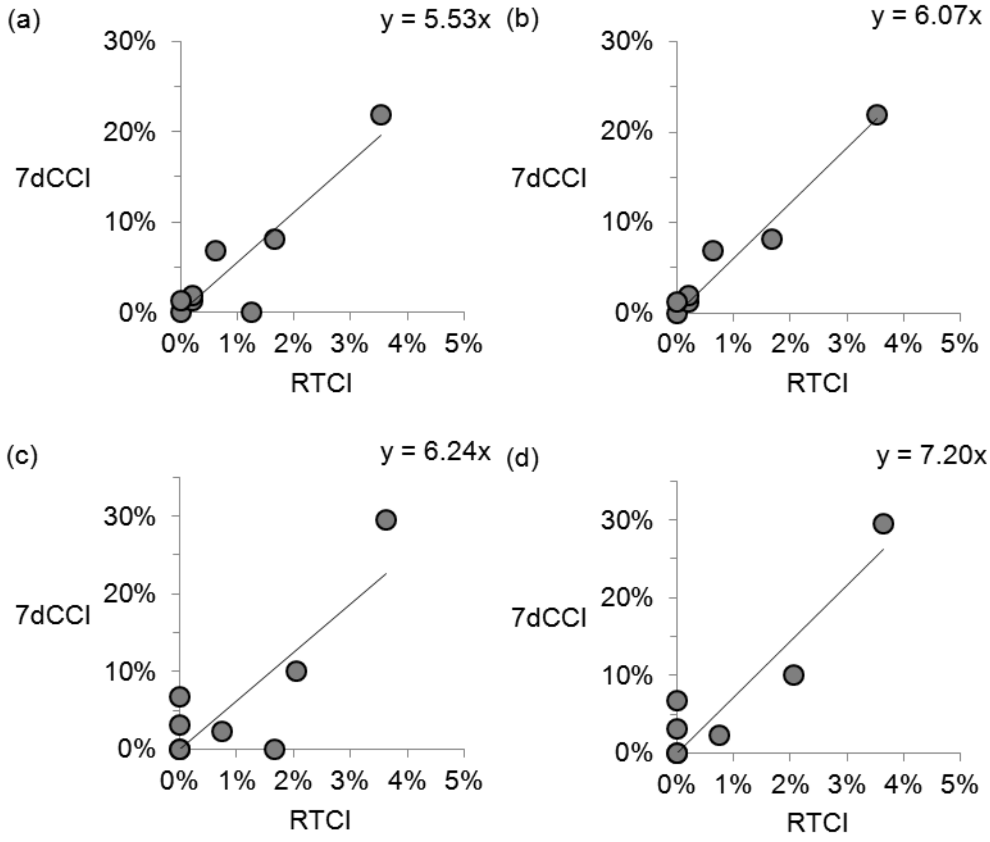


Figure 2 Relationships between 7-day Chewcard Indices (7dCCIs) and nightly trap-catch rates (RTCIs) from 2–3 nights of trapping. Data are the means for each study block (i.e. pooled across four grids of four lines on which 160 of each device were deployed, resulting in 1120 chewcard nights and 320–480 trap-nights per block). The relationship between the two indices is shown with (a) all blocks and all cards included; (b) with the AS2 W outlier excluded, but all cards included; (c) all blocks but only cards not chewed by rats included; and (d) with the AS2 W outlier excluded, and only rat-free cards included. Exclusion of rat-chewed cards usually produces a higher possum 7dCCI because rats may remove the attractant bait before possums find the card, or rat chewing may obscure possum bite marks.

5.1.4 Short-term post-control change in possum 7dCCI

The 7dCCIs recorded for possums 6–8 months after control were closely correlated with those recorded immediately afterward ($r^2 = 0.87$, d.f. = 6, $P = 0.002$; Figure 3a). There was one exception, with 14 chewcard detections on seven separate lines in AS4 immediately after control but just two detections 6–8 months later. Removing that outlier, the 7dCCIs recorded 6–8 months later were 81% of the immediate post-control indices (Figure 3b), but this probably partly reflects a rat effect as the immediately-post and 6–8-month-post indices were similar on the subset of cards not chewed by rats (Figure 3c, d).

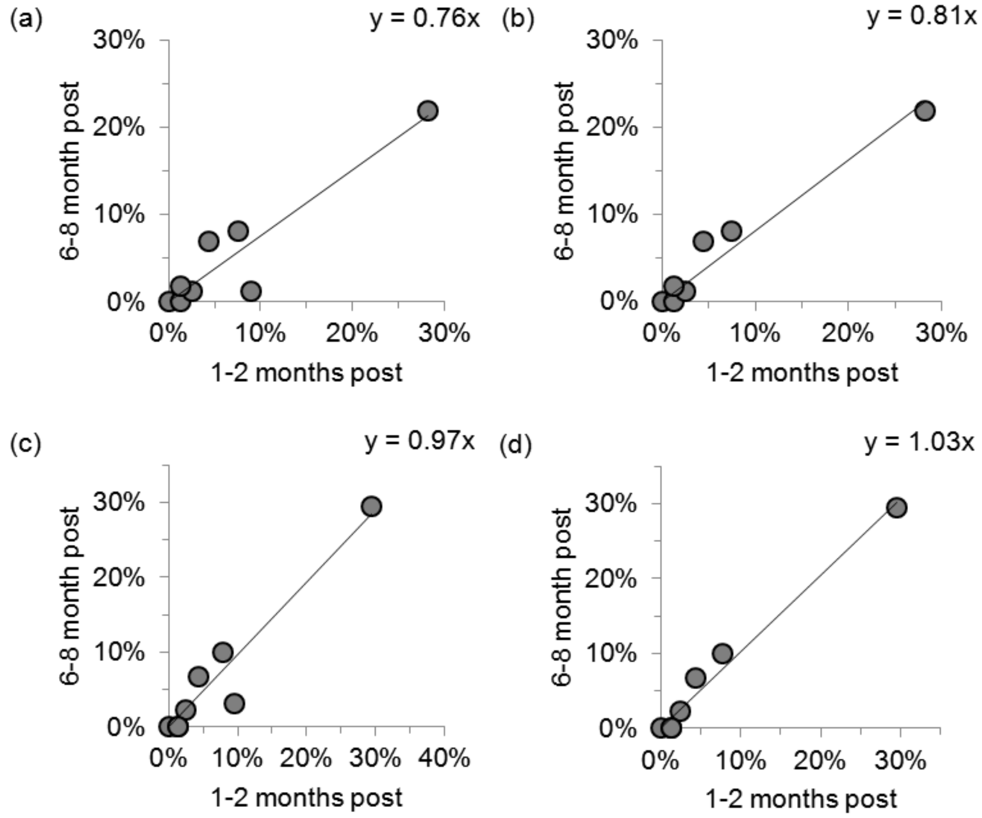


Figure 3 Relationships between the post-control Chewcard Indices (7dCCIs) recorded 6–8 months after control and those recorded immediately after control. Data are the means for each study block using the same set of four grids of four lines in each survey (1120 chewcard nights per block per survey). The relationship between the two indices is shown with (a) all blocks and all cards included; (b) with the AS4 outlier excluded, but all cards included; (c) all blocks but only cards not chewed by rats included; and (d) with the AS4 outlier excluded, and only rat-free cards included**.**

5.1.5 Bait acceptance after comparatively high possum survival (AS2 E)

In the AS2 E block in which the immediate post-control CCI was much higher than in any other block (see Section 5.2.1), possums were confirmed present (by bite marks on chewcards) at just six (5%) of the 120 bait acceptance sites set up in early 2012 to determine whether survivors were shy of cereal bait. Rats were also detected at five of these sites. Averaged across the six sites, 100% of the cinnamon-lured RS5 bait, 75% of the orange-lured Wanganui No. 7 bait, and 58% of the carrot bait had been eaten.

Rats were detected on chewcards at 55% and mice on 68% of the 120 baiting sites. Over all baiting sites 74% of cinnamon-lured RS5 bait, 46% of orange-lured Wanganui No. 7 bait, and 7% of carrot bait was eaten.

5.1.6 Possum and rat survival within riparian buffers

There was no evidence that large numbers of possums survived in the riparian buffer alongside the Waihaha River despite some parts of that buffer being up to 325 m from the nearest flight path sown with toxic bait. There were only two possum detections on the 89 chewcards deployed (2.2%), both within 25 m of the nearest flight path. The detections were only 195 m apart so could have been the same possum.

Rats were detected on 27% of the cards, with the 7dCCI increasing from 18% on the 32 cards less than 100 m from the nearest flight path to 31% on cards 100–200 m away, and 34% on more distant cards. However, this weak positive correlation between 7dCCI and distance from flight path was not statistically significant ($r^2 = 0.12$, d.f. = 11, $P = 0.16$).

5.2 Comparison of strip and broadcast sowing for aerial 1080 baiting

5.2.1 Possums

For possums, the 7dCCIs in the eight study blocks varied widely before control (range 2.5–47.5%). The Poisson-transformed long-run 80dCCIs were mostly about 1.8 times higher than the 7dCCIs, but almost 3 times higher in the AS2 E block (Figure 4a), indicating higher possum abundance there than inferred from the 7-day index. The AS2 E 7dCCI index was therefore ‘corrected’ using the relationship in Figure 4b.

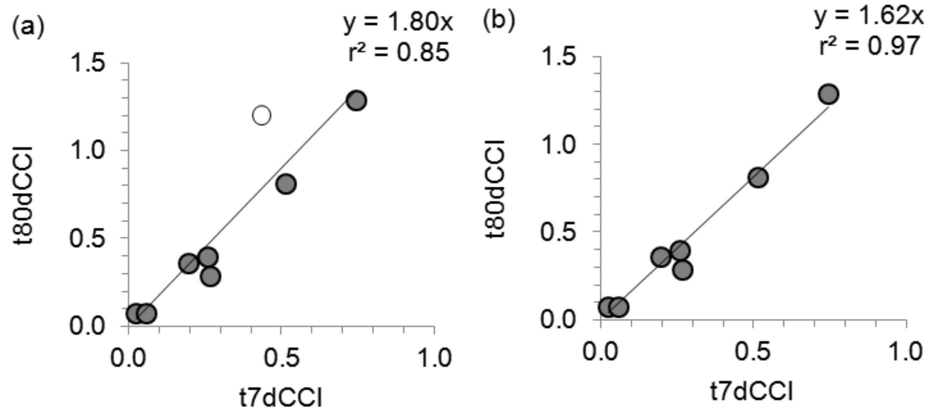


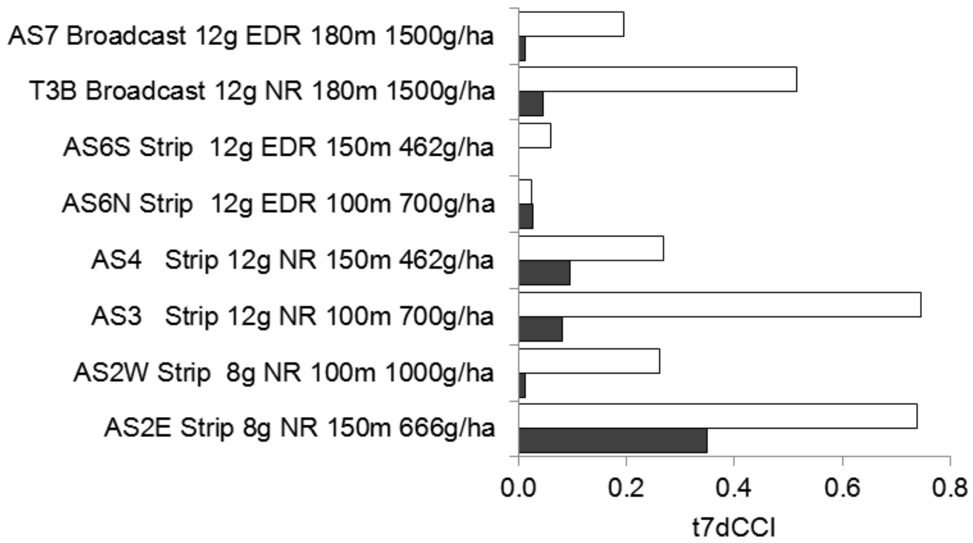
Figure 4 Relationships between the Poisson-transformed long-run Chewcard Indices (t80dCCIs) recorded for the ~80 day interval between pre- and post-control monitoring against those recorded over a one-week interval before control (t7dCCIs). Data are the means for each study block using the same set of four grids of four lines in each survey. The relationship between the two indices is shown with (a) all blocks; (b) with the AS2 outlier (the empty circle in (a)) excluded.

Immediately after control, the 7dCCI were all below 10% except in AS2 E (Figure 5). Assuming a 6–7 times RTCI-7dCCI multiplier (section 5.1.3), these figures suggested post-control RTCI's would have been below 1% in most blocks, but 1–2% in AS3 and AS4, and ~5% in AS2 East. That prediction is consistent with, but slightly higher than the RTCI outcomes recorded 6–8 months later, except that a RTCI of 0% was recorded in AS4 rather than the 1–2% predicted (Table 2).

The indices of relative change in possum abundance take into account pre-control abundance, but in the two AS6 blocks, pre-control densities were too low (Figure 5a) to expect meaningful estimates of change so the relative change in activity indices (RCAIs) for those two blocks should be ignored. For the remaining blocks, the RCAIs indicate large reductions in both broadcast blocks, and in the two blocks strip-sown with 100-m FPS, but poorer reductions in the two blocks strip sown at 150-m FPS.

The similar RCAIs for Tihoi 3B and AS7 suggest using EDR with broadcast bait did not affect efficacy against possums. As already noted, there were too few pre-control data in the two AS6 blocks to allow any parallel inference for strip sowing. High pre-control abundance of either possum or rats also had no negative effect on the possum RCAI, with non-significant positive correlations for both ($r^2 = 0.005$, d.f. = 29, $P = 0.68$ and $r^2 = 0.009$, d.f. = 30, $P = 0.60$ respectively).

(a) Pre- and Post-control indices



(b) Relative change in abundance

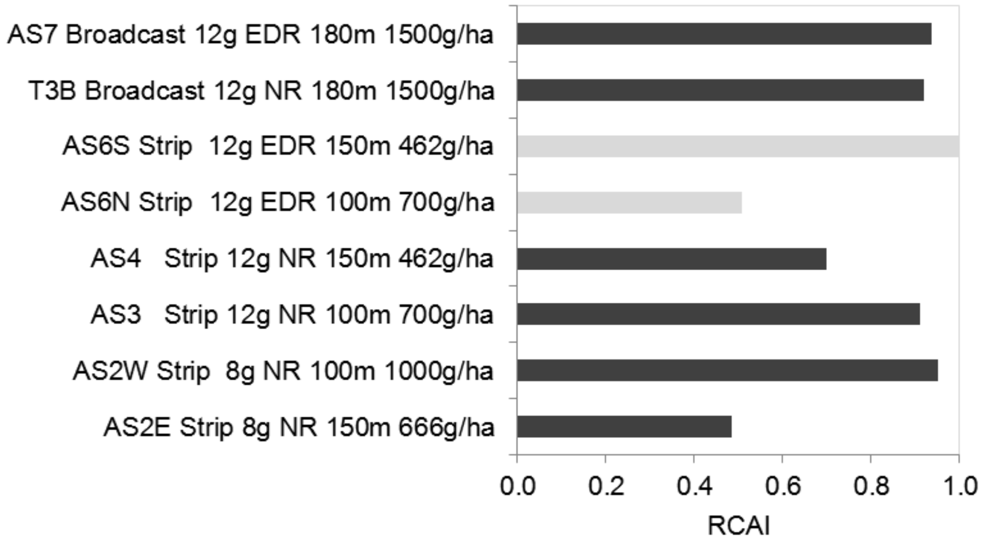


Figure 5 Changes in possum abundance, as shown by (a) the changes in the Poisson-transformed 7-day CCI between pre- and post-control surveys (open and filled bars respectively), and (b) the relative change in activity indices (RCAI; see Methods, Section 4.2.5). The RCAIs should not be intepreted as equivalent to percentage reductions, but rather indicate the rank order of relative reductions. The RCAIs for the two AS6 blocks (shown in grey in (b)) are considered unreliable because of the very low pre-control CCIs in those two blocks.

5.2.2 Rats

Before control, the 7-day Chewcard Indices of rat abundance were closely correlated with but lower than the 1-night Tracking Tunnel Indices, despite the seven-times-longer monitoring interval (Figure 6a, b; $r^2 = 0.86$, d.f. = 6, $P = 0.001$ for the block-level relationship). After control, the relationship was weaker, and the 7dCCIs were substantially higher than the corresponding 1nTTI (Figure 6c, d; $r^2 = 0.80$, d.f. = 6, $P = 0.002$ for the block-level relationship), but most of the increase was attributable to two grids in the AS4 block where over half of the post-control cards were chewed. With the AS4 data excluded, the two indices were only weakly correlated ($r^2 = 0.47$, d.f. = 7, $P = 0.09$).

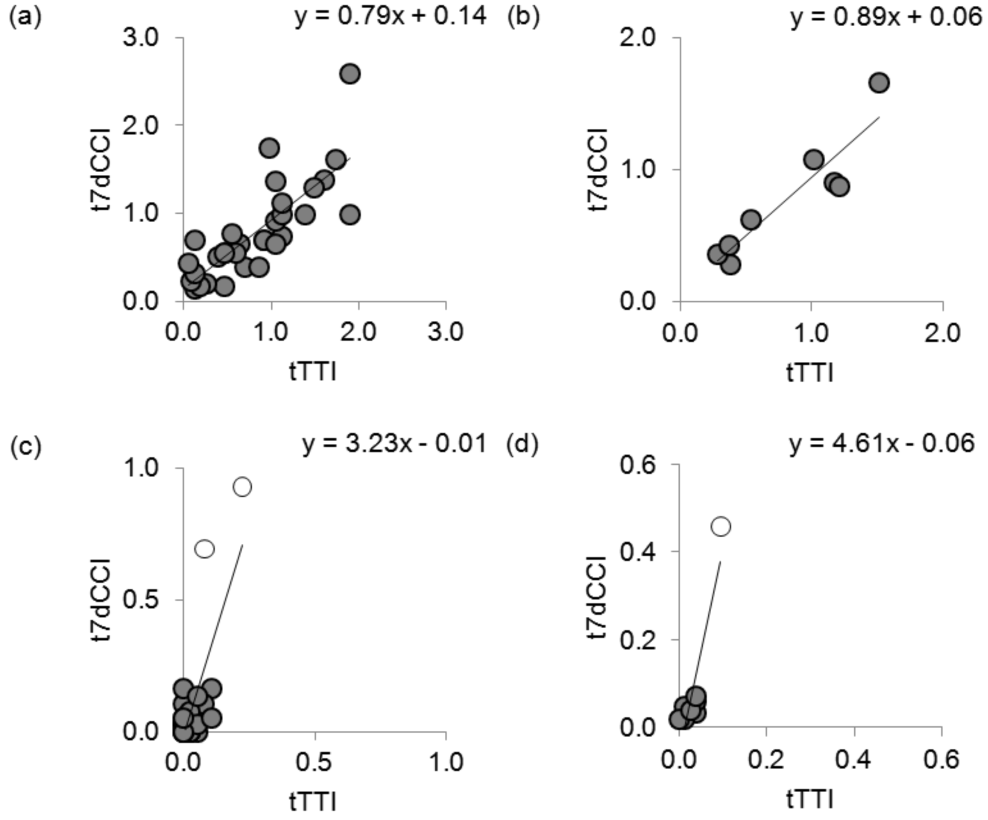
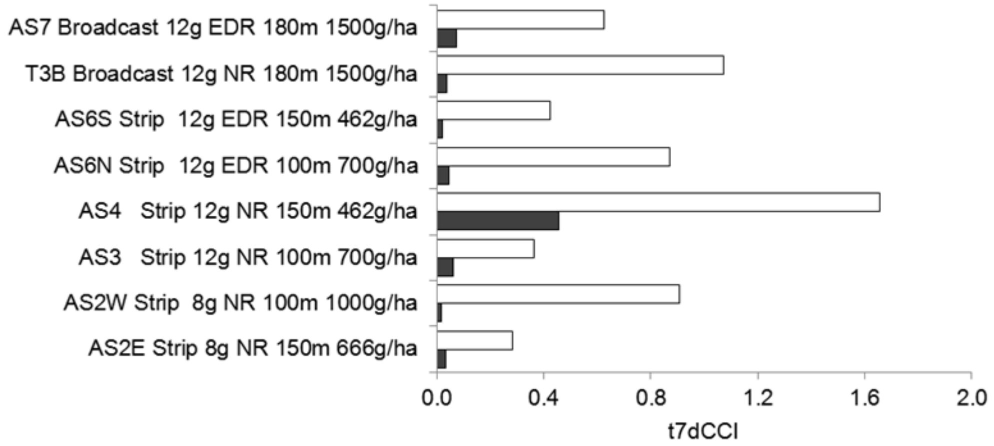


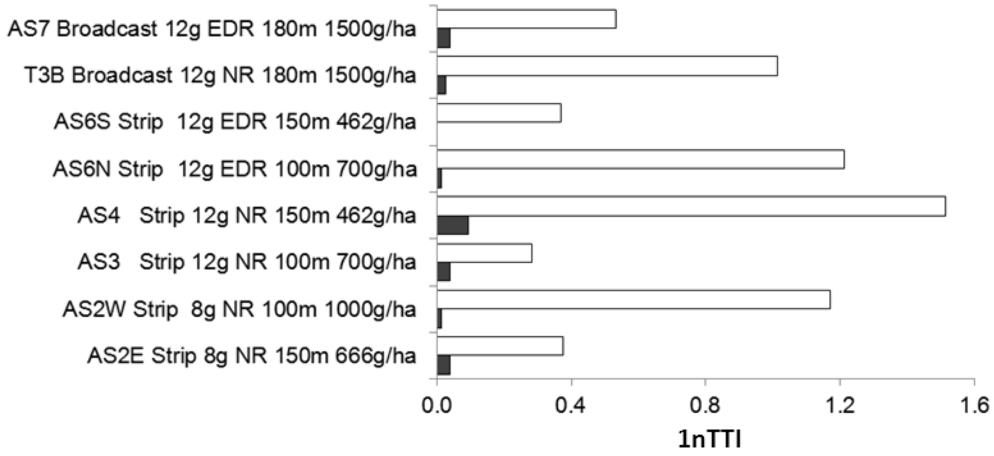
Figure 6 Relationships between Poisson-transformed 1-night Tracking Tunnel Indices (tTTIs) and 7-day Chewcard Indices (t7cCCIs) of rat abundance for (a, c) each of the 32 grids of four monitoring lines (40 devices), and (b, d) each of the eight blocks surveyed. The top row of graphs (a, b) are for the pre-control surveys and the bottom row (c, d) are for immediate post-control surveys. In the latter the two grids in the AS4 block in which the post-control CCI were well above average are shown as empty circles.

Before control, rat abundance was moderate, with an overall 1nTTI of 49.2% (range 23.8–76.9%) and a 7dCCI of 48.5% (range 23.1–78.6%) (Figure 7a, b). After control, rat survivors were detected at low levels in all blocks, but with exceptionally high survival in AS4 (Figure 7a, b). That high survival largely reflected particularly high rat abundance in AS4 before control, as the relative change in rat activity for that block was similar to that recorded in two other strip-sown blocks (AS3 and AS2E) (Figure 7c). In the remaining five blocks (two broadcast, three strip-sown) the reductions were all large.

(a) Pre- and Post-control CC indices



(b) Pre- and Post-control TT indices



(c) Relative change in abundance

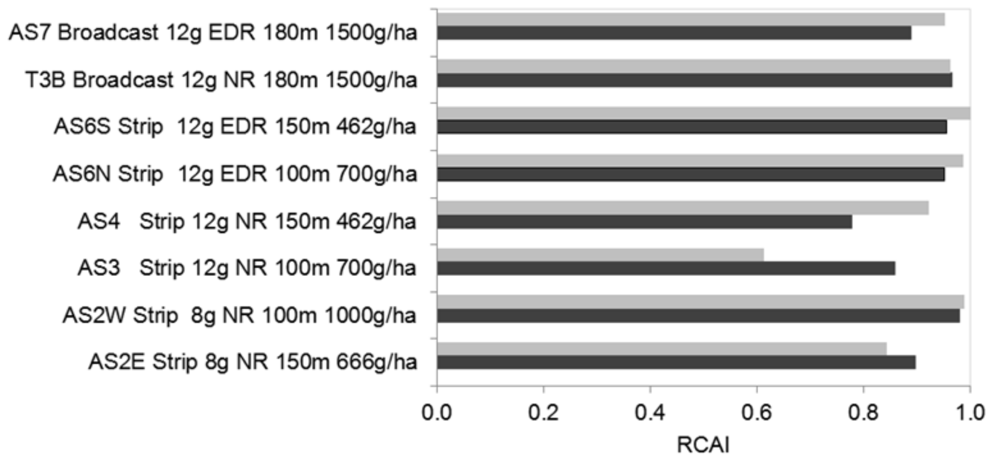


Figure 7 Changes in rat abundance, as shown by (a) the changes in the Poisson-transformed 7-day CCI and (b) 1-night TTIs between pre- and post-control surveys (open and filled bars respectively), and (c) the relative change in tracking tunnel and chewcard activity indices (grey and black bars respectively). The RCAIs should not be intepreted as equivalent to percentage reductions, but rather indicate the rank order of relative reductions.

Rat abundance increased quickly after control, with an overall 7dCCI of 67.0% 6–8 months after control compared with 7.5% immediately afterward. The 7dCCI 6–8 months after control was not correlated to the post-control index, regardless of whether or not the block with an exceptionally high post-control index was included (Figure 8a, b).

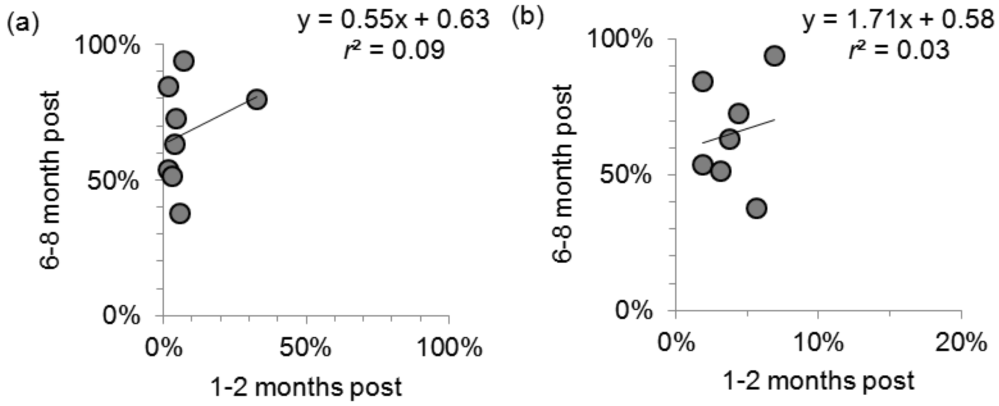


Figure 8 Relationships between the post-control rat Chewcard Indices (7dCCIs) recorded 6–8 months after control against those recorded immediately after control. Data are the means for each study block using the same set of four grids of four lines in each survey (1120 chewcard nights per block per survey). The relationship between the two indices is shown with (a) all blocks included; (b) with the AS4 outlier (which had a much higher than average 7dCCI imeediately after control) excluded.

By late summer 2012 (6–8 months after control), the 7dCCIs were about one-third higher than those recorded in Autumn 2011 (pre-control). At the block level, there was no correlation between these two surveys (r^2 = 0.12, d.f. = 6, P = 0.39). At the level of individual ~60-ha monitoring grids, however, there was a signficant positive relationship (r^2 = 0.34, d.f. = 30, P < 0.001; Figure 9).

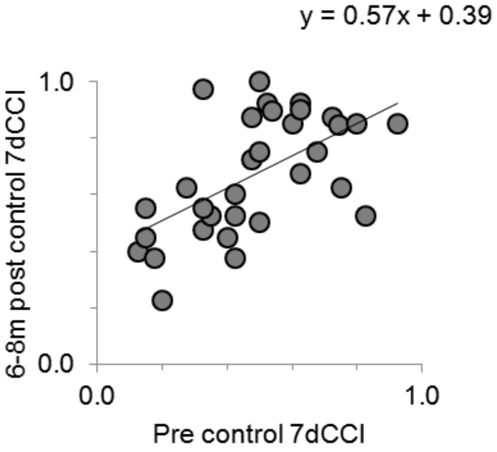


Figure 9 Relationship between the 7dCCIs recorded on individual montoring grids (40 chewcards per grid) before control in Autumn 2011 and that recorded 6–8 months after control in Summer 2012.

5.3 Effect of strip sowing on deer repellent efficacy during aerial 1080 baiting

5.3.1 Deer deaths on systematically searched grids

The index of deer faecal pellet abundance recorded immediately after control (which we used as an index of pre-control abundance) was moderately high (overall mean = 25.7% of plots with faecal pellets present) and broadly similar between the four blocks (range 21.1–31.0%; Table 3). However, a large number of sightings in AS3 before and after control suggests deer numbers were probably highest there (Tables 3 and 4).

No dead deer were found during systematic searches in the four grids in which deer repellent was used, but 15 were found in the four grids in Tihoi 3B and AS3 (six and nine dead deer, respectively) where no repellent was used. One deer in Tihoi 3B had no detectable 1080 and one deer in AS3 was fully scavenged by pigs so insufficient tissue remained for residue analysis – both were removed from further data analyses.

A further 27 deer were found dead in these and other blocks during the course of other work, all in blocks in which no repellent was used (Table 4). Of the 42 deer found dead four had been scavenged by pigs leaving too little material for muscle tissue sampling. Subsequent laboratory analysis identified 0.003–2.6 mg/kg of 1080 in 37 of the deer (mean = 0.74 mg/kg), indicating almost all had been poisoned. The age of dead deer found ranged from 6–8-month-old fawns to a hind > 6 years old, but the majority were less than 3 years old (Appendix 3).

In the systematically searched grids, 18.3–30.1% of the ~100 sacks deployed in each were found, depending on the block. Assuming the same block-specific search efficiency was achieved for deer carcasses in both searches of each grid, we estimate that approximately 3 and 7 deer/km^2 were killed in the broadcast- and strip-sown blocks (T3A and AS3 respectively; Table 3). Despite that, fresh tracks were still common in these two blocks after poisoning, and the total number of deer seen in these blocks was the same before and after poisoning (combined total of 19 each time; Table 3).

5.3.2 Incidental observations of deer (and other large mammals)

Across the eight main trial blocks, project staff engaged in other monitoring recorded live sightings of 40 deer, 7 pigs and 12 goats during the pre-control surveys (104 field-days), 67 deer, 23 pigs and 38 goats during the immediate-post-control surveys (248 days, including the systematic carcass searches), and 68 deer, 35 pigs and 36 goats 6 months later (168 days; Table 4). The sighting rate recorded for deer declined from 0.37 per day before control to 0.27 per day immediately afterward, but then rose to 0.40 per day after 6 months. The proportion of total deer sightings recorded in the three blocks treated with EDR repellent increased from 17.5% (7/40) before control to 29.4% (20/68) 6–8 months after control, but the difference was not significant (Pearson chi-square= 1.91, d.f. = 1, $P = 0.16$).

No pigs or goats were found dead, and the overall numbers of these species sighted after control were higher than before control (Table 4).

Table 3 Outcomes of systematic searches for deer carcasses. Numbers of deer seen alive or found dead during two searches of 3.2-km^2 sub-areas in four blocks following aerial application of cereal 1080 baits (two with and two without deer repellent) in Winter 2011. Also shown are the numbers of paper bags (simulated deer carcasses) deployed in the first search of each block, the percentage of those found during subsequent searches, the percentage detection estimated from all searches, the estimated total number and density of dead deer in each block, and the various tracking and pellet count indices recorded.

Vector Control Zone	T3B	AS3	AS7 W	AS6 N
Sowing method	Broadcast	Strip	Broadcast	Strip
Treatment	No repellent	No repellent	Repellent	Repellent
No. of sacks deployed	208	206	208	208
% sacks found in the 2nd search	30.8	20.0	18.3	23.1
Estimated % of area covered	52.1	36.0	33.2	40.8
No. of dead deer found	5[1]	8[2]	0	0
Estimated total dead deer	**9.6**	**22.2**	**0**	**0**
Density of dead deer (per km^2)	2.9	6.9	0	0
Frequency (%) of plots with deer pellets present (= pre)	31.0	26.5	24.1	21.1
Ratio of dead deer density: pellet frequency	**0.09**	**0.29**	**0.00**	**0.00**
% of 100-m segments with fresh deer tracks (= post)	43.5	57.8	47.1	52.0
Ratio of post (= % tracks) to pre (= % pellets)	**1.40**	**2.18**	**1.95**	**2.46**
No. live deer seen before control	2	17	4	3
No. live deer seen after control	11	8	3	5

[1] No 1080 was detected in one other deer found dead in this block so it was not included in the dataset.

[2] One additional carcass was found in this block, but had too little tissue remaining to analyse for 1080 presence, so it was also excluded from the dataset.

Table 4 Deer, pig and goat sightings prior to and after aerial 1080 baiting, Hauhungaroa Ranges, Winter 2011. No repellent = standard 1080 bait; EDR = Epro deer repellent 1080 bait.

VCZ	AS2 W	AS2 E	AS3	AS4	AS6 N	AS6 S	AS7 W	T3B
Repellent	No repellent	No repellent	No repellent	No repellent	Repellent (EDR)	Repellent (EDR)	Repellent (EDR)	No repellent
No. deer seen alive before control	6	1	17	7	3	0	4	2
No. deer seen alive immediately after control	6	5	26	0	10	1	7	12
No. deer found dead immediately after control	8	1	22	1	0	0	0	10
No. deer seen alive 6–8 months after control	4	14	24	0	4	3	13	6
No. pigs seen alive before control	0	0	0	0	0	0	7	0
No. pigs seen alive immediately after control	2	14	1	0	1	0	0	5
No. pigs found dead immediately after control	0	0	0	0	0	0	0	0
No. pigs seen alive 6–8 months after control	0	2	13	0	7	5	0	8
No. goats alive before control	0	0	0	0	10	0	2	0
No. goats alive immediately after control	0	0	1	0	21	0	16	0
No. goats found dead immediately after control	0	0	0	0	0	0	0	0
No. goats seen alive 6–8 months after control	1	1	3	0	23	3	5	0

5.4 Effect of strip sowing and deer repellent on non-target birds

5.4.1 Birds (and small mammals) found dead

Across the eight main trial blocks (and the two unpoisoned areas), project staff engaged in monitoring found no dead birds or small mammals before poison baiting, 11 dead birds and 102 dead small mammals immediately after control (Table 5), and none 6–8 months after control. These were mostly possums (60) and rats (38), but also three hedgehogs, one mouse, six blackbirds, four kererū, and one fantail. Two of the kererū had obvious signs of predation, and the fantail was found freshly dead after a heavy snowfall.

No 1080 residue was found in any of the five native birds, but 1080 was present in five of the six blackbirds at concentrations of 0.27–1.73 mg/kg (MDL = method detection limit of 0.001 mg/kg).

Table 5 Birds and small mammals found dead after aerial 1080 baiting, Hauhungaroa Ranges, Winter 2011. Observations were made during the course of other monitoring work, with a greater number of field days spent in blocks in which both chewcard surveys and deer carcass searches were conducted (AS3, AS6N, T3B, AS7 W) than in the remainder. No repellent = non-repellent 1080 bait; EDR = Epro deer repellent 1080 bait.

VCZ	AS2 W	AS2 E	AS3	AS4	AS6 N	AS6 S	AS7 W	T3B
	No repellent	No repellent	No repellent	No repellent	Repellent (EDR)	Repellent (EDR)	Repellent (EDR)	No repellent
Possum	6	9	22		2	1	15	5
Rat		1	17	4	6	1	3	6
Hedgehog		2					1	
Mouse			1					
Kererū			1		1		1	1
Blackbird			4		1			1
Fantail					1			

5.4.2 Effect on bird counts

Overall

Across all surveys, 33 species of bird were recorded during five-minute bird counts, comprising 20 native and 13 introduced species (Appendix 4).

The most common species recorded were tūī (1.82 per count) and silvereye (1.67 per count), both ~2.5 times higher than the next most common species (tomtit; 0.70 per count). Whitehead, kererū, grey warbler, bellbird, and robin were the next most commonly recorded, followed by a group of three introduced species (chaffinch, thrush and blackbird), then fantails, rifleman, introduced greenfinch, parakeet species and kākā. The remaining 15 species were either recorded on less than 1% of counts or are considered not to be forest birds.

The overall all-species mean count (per 5 min) was 7.9 per count, (9.1 per count before control, 7.0 per count after control; including unpoisoned non-treatment blocks). For the six poisoned blocks, the pre-and post-control averages per block were 9.1 and 6.8 per count, respectively, compared with 8.6 and 7.4 per count respectively across the three pairs of counts completed in unpoisoned areas.

By species

There were no major declines of any bird species across all poisoned blocks and also in both of the unpoisoned blocks. There were, however, major changes, both increases and decreases, in the counts of some individual species, with patterns that varied widely between blocks (Appendix 5).

For silvereye (Figure 10a), counts before and after poisoning were similar in the two broadcast blocks, but lower in the four strip-sown blocks, especially in AS6 S. In the three-times-counted unpoisoned Waipari (WP) block, mean 5mbcs increased from 1.8 per count in May to 2.8 per count in August 2011, but then fell to 1.5 per count in September 2011, indicating seasonal variation in this species. The highest AS6 S block aside, silvereyes remained the first or second most commonly counted species in all blocks after control.

For tūī, the pattern was similar, with little change in the two broadcast-sown blocks, but with declines in the strip-sown blocks, with the largest reduction again recorded in AS6 S. However, there was also a large decline in tūī counts in the unpoisoned WP area, especially between August and September 2011(Figure 10b).

For the remaining 14 most common forest species, overall counts were mostly lower in winter (June, August, and September 2011) than in autumn (May 2011), as shown in the post- vs pre-control trend-line slopes of <1 in Figure 11. The trend-line slopes were similar or higher in individual poisoned areas compared to those for the matching unpoisoned block surveyed at the same time (Figure 11).

Visual inspection of these pre-vs-post plots was used to identify (and label in Figure 11) species in which post-control counts appeared to be lower than the overall average. In the three post control counts of unpoisoned areas, 1–3 such species were identified in each block, spanning five species in total (Figure 11). For three species, bellbird, kererū, and thrush, there was sometimes a matching low count in one or more of the poisoned areas surveyed at the same time (particularly in the blocks that were not resurveyed until four months after the pre-control count). Only two low counts in poisoned areas that were not matched by low counts in unpoisoned areas, a low tomtit count in AS7 (broadcast sown repellent) and a low thrush count in AS6N (strip-sown repellent 100 m FPS).

There were also examples of higher-than-average counts of some species in both poisoned and unpoisoned blocks (Figure 11).

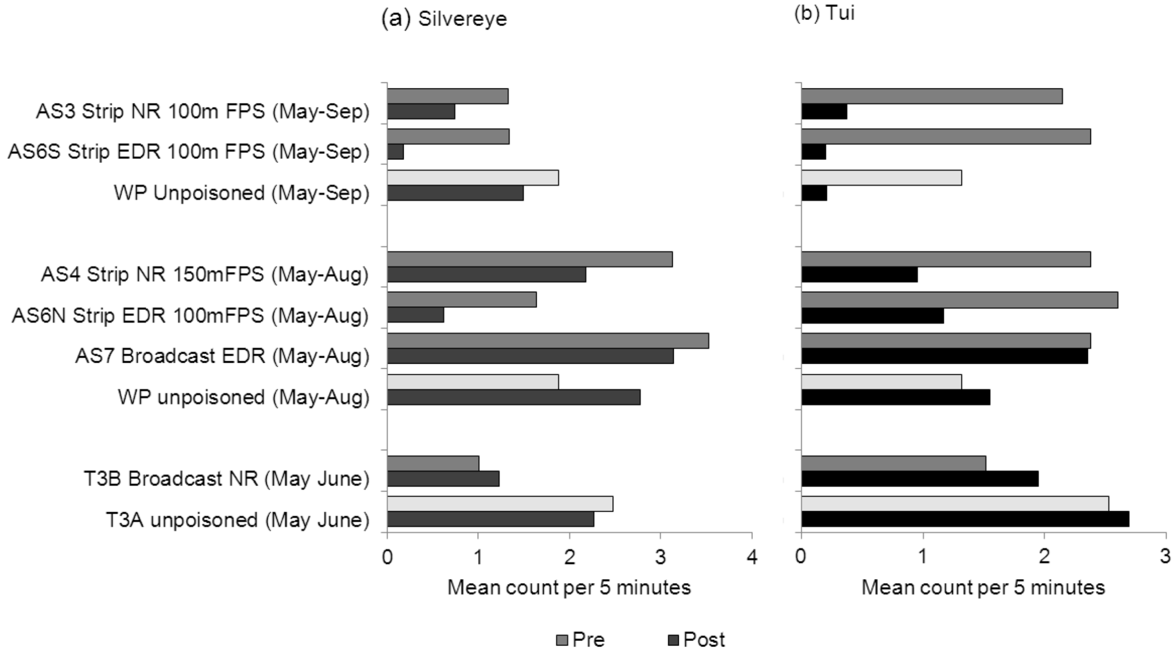


Figure 10 Changes in mean Five-Minute Count Indices for (a) silvereye and (b) tūī, before and after control in eight blocks. Two blocks (T3A and WP) were not aerially poisoned (shown with paler shading; the WP area was surveyed twice after control), two were poisoned with broadcast 1080 pellets, and four with strip-sown 1080 pellets at either 100-m flight-path spacing (100-m FPS) or 150-m (150-m FPS). EDR deer repellent was used in three of the 1080 blocks, and not (NR) in the other three.

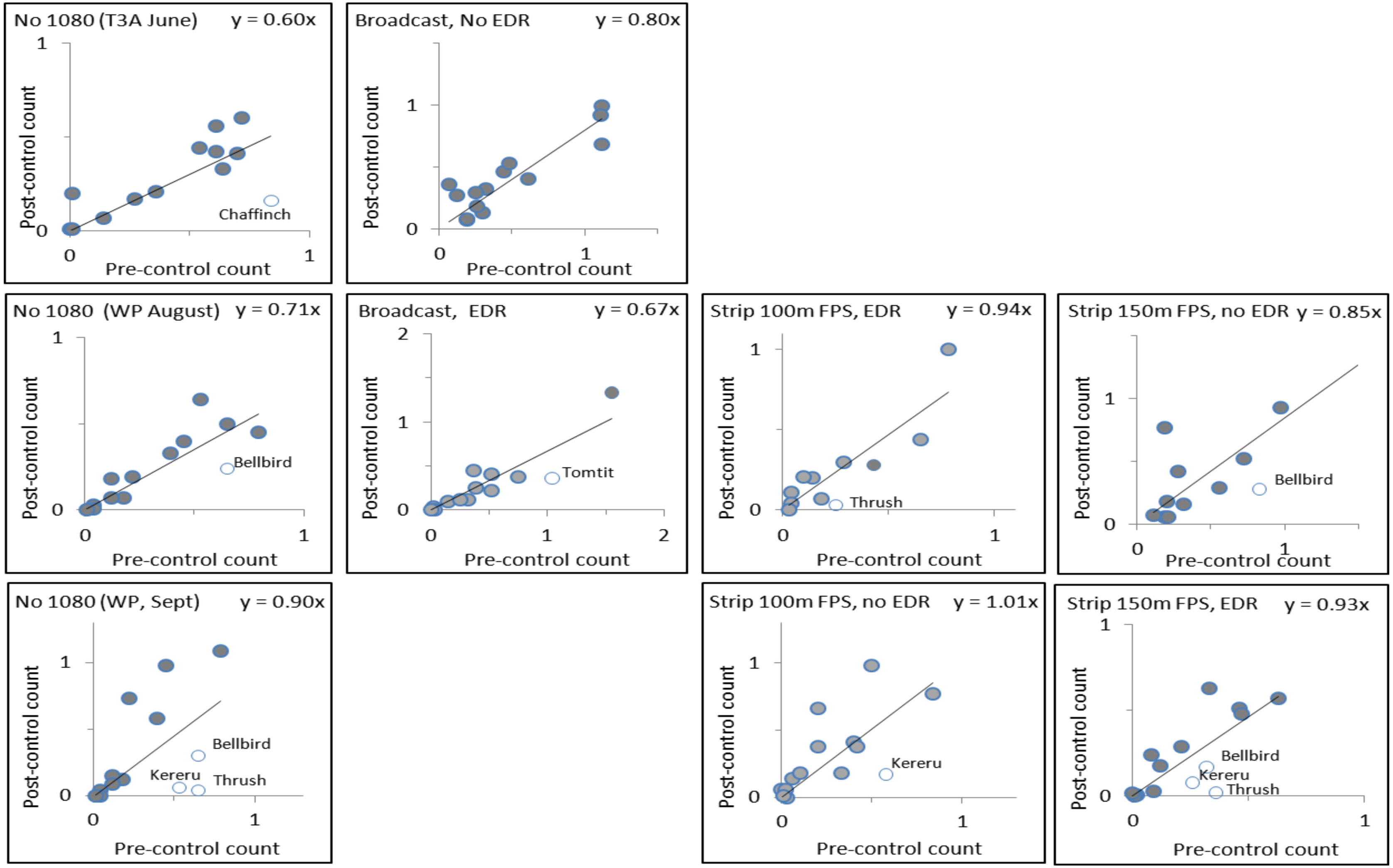


Figure 11 Comparison of pre- and post-control counts for the 14 most common minor species (where present) after tūī and silvereye. Treatment blocks are arranged in rows according to whether the post-control count was conducted 1 month after the pre-control count (in June 2011; top row), 3 months after (in August 2011; middle row) or 4 months after (in September 2011, bottom row). The first graph in each row is for the unpoisoned non-treatment area surveyed at the same time. Species subjectively identified as having lower than average post-control counts (open circles) are labelled. The slope of a trend line through zero is shown in the top-right corner of each graph.

6 Conclusions

6.1 Overall operational outcomes and ancillary findings

6.1.1 Operational outcomes

Overall, the whole operation successfully reduced possum abundance to below 2.5% RTCI in all areas, and to below 1% RTCI in most areas. These RTCI estimates were measured 6–8 months after control, and are therefore likely to be higher than if they had been measured immediately after control because immediate-post-control estimates are biased low (Nugent et al. 2010). Survivors were most abundant in the north-western part of the operational areas (AS2 and AS3), reflecting a mix of both moderate efficacy and higher than average possum abundance there before control. Based on the 7dCCI–RTCI relationship in Figure 2, the relatively high pre-control abundance of possums in AS2 E and AS3 (7dCCI >70%, Figure 5) equates to a pre-control RTCI of >10%, far higher than expected given the 0.0% and 0.4% RTCIs recorded in AS2 and AS3, respectively, in an AHB trend monitor before control in 2010 (Table 2). The discrepancy highlights the unreliability of RTCIs (or any index) at low possum densities (Jones & Warburton 2011).

Despite the poor operational outcome for the north-western part of the area, the post-control RTCI was still less than half the 5% RTCI level identified in Nugent (2005) as the threshold level for medium-term persistence of TB in possums. The absence of TB lesions from 38 deer and 7 pigs from the AS2/AS3 area indicates TB levels there have declined hugely from the 40% prevalence of TB in deer (*n* = 89) and 80% prevalence in pigs (*n* = 5) in the AS2/AS3/AS4 area in 1998–2000 (Nugent 2005). This suggests TB may have already been eliminated from this area but, if it is still present, then the RTCI is low enough to ensure that it will continue to decline for at least 2–3 years, rather than begin to recover.

6.1.2 Ancillary investigations

Calibration of RTC and CC indices

The very weak correlation between RTC and CC indices recorded for individual lines contrasts sharply with the much stronger correlation at the block level (Figure 2), indicating a sample size of 10 devices is too small to provide reliable estimation of local ‘line level’ possum abundance. Despite that, the greatly improved correlation at block level (160 devices for a total of either 480 nights (traps) or 1120 nights (chewcards)) suggests that both indices are estimating the same parameter (which we assume is linked to possum abundance).

The 6–7-fold higher value of the 7dCCI relative to the nightly trap-catch rate (RTCI) suggests that the nightly probability of possum interference on chewcards is much the same as their probability of being captured in a ground-set leg-hold trap, at least in the Hauhungaroa Ranges.

Short-term post-control change in 7dCCI

The 7dCCIs did not increase greatly over the 6–8 months after poisoning, as is suspected to occur with RTCIs (Nugent et al. 2010). Some increase was expected, given that pouch young present during Winter 2011 would have become independent by Summer 2012. Whatever causes the short-term changes in RTCIs either does not affect CCIs, or large short-term changes in post-control RTCIs only occur when possums are being reduced from near carrying capacity. As the various hypotheses advanced to explain the changes in RTCI usually invoke some change in possum movement behaviour, the former explanation seems unlikely.

Bait acceptance after comparatively high possum survival (AS2 E)

The low number of possum detections during the bait acceptance trial in AS2 E prevents strong inference, but the fact that not all cereal bait was consumed at sites at which possums were confirmed present suggests some degree of bait shyness in possums. That suggests at least some of the survivors encountered and consumed some bait but were not killed. The findings are consistent with that effect being stronger for orange-lured than for cinnamon - lured RS5 bait for both possums and rats. Carrot consumption was also low, which suggests cinnamon-lured RS5 bait would be the best bait type should a repeat 1080 baiting operation be conducted within the next two years to ‘mop up’ surviving possums. We suggest, however, that a larger bait acceptance trial be conducted to confirm (or not) the validity of that inference, especially since preference could vary seasonally.

Possum and rat survival within riparian buffers

Use of a riparian buffer nominally 150 m wide (but in reality up to 325 m in places) to minimise the risk of sowing toxic bait into a major waterway did not result in high possum survival near the waterway. However, the overall 7dCCI for rats in this buffer area (27%) was higher than that recorded in the block surrounding it (T3B; 3.8%). That, coupled with a suggestive trend in the rat index with increasing distance from the nearest flight path, suggests that rat survival may have been higher near the waterway.

6.2 Comparison of strip and broadcast sowing for aerial 1080 baiting

6.2.1 Possums

Broadcast baiting reduced possum abundance by more than 90%, albeit from levels that were already low or moderate. There was no indication that use of EDR deer repellent affected efficacy against possums, at least with broadcast baiting.

Strip sowing at 100-m FPS appeared to match broadcast sowing in efficacy against possums, regardless of whether the sowing rate was 1.0 kg/ha with 8-g baits or 0.7 kg/ha with 12-g baits. That suggests fixed-wing aircraft could be used to reduce the flying costs involved in sowing bait. Using a 0.5 kg/ha non-toxic prefeed sowing rate and a 0.7 kg/ha toxic sowing rate, a 100-m FPS (as in AS3), and fixed-wing sowing would almost halve the direct costs of bait and bait application compared with the helicopter-based broadcast baiting regime applied in T3B, a regime that was already a lower-cost regime than previously used in the Hauhungaroa Ranges. In absolute terms, the savings would be 1kg/ha of pre-feed ($2-3/ha including transport and storage), and 0.8kg of toxic bait ($3/ha). The savings in flying costs are difficult to judge without access to detailed operational data on ferry times, turning times, and average sowing speeds, but in a related project at Whanganui (Nugent et al. 2012) we estimated potential savings of $2.50/ha in flying costs through using fixed wing aircraft.

With strip sowing, increasing the distance between baited swaths to 150 m may have reduced efficacy because possums had to move longer distances to encounter toxic bait, and in AS2E in particular, this may have been exacerbated by use of smaller baits. This result contrasts with previous trials. At Maruia, in 2010, we obtained a 100% reduction in three blocks cluster-sown at 150 m, while at Cascade there was no significant difference between cluster sowing at 100-m or 150-m FPS (Nugent & Morriss 2011). Including this trial, we have now compared possum reductions with 100-m and 150-m FPS in a total of 10 pairs of blocks. In one case the reduction has been higher with 150-m FPS, in three it has been the same (all 100% reductions at Maruia), and in six cases the reduction has been smaller at 150-m FPS. That difference is not statistically meaningful, but it does indicate that further trials are needed before a >100-m FPS could be adopted or rejected as an operational standard.

6.2.2 Rats

Broadcast baiting resulted in high rat reductions, as did two of the three strip-sowing treatments using 100-m FPS, and one of the three treatments using 150-m FPS. Again these results contrast with previous trials in which cluster-sowing efficacy for rats at 100-m or 150-m spacing has been as high or higher than with broadcast sowing (Nugent & Morriss 2010, 2011). It is unclear whether the difference reflects some Hauhungaroa-specific characteristic, or some difference in the way(s) in which strip and cluster sowing work. Despite the less-than-ideal results from this trial, we suggest that further testing of strip sowing against rats is warranted given the high efficacy against rats achieved with that method in Whanganui in 2011 (Nugent et al. 2012). As in section 6.2.1 above, we suggest that further trials should investigate the effect of pre-feed interval in strip sowing efficacy.

Within about 6 months of control, rat numbers had increased to levels higher than immediately before control, but the level of rat abundance reached was not related to control efficacy. The implication is that, in face of what appears to have been very good breeding conditions for rats in this particular spring-summer period, the sowing methods were effective enough to provide only a few months of protection for native animals vulnerable to rat predation.

6.3 Effect of strip sowing on deer repellent efficacy during aerial 1080 baiting

EDR was highly effective in reducing deer by-kill, and aggregating baiting in strips did not reduce the repellent effect.

Substantial numbers of deer were killed in blocks in which no repellent was used, and there were some weak indications that the by-kill may have been greater in AS3 (strip-sown at 100-m FPS) than in T3B (broadcast). In particular, the estimated density of deer killed by 1080 relative to the estimate of pre-control deer abundance was higher in AS3 than in T3B

(Table 3). However, fresh tracks and live deer were still commonly seen in AS3 after poisoning (Tables 3 and 4) and, without replication, it is not possible to judge whether this difference is due to sowing method or some difference in deer density or habitat between the blocks. Overall, and based on the lesser increase in deer sightings in all five non-repellent blocks from before control to 6–8 months after control (33 to 38) to that in the three repellent blocks (7 to 20), we suggest that about one-third of the deer population may have been killed in the non-repellent blocks. That is consistent with previous estimates in nearby areas (Fraser et al. 1995).

Our incidental observations suggest there was no indication of any effect of aerial 1080 baiting on the low density pig and goat populations present.

6.4 Effect of strip sowing and deer repellent on non target birds

The progressive implementation of our various experimental treatments over several months (mostly as a consequence of weather-induced delays) resulted in a range of intervals between pre- and post-control bird counts. Adding to that, there were no non-treatment areas available that closely matched the terrain, altitude, and vegetation of the western side of the range. Those shortcomings in our design, and the lack of replication (at least at this stage of the project), preclude strong inference about the cause of any observed changes within blocks and between treatment and non-treatment blocks.

However, some firm observational conclusions can be drawn. There was no evidence from this trial that 1080 poisoning or use of EDR resulted in any consistent declines in overall bird abundance in all treatment blocks, after taking into account natural changes in bird abundance in the unpoisoned blocks.

There were major changes in the counts of the two most commonly counted species, silvereye and tūī, but only in the strip-sown blocks on the western side of the range. For silvereye, the biggest changes were for the two AS6 sub-blocks. For tūī, counts were particularly low in the three blocks resurveyed in September, including the unpoisoned block. Thus, for these two species, there was no indication at all of any major reduction in counts with broadcast sowing, with or without EDR. With strip sowing, counts were lower after poisoning both with and without EDR, providing no indication that use of EDR had any effect on tūī or silvereye. Given the tūī count in the unpoisoned block surveyed 4 months after control was much lower than before control, the changes in tūī counts, at least, appear likely to have been a seasonal effect. Strongly supporting that, no dead tūī were found, despite the decline in counts from 2.4 to 0.7 per count (i.e. a reduction of 1.7 per count) for the four strip-sown blocks combined. In contrast, there was no change in counts of blackbirds (0.26 per count both pre- and post-control) in these four blocks) yet five dead blackbirds were found. As blackbirds and tūī are similar in size and colour, we suggest it is highly unlikely that a large proportion of tūī were killed. Although silvereyes are smaller, the same logic can be applied to them. We also note that in the non-breeding season (winter), tūī and silveryeye can be highly mobile, with tūī known to undertake 10-20 km journeys to find suitable food, and silvereyes sometimes noted as being nomadic or migratory (Higgins et al. 2001); such movements could account for the declines observed for these species in this study.

For the 14 less-common-but-widespread species, total counts were generally somewhat lower in winter than in autumn in both poisoned and unpoisoned areas, with no indication of bigger changes in the poisoned area (Figure 11). For individual species, most counts in a poisoned area were matched to a similarly low count in the unpoisoned area surveyed at the same time, suggesting the lower count was a seasonal effect. For the exception, a lower tomtit count in AS7 W (broadcast-sown EDR), a 1080 effect remains one possible explanation, but we note lower counts were also sometimes observed in unpoisoned areas but not in poisoned areas (e.g.; chaffinch in T3A; Fig. 11), so this single exception could equally be a localised seasonal effect or simple sampling variation.

Overall, we conclude that there was no evidence of a consistent and large effect of aerial 1080 baiting on any of these 14 less common but widespread species. Likewise, there was no indication of any consistent substantial effect on any individual species that could be related to sowing or repellent treatment. If aerial 1080 baiting in general, or the use of EDR and/or strip sowing, or strip sowing did affect any of the more common species, the effect was idiosyncratic.

Taken in conjunction with the lack of any consistent pattern in common species other than silvereye, our finding of 11 dead birds but of no native species killed by 1080 suggests the changes observed in native species were more likely to be seasonal effects rather than as a result of 1080 baiting. Further counts are currently (May–June 2012) being completed in a new AHB-funded project (*R-10753 Maintaining low possum and rat densities*) in four of the blocks studied (AS6 S, AS6 N, AS4, and T3B), and we predict that silvereye and tūī counts will match those observed in May 2011.

7 Recommendations

- The AS2 and AS3 block should be given priority for repeat control, given the higher than average RTCIs recorded there, but repeat control could be delayed until Winter 2014 without negating the downward pressure on TB levels in possums (note: control of AS3 is underway as part of AHB research project R10731).
- Further operational trials should be conducted to test the efficacy of strip-sowing at 100 m FPS. These should be conducted using fixed-wing aircraft to maximise cost savings, and should include investigation of prefeed interval on strip sowing efficacy. Given the variability in outcomes with strip sowing in this and previous trials, it is likely that a substantial number of such trials are needed to assess the trade-offs between potential cost savings and reliability in achieving desired outcomes.
- Given that the post-control RTCI of (0.60 ± 0.2%(s.e.)) recorded with broadcast baiting (T3B and AS7) in this trial was more than 10 times the 0.05 ± 0.01% RTCI recorded after the mostly dual-prefed broadcast operation in 2005 (Coleman et al. 2007), we further suggest that the fixed-wing strip sowing trial recommended above also include exploration of dual strip-sown prefeeding (at 100 m FPS).
- The EDR deer repellent should be considered for use with both broadcast and strip sowing on areas where AHB wishes to avoid having a substantial impact on deer abundance. The planned replication of the investigation of the effect of bait aggregation on EDR efficacy in protecting deer is considered desirable but a lower priority than replication of the effect of EDR and bait aggregation effects on non-target bird numbers (see below).

- The planned replication of the investigation of EDR and bait aggregation (as a result of strip or cluster sowing) effects on non-target bird numbers should be continued, but with priority given to determining the effect of bait aggregation. The trial should accordingly include a redesign and consideration of alternative methods including automated counters and systematic searches for bird carcasses.

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9 References

Coleman JD, de Lisle GW 2007. Necropsy and laboratory protocols for examining NVL possums for *Mycobacterium bovis*. Landcare Research Contract Report LC0607/106 for AHB. 28 p.

Collet D 1991. Modelling binary data. Florida, USA, Chapman & Hall / CRC.

Dawson DG, Bull PC 1975. Counting birds in New Zealand forests. Notornis 22: 101–109.

Forsyth DM, Link WA, Webster R, Nugent G, Warburton B 2005. Nonlinearity and seasonal bias in an index of brushtail possum abundance. Journal of Wildlife Management 69: 976–984.

Fraser K, Coleman JD, Nugent G 1995. Optimal buffer widths for control of possums in the Hauhungaroa Range: 1994 - initial population reductions and Tb prevalence in possums, deer, and pigs. Landcare Research Contract Report LC9495/119 for AHB. 32 p.

Higgins PJ, Peter JM, Steele WK 2001. Handbook of Australian, New Zealand and Antarctic Birds 5. Oxford University Press, Melbourne, Australia.

Jones C, Warburton B 2011. Relationships between commonly used indices of possum abundance. Landcare Research Contract Report LC709 for AHB.

King CM, Edgar RL 1977. Techniques for trapping and tracking stoats (Mustela erminea); a review, and a new system. New Zealand Journal of Zoology 4: 193–212.

Morriss GA 2007. Epro deer repellent for baits used in possum control: Review of development and use 2001–2006. Landcare Research Contract Report LC0607/147. 20 p.

Morriss GA, Nugent G 2008. AHB Project R-10697: Monitoring the impact of aerially sown 1080 EDR cereal bait on fallow deer in the Blue Mountains, Otago. Landcare Research Contract Report LC0809/032 for AHB. 18 p.

Morriss GA, Nugent G, Lorigan R, Speedy C 2005. Development and testing of a deer repellent cereal bait for possum control Part III: cereal bait field trial. Landcare Research Contract Report LC0506/044 for AHB. 27 p.

National Possum Control Agencies (NPCA) 2007. Pest mustelids: Monitoring and control. Wellington, National Pest Control Authority.

National Possum Control Agencies (NPCA) 2011. Trap-catch for monitoring possum populations. Wellington, National Pest Control Authority.

Nugent G 1990. Monitoring the Blue Mountains Recreational Hunting Area. Forest Research Institute Contract Report FEW 90/24 (unpublished). 25 p.

Nugent G 2005. The role of wild deer in the epidemiology and management of bovine tuberculosis in New Zealand. Unpublished PhD thesis, Lincoln University, New Zealand 170 p.

Nugent G, Fraser KW 1993. Pest or valued resource: conflicts in game management. New Zealand Journal of Zoology 20: 361–366.

Nugent G, Morriss G 2010. R-10710: Low-cost aerial poisoning: Comparing the efficacy of clustered and broadcast baiting in two 2009 field trials. Landcare Research Contract Report LC0910/075 for AHB. 26 p.

Nugent G, Morriss G 2011. R-10710: Low-cost aerial poisoning II: Refinement and testing of cluster sowing 2009–2010. Landcare Research Contract Report LC136 for AHB. 36 p.

Nugent G, Whitford J 2006. Animal Health Board Project No. R-10577: Part 3. The short-term effect of possum control on tb prevalence in pigs. Landcare Research Contract Report LC0607/002. 31 p.

Nugent G, Morriss GA, Ball S, O’Connor CE 2004. Field testing of a deer-repellent carrot bait for possum control: Tataraakina replicate. Landcare Research Contract Report LC0304/074 for AHB.

Nugent G, Warburton B, Morgan D, Sweetapple P, Clayton R, Thompson C, Coleman M 2008. Animal Health Board Project No. R-10669: Local Elimination: A New Strategic Approach to Large-scale Control of Small Mammal Pests. Landcare Research Contract Report: LC0708/149. 110p.

Nugent G, Yockney I, Morgan D 2009. R10629: Increased cost-effectiveness of aerial 1080 poisoning of possums for reducing TB incidence on Molesworth Station: Pt 1: Effect of reduced coverage and sowing rates on possum abundance. Landcare Research Contract Report LC0809/163 for AHB. 30 p.

Nugent G, Whitford J, Sweetapple P, Duncan R, Holland P 2010. Effect of one-hit control on the density of possums (*Trichosurus vulpecula*) and their impacts on native forests. Science for Conservation 304. Wellington, Department of Conservation. 64 p.

Nugent G, Morgan D, Clayton R, Warburton B 2011a. Improving the efficacy of aerial poisoning of brushtail possums (*Trichosurus vulpecula*) through reduced fragmentation of bait. International Journal of Pest Management 57: 51–59.

Nugent G, Yockney I, Whitford J 2011b. R-10629_02 Eliminating TB from Molesworth Station: II. Persistence of TB on Molesworth Station two years after aerial 1080 baiting. Landcare Research Contract Report LC764 for AHB. 29 p.

Nugent G, Warburton B, Thomson C, Cross ML, Coleman, MC 2012a. Bait aggregation to reduce cost and toxin use in aerial 1080 baiting of small mammal pests in New Zealand. *Wildlife Research (in press)*

Nugent G, Morriss G, Warburton B, Farrell T, Smillie R 2012b. Low-cost aerial poisoning III: Refinement and testing of strip and cluster sowing, 2011. Landcare Research Contract Report LC990 for AHB. 29p.

Pinheiro J, Bates D, DebRoy S, Sarkar D & the R Development Core Team 2012. nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-103.

Sweetapple PJ, Nugent G. 2008. AHB Project R-10681: Tools for mapping and eliminating surviving possums following possum control. Landcare Research contract report LC0809/017. 16 p.

Sweetapple P, Nugent G 2009. Possum demographics and distribution after reduction to near–zero density, New Zealand Journal of Zoology 36: 461–471.

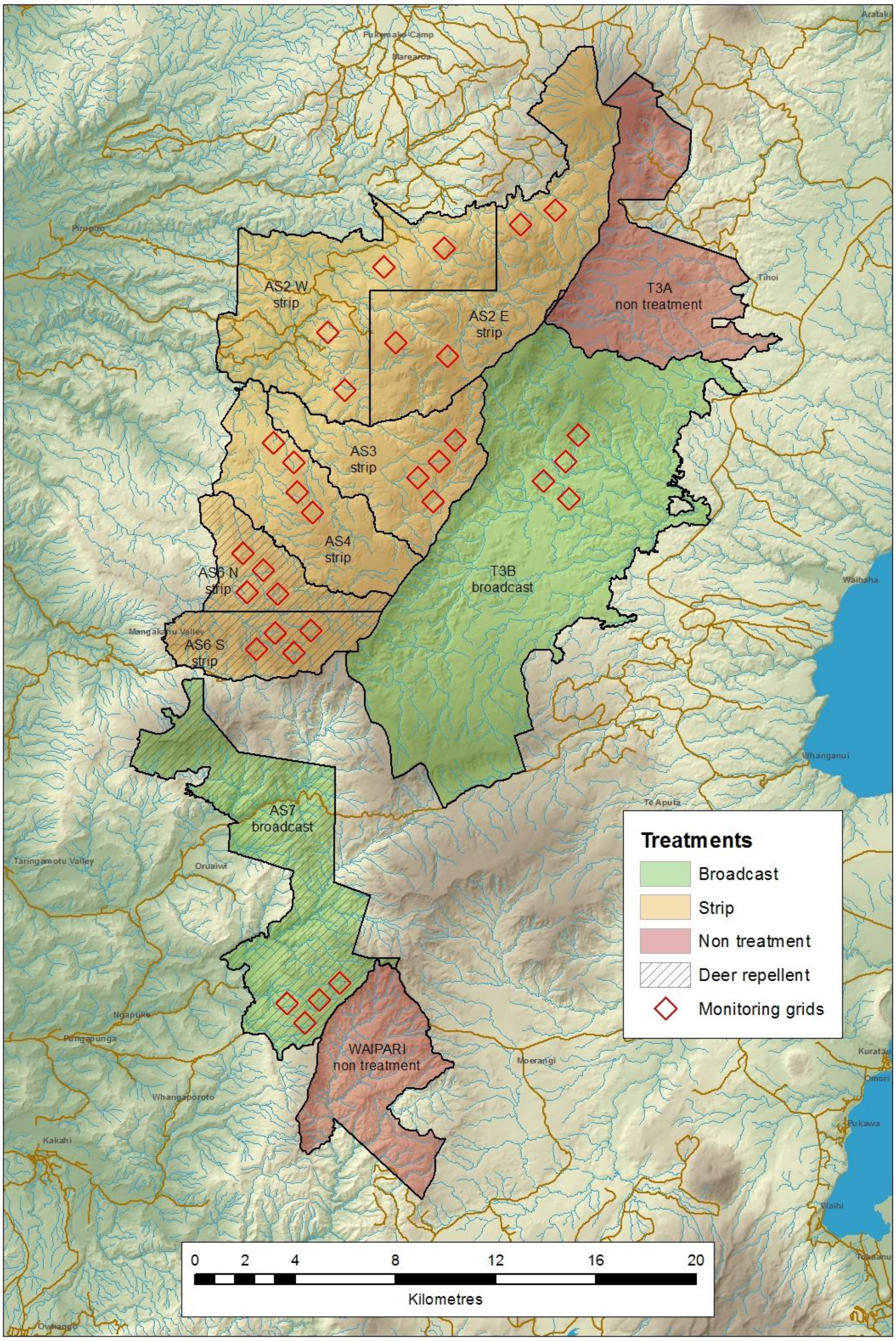
Sweetapple P, Nugent G 2011. Chew-track-cards: a multiple-species small mammal detection device. New Zealand Journal of Ecology 32: 152-162

Sweetapple P, Anderson D, Nugent G 2010. AHB Project R-10681: No possums, no TB. Landcare Research Contract Report LC0910. 35 p.

Warburton B, Clayton R, Nugent, G, Forrester G 2009. Effect of prefeeding on foraging patterns of brushtail possums (Trichosurus vulpecula) about prefeed transects. Wildlife Research 36, 659–665

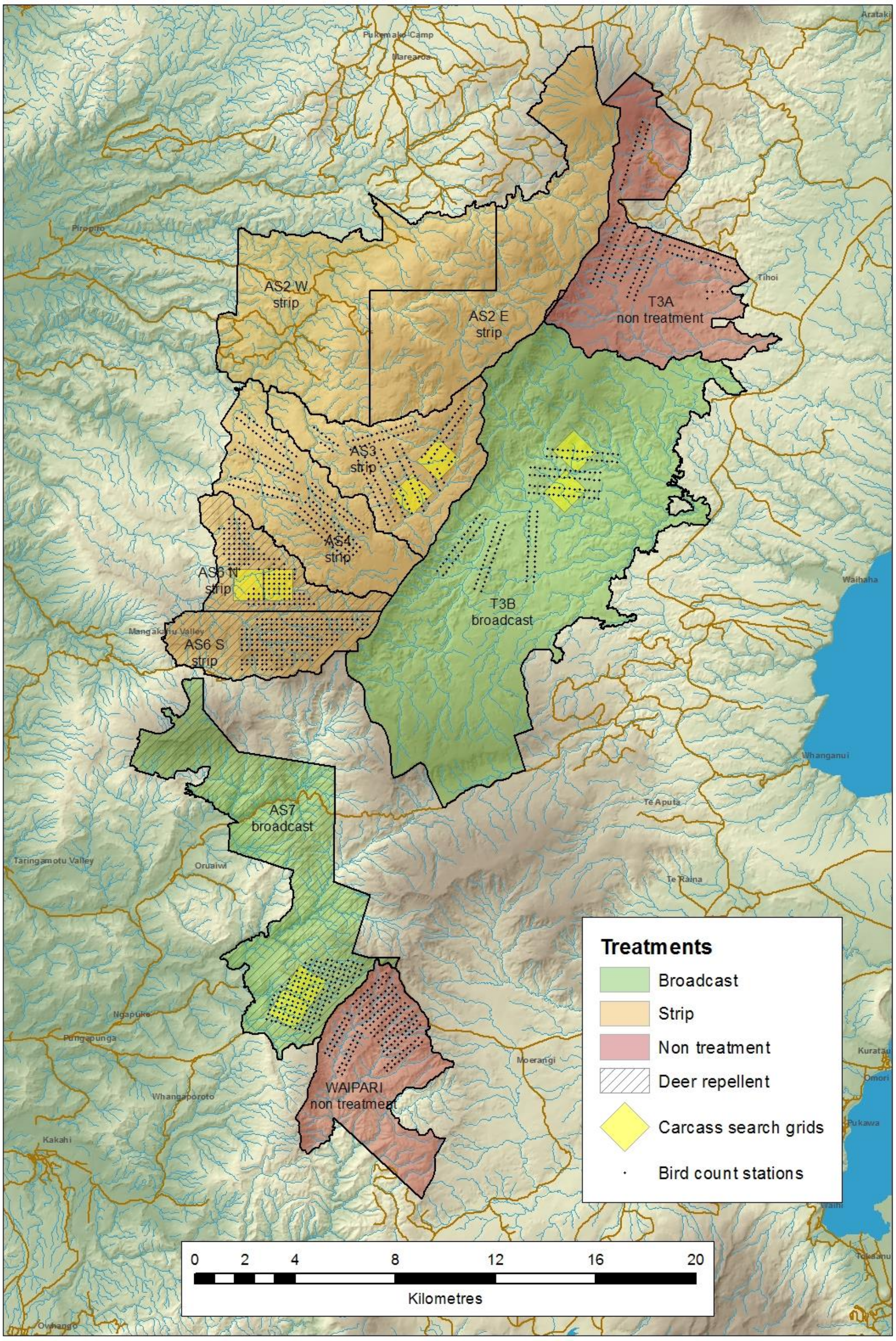
Appendix 1 – Study areas in the Hauhungaroa Ranges

Map of the 10 study blocks used in this project, showing the different aerial 1080 baiting treatments applied, and the chewcard and tracking tunnel grids (*n* = 4 per block) used to survey the eight main study blocks.



Appendix 2 – Bird count lines and deer carcass search grids

Map of the study areas used to assess non-target impacts. As in Appendix 1, the various aerial 1080 baiting treatments are shown, along with the location of the grids used in systematic searches for deer carcasses and the sites at which five-minute bird counts were conducted.



Appendix 3 – Concentration of 1080 residue in deer tissue samples

Concentration of 1080 in muscle samples from red deer collected in the Hauhungaroa Ranges following aerial application of EDR-coated and standard cereal 1080 baits in Winter 2011 (MDL = method detection limit of 0.001 mg/kg).

Study block	ID	Sex	Age class (Years)	Muscle 1080 concentration (mg/kg)
T3B	13549	M	2-3	0.05
T3B	13662	NR	0-1	0.69
T3B	13591	F	2-3	0.51
T3B	13563	M	3-4	0.60
T3B	13678	F	>6	0.17
T3B	13582	NR	NR	< MDL
T3B	Deer1	M	1-2	0.9
T3B	Deer2	M	2-3	0.79
T3B	SB201	M	2-3	1.1
T3B	SB202	F	0-1	2.6
AS3	13536	M	2-3	1.81
AS3	13661	F	1-2	0.35
AS3	13520	F	3-4	1.81
AS3	13622	M	1-2	0.41
AS3	13715	F	2-3	1.34
AS3	13602	F	2-3	0.73
AS3	13521	M	1-2	0.54
AS3	13565	M	0-1	0.42
AS3	13517	NR	0-1	0.003
AS3	13679	F	>6	0.17
AS3	13655	F	0-1	0.83
AS3	13680	F	0-1	1.05
AS3	002	NR	0-1	1.87
AS3	13596	M	2-3	1.91
AS3	13586	F	2-3	2.01
AS3	13547	F	1-2	0.57
AS3	13627	M	1-2	0.61
AS3	906	NR	>4	0.51
AS2 W	13539	F	1-2	0.018
AS2 W	13598	F	1-2	0.02
AS2 W	13675	M	2-3	0.11
AS2 W	13666	F	3-4	0.23
AS2 W	13620	M	2-3	0.25
AS2 W	13562	F	1-2	0.59
AS2 W	13606	M	2-3	0.34
AS2 W	13583	M	1-2	0.41
AS2 E	13637	M	1-2	0.45
AS4	075	F	2-3	0.69

NR = Not recorded

Appendix 4 – Bird species counted in the Hauhungaroa Ranges, Winter 2011

Species are listed in order of most common to least common as heard and sighted during all bird counts. Introduced species highlighted in blue.

Common name	Scientific name	Native/Introduced
Silvereye	*Zosterops lateralis*	Native
Tūī	*Prosthemadera novaeseelandiae*	Native
Tomtit	*Petroica macrocephala*	Native
Whitehead	*Mohoua albicilla*	Native
Kererū	*Hemiphaga novaeseelandiae*	Native
Grey warbler	*Gerygone igata*	Native
Bellbird	*Anthornis melanura*	Native
North Island robin	*Petroica longipes*	Native
Chaffinch	*Fringilla coelebs*	Introduced
Thrush	*Turdus philomelos*	Introduced
Blackbird	*Turdus merula*	Introduced
Fantail	*Rhipidura fuliginosa*	Native
Rifleman	*Acanthisitta chloris*	Native
Greenfinch	*Carduelis chloris*	Introduced
Kākāriki spp.	*Cyanoramphus spp*	Native
Kākā	*Nestor meridionalis*	Native
Magpie	*Gymnorhina tibicen*	Introduced
Redpoll	*Carduelis flammea*	Introduced
Harrier	*Circus approximans*	Native
Fernbird	*Megalurus punctatus*	Native
Morepork	*Ninox novaeseelandiae*	Native
Whio	*Hymenolaimus malacorhynchos*	Native
Starling	*Sturnus vulgaris*	Introduced
Falcon	*Falco novaeseelandiae*	Native
Paradise shelduck	*Tadorna variegata*	Native
Welcome swallow	*Hirundo neoxena*	Native
Yellowhammer	*Emberiza citrinella*	Introduced
Dunnock	*Prunella modularis*	Introduced
Goldfinch	*Carduelis carduelis*	Introduced
Kingfisher	*Halcyon sancta*	Native
Californian quail	*Callipepla californica*	Introduced
Eastern rosella	*Platycercus eximius*	Introduced
Pheasant	*Phasianus colchicus*	Introduced

Appendix 5 – Bird count data, Hauhungaroa Ranges, Winter 2011

Mean (and SE) five-minute counts, by species, for the eight blocks in which bird count monitoring was conducted. Blocks are arranged in three groups, according to the month in which the second (or third) count was conducted. Species are arranged in decreasing order of the overall (8-block) mean count.

	T3A (non-treatment)				T3B (broadcast 1080, no EDR)			
	May		June		May		June	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Silvereye	2.48	0.13	2.27	0.36	1.01	0.08	1.23	0.18
Tūī	2.53	0.12	2.69	0.12	1.52	0.07	1.95	0.09
Tomtit	0.61	0.07	0.42	0.05	1.12	0.05	0.99	0.05
Whitehead	0.72	0.21	0.6	0.12	0.32	0.07	0.32	0.05
Kererū	0.61	0.08	0.56	0.1	1.11	0.09	0.92	0.06
Grey warbler	0.7	0.08	0.41	0.05	0.44	0.04	0.46	0.04
Bellbird	0.64	0.07	0.33	0.05	1.12	0.06	0.68	0.05
NI robin	0.36	0.06	0.21	0.04	0.48	0.05	0.53	0.05
Chaffinch	0.84	0.14	0.16	0.03	0.25	0.04	0.29	0.04
Thrush	0.01	0.01	0.2	0.04	0.07	0.02	0.36	0.04
Blackbird	0.54	0.06	0.44	0.06	0.19	0.04	0.07	0.02
Fantail	0.27	0.04	0.17	0.04	0.61	0.05	0.4	0.04
Rifleman	0.14	0.04	0.07	0.03	0.19	0.04	0.08	0.02
Greenfinch			0.01	0.01	0.3	0.04	0.13	0.03
Kākāriki spp.	0.01	0.01	0.01	0.01	0.12	0.03	0.27	0.04
Kākā					0.26	0.05	0.18	0.04
Magpie	0.01	0.01			0.02	0.01	0.01	0.01
Redpoll	0.01	0.01			0.01	0.01		
Harrier	0.01	0.01	0.02	0.01				
Fernbird	0.04	0.02	0.01	0.01				
Morepork	0.01	0.01			0.02	0.01		
Whio					0.01	0.01	0.01	0.01
Starling							0.01	0.01
Falcon					0.01	0.01	0.01	0.01
P. shelduck					0.01	0.01		
W. swallow					0.01	0.01		
Y. hammer	0.01	0.01						

Appendix 5 (continued)

	WP (non-treatment)				AS4 (strip 1080; no EDR)				AS6 N (strip 1080; EDR)				AS7 (broadcast 1080; EDR)			
	May		August		May		August		May		August		May		August	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Silvereye	1.88	0.12	2.77	0.25	3.13	0.21	2.18	0.12	1.64	0.13	0.62	0.08	3.52	0.36	3.14	0.49
Tūī	1.32	0.07	1.55	0.07	2.38	0.09	0.95	0.07	2.6	0.14	1.17	0.08	2.38	0.11	2.35	0.12
Tomtit	0.79	0.06	0.45	0.04	0.97	0.06	0.93	0.07	0.29	0.05	0.3	0.05	1.04	0.07	0.36	0.05
Whitehead	0.45	0.09	0.4	0.05	1.71	0.12	1.64	0.12	0.78	0.12	1.0	0.1	0.37	0.08	0.45	0.07
Kererū	0.53	0.05	0.64	0.06	0.56	0.06	0.29	0.04	0.43	0.07	0.28	0.05	1.55	0.17	1.33	0.13
G. warbler	0.39	0.04	0.33	0.04	0.28	0.04	0.42	0.07	0.14	0.03	0.2	0.04	0.52	0.06	0.41	0.04
Bellbird	0.65	0.05	0.24	0.03	0.83	0.06	0.28	0.04	0.18	0.04	0.07	0.02	0.32	0.04	0.12	0.03
NI Robin	0.18	0.03	0.07	0.02	0.72	0.07	0.52	0.06	0.65	0.07	0.44	0.07	0.15	0.04	0.1	0.03
Chaffinch	0.22	0.03	0.19	0.03	0.19	0.04	0.77	0.07	0.04	0.02	0.11	0.03	0.52	0.06	0.22	0.03
Thrush	0.65	0.05	0.5	0.04	0.19	0.03	0.06	0.02	0.25	0.04	0.03	0.01	0.75	0.07	0.38	0.04
Blackbird	0.12	0.03	0.18	0.03	0.32	0.05	0.16	0.03	0.1	0.03	0.21	0.05	0.38	0.05	0.25	0.04
Fantail	0.12	0.02	0.07	0.02	0.21	0.04	0.06	0.02	0.04	0.02	0.04	0.02	0.25	0.04	0.12	0.03
Rifleman	0.04	0.02	0.03	0.01	0.2	0.04	0.18	0.04	0.03	0.01			0.02	0.01	0.04	0.02
Greenfinch	0.04	0.02	0.01	0.01									0.03	0.02		
Kākāriki spp.					0.11	0.03	0.07	0.02								
Kākā	0.01	0.01													0.01	0.01
Magpie	0.1	0.02	0.06	0.02			0.01	0.01			0.01	0.01	0.05	0.03	0.02	0.01
Redpoll	0.03	0.01	0.01	0.01	0.03	0.02	0.02	0.01								
Dunnock	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01							0.03	0.01
Harrier					0.01	0.01	0.01	0.01			0.01	0.01	0.01	0.01	0.02	0.01
Goldfinch	0.03	0.01	0.01	0.01	0.01	0.01										
Fernbird			0.01	0.01			0.01	0.01							0.01	0.01
Morepork									0.01	0.01						
Quail									0.01	0.01						
Pheasant							0.01	0.01								
Rosella											0.01	0.01			0.01	0.01
Falcon									0.01	0.01						
Kingfisher					0.01	0.01										
W. swallow													0.01	0.01		
Y. hammer													0.01	0.01		

Appendix 5 (continued)

	WP (non-treatment)				AS6 S (strip 1080; EDR)				AS3 (strip 1080; no EDR)			
	May		September		May		September		May		September	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Silvereye	1.88	0.12	1.49	0.1	1.34	0.13	0.18	0.03	1.33	0.12	0.74	0.08
Tūī	1.32	0.07	0.21	0.04	2.38	0.07	0.2	0.03	2.15	0.1	0.37	0.06
Tomtit	0.79	0.06	1.09	0.07	0.46	0.04	0.51	0.05	0.84	0.06	0.77	0.06
Whitehead	0.45	0.09	0.98	0.09	0.33	0.07	0.63	0.06	0.2	0.04	0.66	0.07
Kererū	0.53	0.05	0.06	0.02	0.26	0.04	0.08	0.02	0.58	0.06	0.17	0.03
Grey warbler	0.39	0.04	0.58	0.05	0.47	0.04	0.48	0.04	0.5	0.05	0.98	0.05
Bellbird	0.65	0.05	0.3	0.04	0.32	0.04	0.17	0.03	0.4	0.04	0.41	0.05
NI robin	0.18	0.03	0.12	0.03	0.63	0.05	0.57	0.05	0.33	0.04	0.18	0.03
Chaffinch	0.22	0.03	0.73	0.06	0.08	0.02	0.24	0.04	0.2	0.03	0.38	0.05
Thrush	0.65	0.05	0.04	0.01	0.36	0.04	0.02	0.01	0.03	0.01		
Blackbird	0.12	0.03	0.15	0.03	0.21	0.04	0.29	0.04	0.42	0.05	0.38	0.04
Fantail	0.12	0.02	0.09	0.02	0.02	0.01	0.01	0.01	0.06	0.02	0.14	0.03
Rifleman	0.04	0.02	0.04	0.02	0.12	0.03	0.18	0.03	0.1	0.02	0.18	0.04
Greenfinch	0.04	0.02			0.09	0.02	0.03	0.01			0.06	0.02
Kākāriki spp.					0.01	0.01			0.02	0.01	0.06	0.02
Kākā	0.01	0.01					0.02	0.01	0.01	0.01	0.01	0.01
Magpie	0.1	0.02	0.05	0.02								
Redpoll	0.03	0.01	0.1	0.03	0.04	0.01	0.05	0.02				
Dunnock	0.01	0.01	0.08	0.02			0.01	0.01			0.01	0.01
Harrier			0.04	0.02					0.01	0.01	0.02	0.01
Goldfinch	0.03	0.01			0.01	0.01						
Fernbird					0.01	0.01	0.01	0.01				
Quail			0.01	0.01								
Falcon			0.01	0.01	0.01	0.01						
P. shelduck			0.01	0.01								