R 10629: 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

Graham Nugent, Ivor Yockney, and Dave Morgan






Landcare Research
Manaaki Whenua

R 10629: 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

Graham Nugent, Ivor Yockney, and Dave Morgan

Landcare Research
PO Box 40, Lincoln 7640
New Zealand

PREPARED FOR:
Animal Health Board
PO Box 3412, Wellington

DATE: June 2009

Reviewed by:	Approved for release by:
Jackie Whitford Scientist Landcare Research	Andrea Byrom Science Team Leader Wildlife Ecology and Epidemiology

DOI: https://doi.org/10.7931/515p-xx56
Landcare Research Contract Report: LC0809/163

Contents

Summary

Project and Client

Landcare Research, Lincoln, was contracted by the Animal Health Board to determine the relative effectiveness of reducing both coverage (at the whole-landscape level) and bait application rates during aerial 1080 poison operations in, firstly, reducing possum abundance and, secondly, in reducing Tb levels in wildlife. This report documents the initial reductions in possum abundance after experimental aerial poisoning, based on research undertaken between August 2008 and June 2009.

Objective

- To determine which combination of reduced coverage and lower baiting rates are more cost effective than current approaches for reducing Tb levels in wildlife in places such as Molesworth Station.

Methods

- In late 2008, experimental aerial 1080 poisoning treatments comprising four main combinations of two levels of landscape coverage (30–40% vs 60–80%) and two sowing methods (broadcast 2.5 kg/ha vs cluster 1.0 kg/ha) were applied to a total of 17 800 ha on Molesworth Station. In a fifth treatment, one of the cluster-sown treatments was prefed. To aerially deliver bait in clusters, we replaced the spinner normally used to broadcast bait with a timed gate mechanism.
- We collected some data on bait distribution and fragmentation and conducted a flight-spacing trial.
- Reductions in pest abundance were assessed by using Chew Cards (CCs) and Wax Tags® (WTs) to assess changes in possum activity and by using the Residual Trap Catch Index method (RTCI) to assess post-control possum abundance.

Results

- The modified bucket successfully sowed bait in clusters, with less fragmentation of bait than when a spinner was used. Even with cluster baiting, it appeared likely that at least 95% of possums would encounter bait using flight path spacings of up to 140 m.
- Few possums remained after control (overall mean RTCI = 0.87 ± 0.38% (95% CI)). For low- and high-coverage areas respectively, the mean RTCI for the two unprefed broadcast blocks sown at 2.5 kg were 1.11 ± 0.90% and 0.76 ± 0.57%, compared with 0.43 ± 0.50% and 1.84 ± 1.46% in the two unprefed cluster blocks sown at 1.0 kg/ha. The RTCI for a small prefed block cluster sown at 1.0 kg/ha was 0.0%.
- The reductions in possum activity were higher in the high-coverage blocks (97.8% with the broadcast application regime, 98.4% with cluster) than in the low-coverage blocks (94.6% broadcast, 94.4% cluster) with no consistent differences between broadcast and cluster sowing.
- Interference indices increased for mice (CCs; 46% before control, 64% after), but were statistically no different for rabbits (CCs; 1.6% before, 1.0% after) and ferrets (WTs; 3.6% before, 1.9% after) and declined for hedgehogs (CCs; 1.3% before, 0.1% after). Five cattle and at least 25 deer were seen dead after poisoning, along with four pigs, approximately 20 goats and a large number of possums.

- Overall, there was a >50% reduction in the combined cost (in $/ha) of bait and flying time in the unprefed cluster blocks relative to the unprefed broadcast block, mainly reflecting the 60% reduction in the amount of bait applied (1.0 kg/ha vs 2.5 kg/ha) and a commensurate reduction in the flying time spent reloading sowing buckets. In the small prefed cluster block the estimated costs including prefeed were similar to those in unprefed broadcast blocks.

Conclusions

- It is feasible to aerially sow bait in clusters, and this is likely to result in less fragmentation of bait than with broadcasting of bait using a high-speed spinner.
- The actual overall reduction in possum abundance (to an average post-control RTCI of 0.9%) is likely to have exceeded 90%. All of the RTCIs for individual blocks were below the 2% RTCI target often applied by AHB as a performance standard, although one of the cluster-sown blocks would have failed a standard that requires no more than two possum captures on any one line. Overall there was no evidence of any consistent difference in efficacy between the broadcast- and cluster-baiting techniques. Most importantly, high reductions and low RTCIs were obtained with cluster baiting despite the 60% reduction in the amount bait used and despite the large gaps in bait distribution between flight paths.
- Although unreplicated, the 0% RTCI recorded in the single prefed cluster-sown block suggests that prefeeding compensated for any loss of efficacy through cluster baiting. The slightly higher kills in the high-coverage blocks may reflect greater openness (i.e. less dense scrubby habitat) in those blocks.
- The poisoning appeared to have little effect on mice, rabbits, and ferrets, but may have reduced hedgehog numbers. Although not rigorously quantified, aggregation of bait in tight clusters may increase the likelihood of non-target deaths of large animals such as deer, cattle, and goats that need multiple baits to be killed.
- As cluster baiting at 1.0 kg/ha delivered similar outcomes to broadcast baiting at 2.5 kg/ha while halving the variable costs, there is clearly potential for major improvements in the cost-effectiveness of current 1080 poison operations. As the high number of baits per cluster seems unnecessary to kill the low density of possums present, sowing rates as low as a few hundred grams per hectare may produce equally good kills and be even more cost effective.

Recommendations

- The AHB should continue with an already planned series of trials to test the efficacy of sowing smaller than usual amounts of toxic bait in strips or clusters.
- Future aerial possum control operations on Molesworth Station (or in similar unforested habitats) should test the efficacy of even lower amounts of toxic bait with and without a small amount of prefeed.

1. Introduction

Landcare Research, Lincoln, was contracted by the Animal Health Board to determine (over the 2008–2011 period) the relative cost-effectiveness of two new tactics in aerial 1080 poisoning of possums in reducing possum abundance and the incidence of Tb in wildlife (as assessed by the levels in released and resident wild pigs) on the eastern parts of Molesworth Station, Marlborough. This report documents the possum reductions achieved under the experimental aerial poisoning operations, which were conducted in late 2008.

2. Background

Molesworth Station and some adjacent areas comprise a vast mountainous landscape that forms the last large farmed area in New Zealand in which possum and other vectors of bovine tuberculosis (Tb) are not yet fully under intensive control. Historically it was considered that the area was too large and contained too few cattle to warrant its inclusion in the second phase of the National Pest Management Strategy for Tb (NPMS), but better than projected progress toward national NPMS goals has allowed some vector control to be initiated in parts of this area. However, the immense size of the area and the low density of farmed livestock it carries inevitably make the cost of vector control very high, both in terms of the total amount of funding required and especially in terms of the cost per livestock unit. There is therefore considerable interest in reducing those costs, and recent research suggested two possibilities.

First, possum densities are naturally low in parts of the area (Byrom et al. 2007), presumably because the unforested semi-arid landscape is sub-optimal habitat for possums, the main vector of Tb. There is a gradient in possum density across Molesworth Station, with highest densities in the central-south-eastern parts, where Tb is also most prevalent in wildlife and livestock (Byrom et al. 2007; Nugent & Whitford 2007). The research suggested that foci of Tb infection in possums occurred (and were likely to persist) only in small isolated patches of more favourable habitat that held above-average densities of possums (Nugent & Whitford 2007). The distribution of the habitat types on Molesworth Station likely to contain the highest numbers of possums has been predicted (Fig. 1). Those predictions are expressed in terms of an index of possum abundance, the Trap Catch Index (TCI; NPCA 2008a). The first new tactic was therefore to impose possum control in only the most 'possumy' parts of the landscape, and we applied this tactic of partial landscape coverage at two levels. Under a safer (but more expensive) 'high coverage' treatment, all habitat in which the predicted possum abundance exceeded a low threshold (5%TCI) was controlled, while under a more risky but lower cost 'low coverage' treatment, only habitat in which the predicted possum abundance exceeded 10%TCI was controlled.

The second tactic for reducing costs was to reduce the cost of aerial 1080 (sodium monofluoroacetate) poisoning, the primary tool used for large-scale possum control in this area. The most recent previous aerial poisoning operations on Molesworth Station had broadcast 1080-laden bait (without any non-toxic prefeeding) at a sowing rate of 2.5 kg/ha, in line with standard practice elsewhere for low or moderate densities of possums. However, high kills of possums had been achieved in two 2007 trials using just 0.4 kg/ha and 0.7 kg/ha

of 1080 baits when the baits were distributed in clusters by hand, to reduce the likelihood of sub-lethal poisoning (Nugent et al. 2008). We therefore compared the effect of reducing the sowing rate by 60%, from the normal 'high' rate of 2.5 kg/ha to a new 'low' rate of 1.0 kg/ha.

The opportunity to determine the effectiveness of these new tactics was provided by a large 28 500-ha poisoning operation planned by the AHB and Molesworth Station for spring 2008. That operation was structured to enable us to apply four different combinations of coverage and sowing rate. This report compares the costs and possum reductions achieved with each combination. Ongoing monitoring of possum abundance and annual surveys of Tb levels in pigs over the next three years (2009–2011) will be used to compare the cost-effectiveness of each combination in reducing Tb levels (the ultimate goal).

The trials in which good possum kills had been achieved with smaller than usual amounts of 1080 bait had relied on hand placement of the bait clusters (Nugent et al. 2008). Hand placement was not affordably feasible on Molesworth Station, so an aerial sowing bucket capable of delivering bait in clusters had to be developed for this trial. This report therefore also documents that development.

3. Objective

- To determine which combination of reduced coverage and lower baiting rates are more cost effective than current approaches for reducing Tb levels in wildlife in places such as Molesworth Station.

4. Methods

4.1 Design

Four main experimental treatments were imposed, effectively comprising an unreplicated 2×2 factorial design with two levels of landscape coverage and two sowing rates:

- Block 1 (low-coverage broadcast): Low coverage of about 30–40% of the landscape with 2.5 kg/ha of 1080 cereal bait broadcast in the areas actually poisoned
- Block 2 (high-coverage cluster): Coverage of about 60–80% of the landscape with bait sown in clusters at the rate of 1.0 kg/ha of 1080 cereal bait in the areas actually poisoned
- Block 3 (high-coverage broadcast): Coverage of about 60–80% of the landscape with 2.5 kg/ha of 1080 bait broadcast in the areas actually poisoned
- Block 4 (low-coverage cluster): Low coverage of about 30–40% of the landscape with bait sown in clusters at the rate of 1.0 kg/ha of 1080 cereal bait in the areas actually poisoned

The third treatment (Block 3) is the one most similar to the most recent previous aerial poisoning operations targeting possums on Molesworth Station. Like those previous operations, prefeeding was not used in the four blocks above because prefeeding almost

doubles the cost. Also previous non-prefed operations on Molesworth had successfully (and quickly) reduced cattle-reactor rates (J. Ward, pers. comm.) and the incidence of Tb in pigs (Byrom et al. 2007). However, to help interpretation of trial outcomes (and at the AHB's request), prefeeding was used in a further area (Block 5), one week before poisoning was carried out with the same specifications as Block 2 (high-coverage cluster).

4.2 Study areas and poison operation

Five study blocks were delineated in consultation with Molesworth Station staff (Fig. 1). The area to be poisoned within each of the five treatment blocks was then defined by using the spatial model developed by Byrom et al. (2007) to identify and exclude strata with a predicted pre-control Trap Catch Index (TCI) of <5% (= high-coverage treatments) or <10% (= low-coverage treatments). As it is not practical to aerially sow bait into (or leave out) small areas of up to 50 ha, the boundaries of respective treatment areas were smoothed to facilitate aerial sowing. In addition, the resource consent for the operation imposed a 150-m exclusion zone alongside the Clarence River.

The total area poisoned was 17 800 ha. For all four of the main treatments, cinnamon-masked green-dyed RS5 cereal bait with a nominal mean weight of 8 g (Animal Control Products, Wanganui) was applied without prefeeding along flight paths spaced 130 m apart. Poison bait was sown on 29–30 October 2008. Two Squirrel helicopters were used with either a 500-kg bait-capacity bucket or 700-kg bucket. The reloading site was at the Molesworth homestead, about 25 km from the centre of the poisoned area.

For the small prefed block (Block 5 – 855 ha) 1 kg/ha of non-toxic, cinnamon-masked, undyed, 8-g RS5 cereal bait was sown on 26 October, 4 days before that block was poisoned.

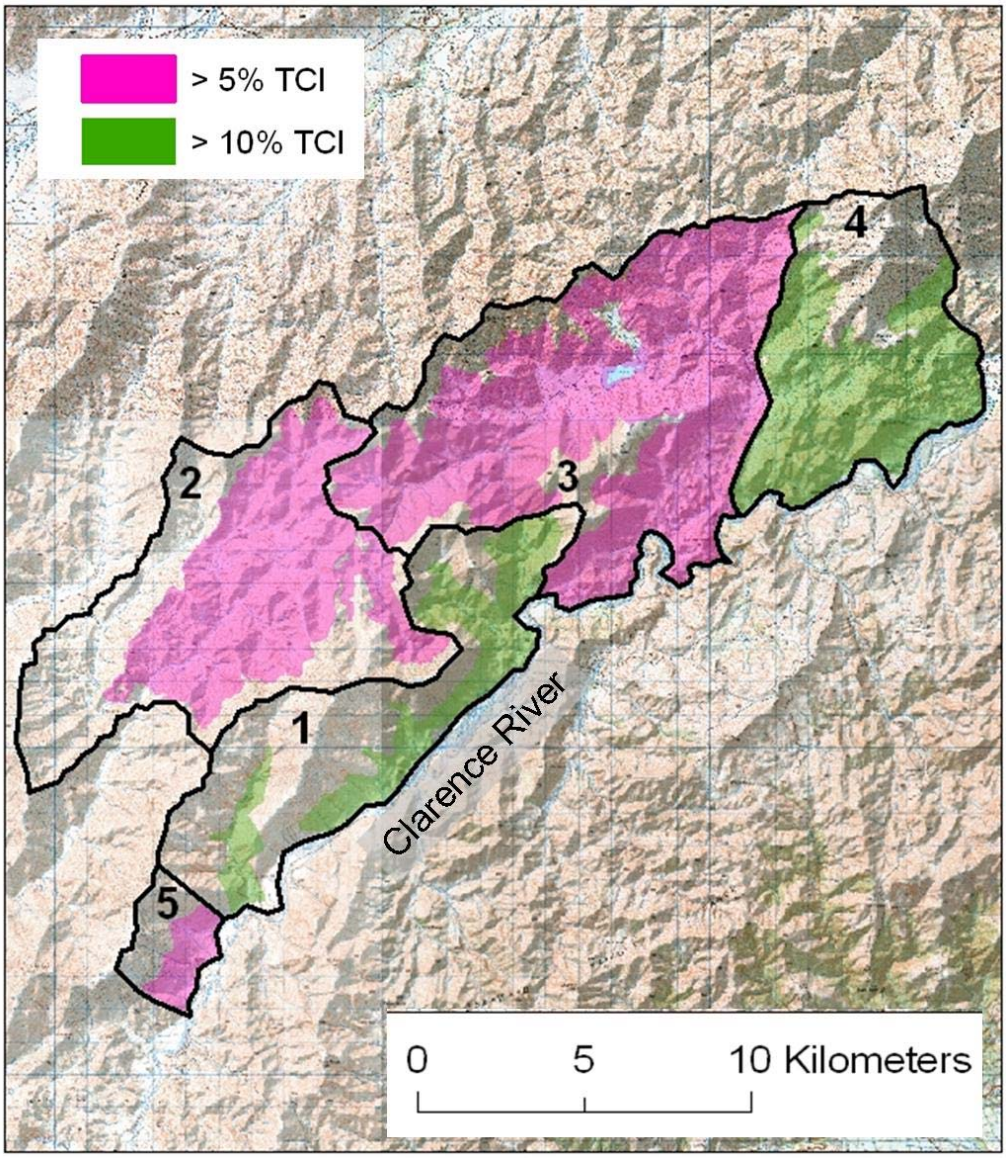

Fig. 1 Study area showing the five blocks, with one of the various aerial poisoning treatments applied to the shaded area in each block. In Blocks 2, 3, and 5, all of the habitat in the shaded treatment area was predicted to have a pre-control possum Trap-Catch Index (TCI) > 5%, whereas in Blocks 1 and 4, only habitat with a predicted TCI > 10% was included.

4.3 Aerial sowing of bait clusters

To aerially deliver bait in clusters a 700-kg-capacity SowLow bucket originally developed to allow reliable broadcasting of bait at lower than usual sowing rates (Morgan et al. 1997; Morgan 2004), was modified. The paddle-wheel mechanism used to regulate bait flow was altered and the broadcast spinner was replaced with a timed gate mechanism that released bait at regular intervals with no lateral momentum at all. Modifications were undertaken by Eagle Engineering of Amberley.

The primary aim was to reduce bait coverage to <10% of the area between flight paths, but to have a density of bait within the area covered that was 4–5 times higher than the average with normal broadcasting of bait, resulting in 60% less bait being sown overall. A secondary aim was to reduce the amount of bait fragmentation caused during sowing, so that there were fewer sub-lethal fragments available to possums.

The performance of the modified SowLow bucket was first field-tested near Hanmer on 22 September 2008. A Squirrel helicopter (flown at 50 knots, 50 m above ground level) was used to sow a single swath of non-toxic 8-g RS5 cereal bait bait over flat, bare ground. A gusty NW wind (15–20 knots at times) made flying to a marked flight path difficult. The sowing pattern and sowing rate was assessed along the flight path. A group of 10 observers located clusters by moving slowly along the direction of the swath until bait was found. The numbers of baits in each cluster were counted, the length and width of each cluster was measured, and the distance between the centres of successive clusters was calculated.

A second calibration trial, using the same bait type, was conducted on 6 October 2008 along a flight path that ran across a hillside with an average slope of 30 degrees. The ground cover was a mixture of rough pasture, scrub, bare ground and rock. Flying speed and the bucket release interval were adjusted in response to results obtained in the first calibration trial, with the aim of achieving an overall rate of 1 kg/ha.

Data on bait distribution and fragmentation was also collected on the first day of the main poisoning operation on Molesworth Station. In Block 3 (broadcast), three 4-m-wide belt transects, 650–950 m long, placed at right angles to the flight paths were searched for bait while in Block 2 (cluster),we searched for clusters along two flight paths. Cluster size and distribution of baits within the cluster were recorded. One of the areas searched comprised a 250-m-long transect along a river flat, the other a 400-m-long transect across a hillside.

All baits found in calibration trials and the main operation were collected and sorted into three size classes (<2 g, 2–6 g, and >6 g). The frequency distribution of size classes of the sown baits was compared with those for baits sampled directly from bags (i.e. not sown). They were also compared with baits collected across the swath, following sowing with a conventional bucket operated at normal bucket speed (1350 rpm) and flying altitude (approximately 100 m) over pasture near Hanmer on 15 September 2008.

4.4 Flight path spacing

One concern arising from the proposal to sow bait in clusters was that possums living midway between the flight paths might not encounter one of the bait clusters, particularly since the 140-m flight-path spacing previously used on Molesworth was wider than that used in many other operations. A non-toxic bait acceptance trial using a bait marker was therefore undertaken to determine the proportion of possums marked when clusters of bait were sown at the standard Molesworth spacing.

Non-toxic RS5 baits (nominal mean weight 8 g) were surface-coated with 0.1% wt:wt rhodamine B (RB) dye. A palatability trial of dyed bait compared with non-dyed bait showed the former to have a palatability value of 32.2% (where 50% means equal consumption of the two bait types).

Baits were sown on 16 September 2008 using the modified SowLow bucket under a GPS-guided Squirrel helicopter along four predetermined flight paths in a steeply mountainous part of the Clarence Valley. The flight paths were each 2.5 km long and were placed across the lower slopes more or less parallel to the river (Fig. 2). The helicopter was flown at 50 knots and the timing interval for cluster delivery was set at 1.5 seconds. It was not possible to maintain a fixed height above the ground because of the steeply undulating terrain.

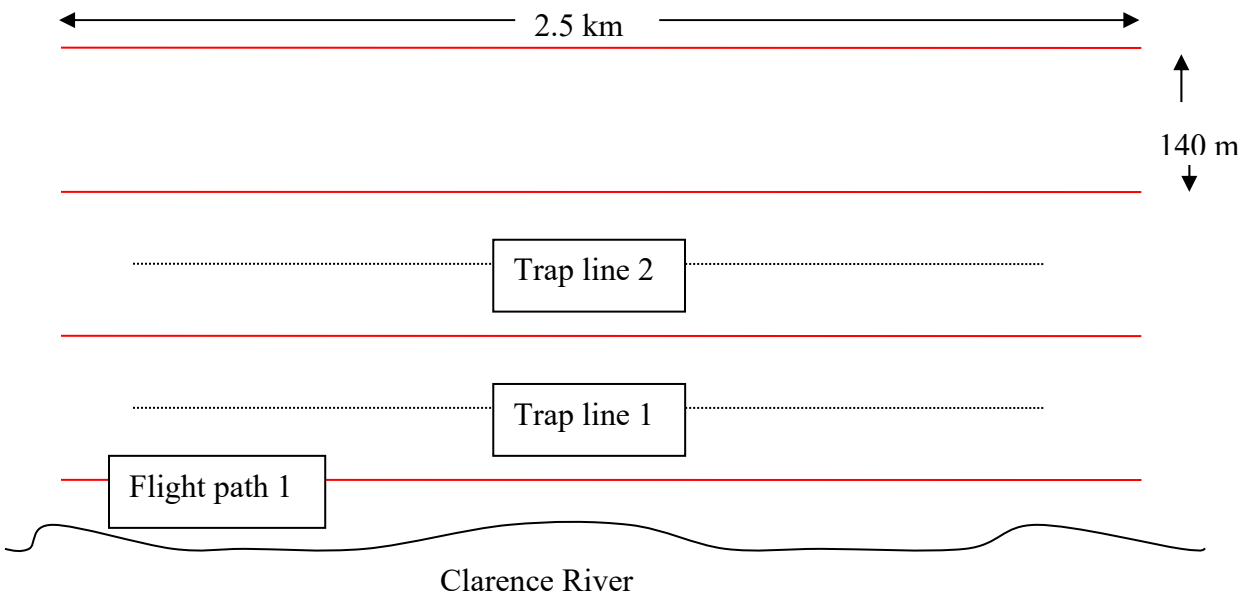

Fig. 2 Layout of flight paths for sowing bait, and trap-lines for subsequent possum capture.

On 19 September, after allowing possums 3 nights to find and eat bait, 50 leghold traps were set 40 m apart along two lines running midway between flight paths (Fig. 2) for 4 nights. Captured possums were euthanized as per Landcare Research's generic Animal Ethics Approval for leg-hold trapping of possums, and their mouths and paws were checked in the field for RB marking. Stomachs were removed whole and later inspected in the laboratory for RB marking. Where RB-dyed material was present, the marked bait was removed and dried (for 24 h at 70°C) to a constant weight.

4.5 Effect on activity indices of possums (and other species)

To determine the relative effect of the different treatments on the densities of possums and other species, we used the rate at which each species left bite marks on two different 'interference' devices: Chew Cards (CCs) and Wax Tags® (WTs). CCs are plastic corflute cards that are baited to attract animals (Sweetapple & Nugent 2008), whereas WTs are functionally similar but unpalatable devices that animals bite out of curiosity (NPCA 2008b). In principle, this difference should make Chew Card Interference rates (CCIs; the percentage of CCs bitten) more sensitive to changes in animal abundance, but for this reason the index is also prone to saturation (i.e. the index rises quickly to near 100% as possum numbers increase, so that there is little ability to distinguish between medium and high densities). Conversely, Wax Tag Interference indices (WTIs; the percentage of WTs bitten) should be less sensitive but, consequently, are less likely to saturate quickly. We therefore used both devices to maximise sensitivity at low possum density immediately after control and to reduce the likelihood of saturation as possum numbers increase during the 3 years of post-control monitoring planned for this project.

In each of the four main treatment blocks 10–12 CC/WT lines were established semi-randomly by identifying random accessible start points on or near main watercourses, and then projecting those upslope for 1 km toward the nearest boundary of the area to be poisoned. Some, but not all, transects extended outside the area to be poisoned by up to 300 m. Cards more than 75 m outside the area to be poisoned were not used to estimate the effect of poisoning, but will be used in subsequent mapping during monitoring of the spatial patterns in possum population recovery over the ensuing 3 years.

Observers were usually flown to the highest point on each transect and then travelled down the transect using a GPS, placing one CC and one WT every 50 m, with the WT 10 m away from the CC. The location of each device was recorded and mapped (Fig. 3).

The night before deployment, CCs were baited with a paste made from commercial cat food on one side and peanut butter with ground lucerne incorporated on the other side of the flute, as recommended by Sweetapple and Nugent (2008). Devices were individually numbered with transect and plot number, and were pegged to the ground using a metal peg.

Chew Cards and Wax Tags were first deployed on 18–24 September (pre-control), checked and replaced between 7 and 9 November (about one week after control), and then, most were pulled in between 18–28 November. However, any cards chewed in the second post-control survey were replaced, and pulled in on 18 December. The long time-interval between first deployment and the immediate post-control check was caused by the poison operation being postponed. The resulting difference in the length of time between checks means that any

reduction in interference rates is likely to be overestimated. However, we assume that this bias will have been the same for all blocks, and therefore that the reductions reported provide a valid *relative* index of the differences in the true reductions between blocks.

Field observers recorded which cards had bite marks, and subjectively assigned the bite marks to the species they considered most likely to have been responsible. The devices were collected and later checked in the laboratory, using a microscope where necessary, to verify the field records. In general, most possum-chewed cards were heavily chewed so the field records were usually correct, but the laboratory checks detected a few more instances of possum interference and a lot more interference by mice.

For statistical analysis, cards outside the poisoned area were excluded as were cards not found on either check. The percentage of devices on each line with bite marks present was calculated to provide a CCI, a WTI, and a WTCCI. The latter is the percent of sites with *either* CC or WT interference. The indices recorded immediately after control were used an index of pre-control abundance, while those recorded 3 weeks after control were used as indices of the post-control abundance. The indices were Poisson-transformed because we presume that this transformation increases the linearity of the index as a measure of abundance.

Reductions in possum activity were estimated by regressing the transformed post-control index of possum activity against the pre-control value for the same transect, with the regression forced through the origin on the assumption that when possums are absent, both pre- and post-control indices must be zero. The differences in reductions between blocks were assessed using *t*-tests to compare the mean reduction per line between pairs of blocks. Five lines with less than 20% WTCCI interference before control (i.e. usually none or only one or two cards interfered with) were excluded from the statistical comparisons because they provided unreliable estimates of the reductions in activity, partly because of the proportionately greater size of sampling error at low values and partly because at least some of these limited data were suspect (i.e. it was sometimes unclear whether the few bite marks observed had been caused by possums, especially with WTs).

4.6 Post-control possum trap catch

Within each of the five treatment areas random trap-line start points were applied at a rate stipulated in the latest NPCA protocol (NPCA 2008a). As all the aerial 1080 application was on previously identified possum habitat (Byrom et al. 2007) none of the blocks were stratified in terms of possum habitat. Therefore 10 trap-lines were allocated for the first 500 ha and thereafter, one line was allocated every 300 ha to a maximum of 40 lines (Table 1).

The trap-catch surveys were conducted as per the NPCA (2008a) protocol for unforested habitat. Trapping was carried out using backing boards on *all* trap sets and all trap-lines were established by currently certified NPCA operators. During line establishment and removal, ground-based trappers were usually positioned at or near line starts by helicopter but, on the 2 days between, trap-lines were checked from the helicopter wherever that was feasible, and the traps only visited on the ground if sprung, interfered with, or they had a capture.

Standard Residual Trap Catch Indices (RTCI; the percentage of trap nights on which possums were captured) were calculated for each trap-line and were compared between treatments using 2×2 between-subjects factorial ANOVA.

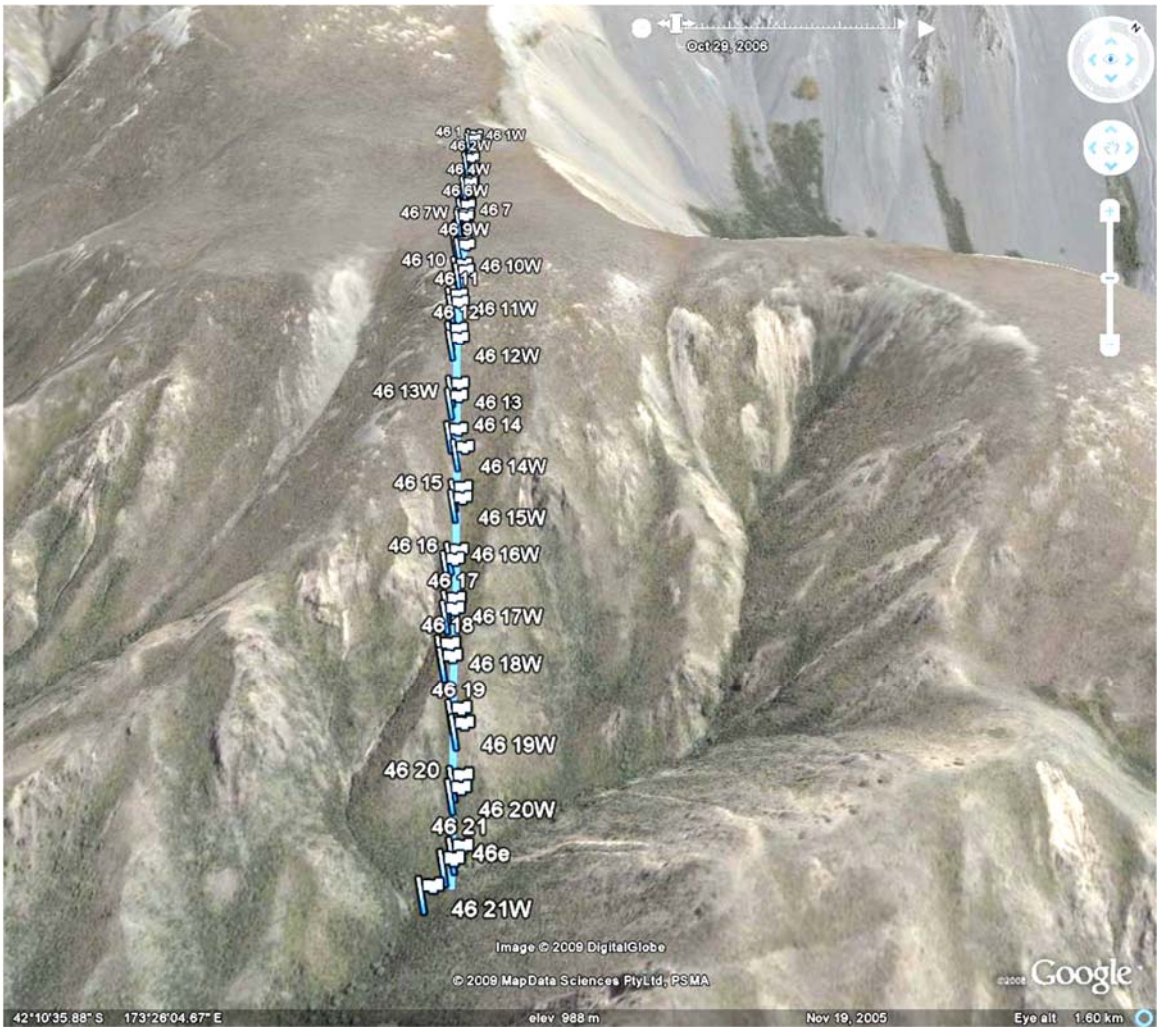

Fig. 3 Typical layout of a Chew Card and WaxTag® (WT) transect, as depicted by Google Earth. The pair of numbers indicate the transect and plot numbers respectively, with the WT sites designated by the W suffix.

Table 1 Number of 10-trap RTCI trap-lines by block

Block	Total area (ha)	Poisoned area (ha)	Percent poisoned	No. of traplines
Block 1 (low-coverage broadcast)	6863	1893	27.6%	15
Block 2 (high-coverage cluster)	6293	4300	68.3%	23
Block 3 (high-coverage broadcast)	9658	7869	81.5%	35
Block 4 (low-coverage cluster)	4934	3358	68.1%	20
Block 5 (prefed high-coverage cluster)	758	359	47.4%	10
Total	28506	17779	62.4%	103

4.7 Difference between treatments in the variable costs of aerial poisoning

A spreadsheet model was developed to characterise the differences between blocks in the cost of bait (including cartage), and in the flying time used to sow bait and to return to reload. The actual flying time obtained from the helicopter company was not broken down into subcomponents and, therefore, the cost for each component was derived from estimates of the time spent on each (given the typical flying speed for the activity). The modelled costs did not include any of the overhead costs such as loading site staff, consultation and consent process, or water quality monitoring.

5. Results

5.1 Ability to aerially deliver bait in clusters

In the first field calibration trial of the SowLow cluster bucket, on flat ground near Hanmer, we located 15 clusters of bait containing, on average, 52 baits and an equivalent sowing rate that exceeded the target of 1.0 kg/ha assuming 130-m swaths(Table 2). Subsequent increases in flying speed and bucket release interval on the hillside near Hanmer reduced the equivalent sowing rate measured, Further adjustments made before the main Molesworth operation resulted in measured equivalent sowing rates that were still less than the target but these estimates are negatively biased because the data are not corrected for the effect of slope on plan area, and an unknown proportion of baits would have remained undetected during searching.

Table 2 Flying speed and bait-release interval used to give clusters with recorded mean dimensions and numbers of baits (and SE) as surveyed during calibration trials at Hanmer, and during the poisoning operation at Molesworth. The estimated sowing shown was calculated from the number of baits per cluster, cluster spacing, and assuming a 130m spacing between flight paths.

Survey	Flying speed (knots)	Bait release interval (secs)	Length (m)	Width (m)	Spacing (m)	No. of baits	Sowing rate (Kg/ha
Calibration trial – Hanmer (pasture)	50	1.2	8.0 (0.9)	5 (0.5)	20.5 (2.4)	52 (2.1)	1.35
Calibration trial – Hanmer (hillside)	60	1.5	18.3 (3.1)	22.3 (1.6)	31.4 (2.1)	35 (6.2)	0.72
Molesworth operation – flats	60	1.0	26.6 (5.7)	20.2 (4.5)	43.1 (4.5)	51.8 (3.9)	0.78
Molesworth operation - hillside	60	1.0	30.1 (5.4)	30.1 (5.4)	48.3 (4.5)	34.2 (2.1)	0.49

The percentage of baits <6 g in size was low before bait was sown, but markedly higher after sowing (Fig. 4a; bait from bags vs all sown bait $\chi^2 = 183$, df = 2, $P < 0.001$). On flat 'soft' pasture near Hanmer, there was less fragmentation in sown bait using the cluster bucket than with the broadcast bucket (Fig. 4a; $\chi^2 = 100$, df = 2, $P < 0.001$). Although very small bait fragments (<2 g) comprised less than 5% of the total weight of bait in each sample (Fig. 4b), they comprised over 25% by number sown with the broadcast bucket but only about 3% of the number sown onto pasture with the cluster bucket (Fig. 4a). Using the cluster bucket on 'harder' terrain on a sloping hillside resulted in greater fragmentation in the sample than from the same bucket on flat pasture, but the difference was not statistically significant (Fig. 4a; $\chi^2 = 4.6$, df = 2, $P = 0.10$).

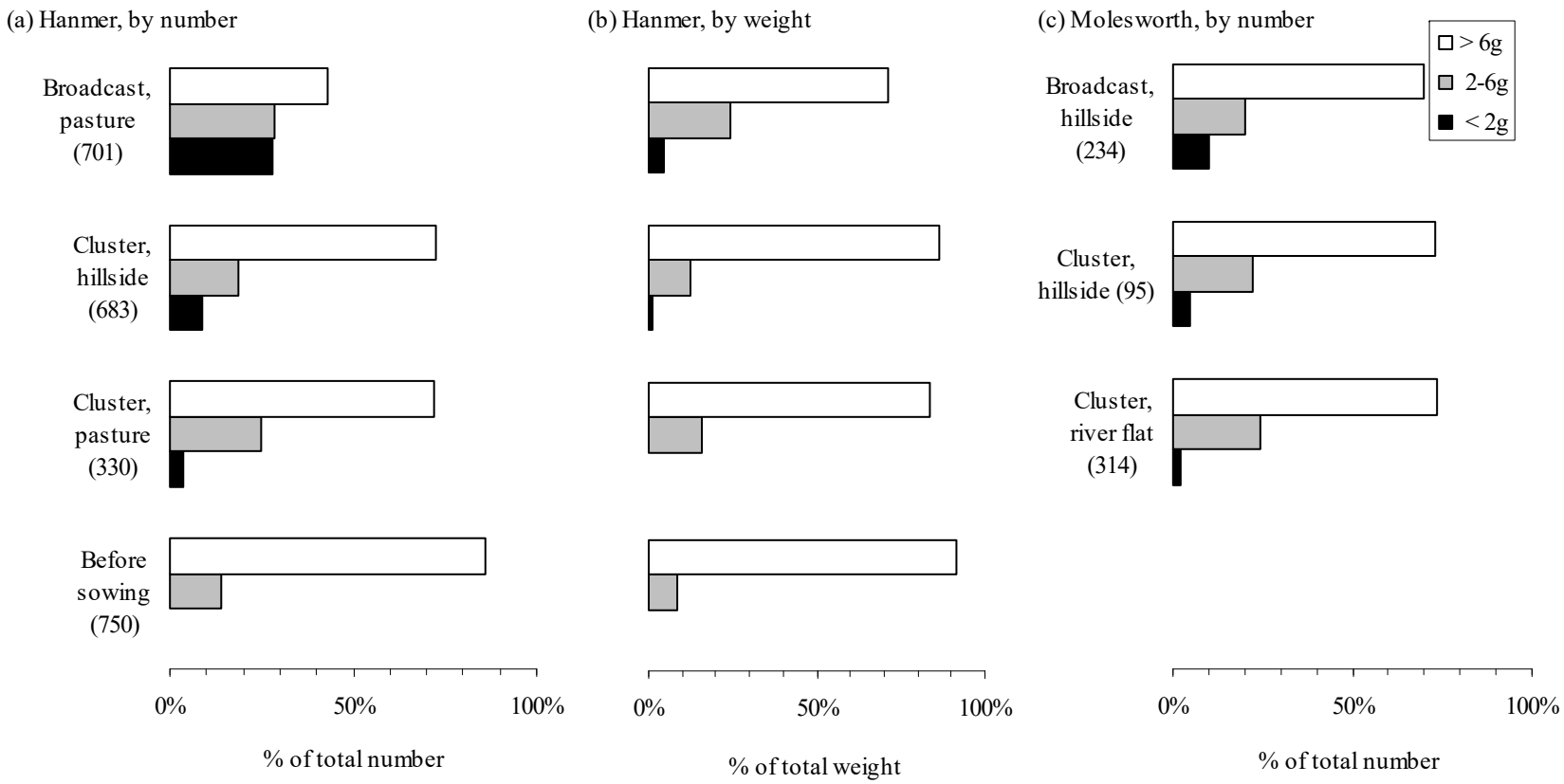

Fig. 4 Percentage of baits in three size classes in samples of bait that were either taken directly from bags of bait as it was being loaded into buckets, or collected from the ground after sowing with either the SowLow cluster bucket or a broadcasting bucket with the spinner operating at 1350 rpm. For the latter, the bucket type and terrain is indicated on the vertical *x*-axis along with (in parentheses) the number of baits in the sample. Results are presented for experimental sowings at Hanmer (a, b) and for the main operation on Molesworth (c).

As in the experimental sowings at Hanmer, there were fewer very small (<2 g) fragments found under the cluster bucket than under the broadcast bucket (Fig. 4c; $\chi^2 = 15.4$, df = 2, $P = 0.005$) but the difference was not as marked.

5.2 Flight path spacing

A total of 180 kg of bait was distributed along 10 km of flight paths, equating to a sowing rate of 1.3 kg/ha, one-third higher than the low-sowing-rate treatment planned for the main operation. Although bait distribution was not formally mapped, field observations indicated far greater dispersion of bait than in the calibration trial above. Bait appeared to be distributed in a more or less continuous belt 20–40 m wide under the flight paths, presumably as a result of the steep terrain causing some baits to bounce downhill on impact, and/or the effect of wind and variable sowing heights on bait dispersion.

A total of 28 possums were caught over 4 nights (7.4% Trap Catch Index, $n = 400$ trap nights). The 40-m spacing between traps is likely to have resulted in this index being higher than a standard TCI based on a 20-m spacing.

All but three possums showed evidence of rhodamine dye indicating that they had both encountered *and* eaten bait). The 15 possums captured on the first two nights of trapping were all marked, but one (16%) of six captured on the third night and two (29%) of seven captured on the fourth night were not marked.

Of the 25 RB-marked possums, no bait was detected in the stomachs of 12, presumably because these had not eaten bait on the night they were captured. All but one of the 13 stomachs in which bait was detected contained at least 8 g of bait (i.e. at least one whole bait). The exception contained only 5 g, while at the other extreme one stomach contained the equivalent of more than four baits (36 g).

5.3 Reduction in possum activity and residual trap catch

The overall average CCI per line ($n = 44$ lines) for the cards classed as being inside the poisoned areas was 64.0 ± 9.4% (95% CI) before control and 9.5 ± 4.6% afterward. For WTI data, the comparable values were 42.7 ± 7.2% and 4.3 ± 2.0% respectively.

Estimates of the reductions in CCI alone, in WTI alone, and in the combined WTCCI showed the same pattern between blocks, so only results based on the most data rich WTCCI index are presented here.

The reductions in the Poisson-transformed WTCCIs estimated by regression through the origin (see Methods) were 97.8% in the Broadcast High-Coverage Block, 98.4% in the Cluster High-Coverage Block, 94.6% in Broadcast Low-Coverage Block, and 94.4% in the Cluster Low-Coverage Block (Fig. 5).

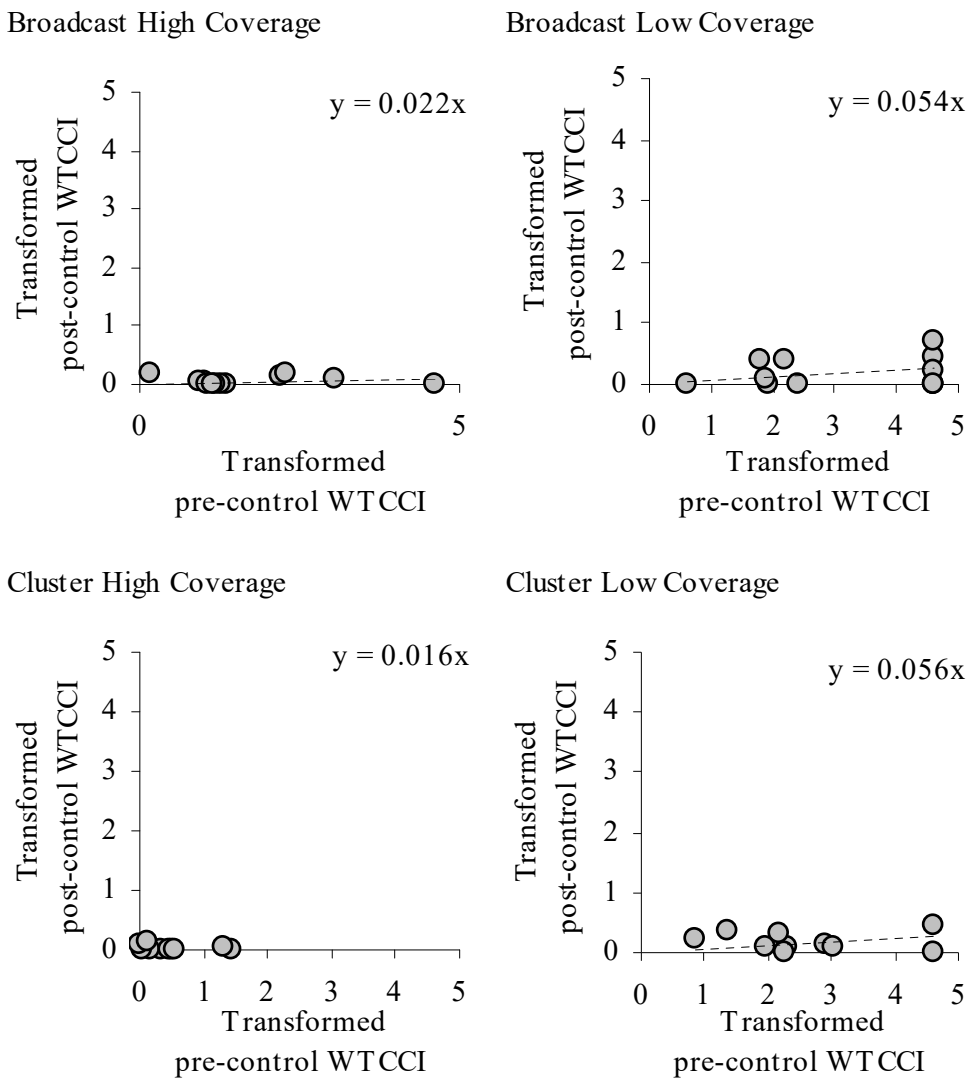

Fig. 5 Relationships for each of the four main treatments between the pre- and post-control indices of possum activity. Data points are the Possion-transformed frequencies for the combined Wax Tag®/Chew Card Indices (WTCCI) of possum activity for each line, and the slopes of the regressions forced through the origin (dotted lines) express the average residual (post-control activity) as a proportion of pre-control activity.

Excluding the five lines with pre WTCCIs < 20% (see Methods) there were significantly larger reductions per line in the high-coverage block than in the low-coverage block in both the broadcast-baited area ($t_{212} = 2.86$ $P = 0.009$) and in the cluster-baited area ($t_{18} = 2.23$, $P = 0.043$). There was no difference in the reductions per line between the cluster and broadcast blocks in either the high-coverage area ($t_{18} = -1.1$, $P = 0.29$) or in the low-coverage area ($t_{20} = 1.32$, $P = 0.20$).

The overall average RTCI was 0.9%. No possums were captured on 81 (79%) of the lines, one possum was captured on 19 (18%) of the lines, two possums on one line in Block 3, and three possums on each of two lines in Block 4.

There was no difference in the RTCI per line between the cluster and broadcast blocks in either the high-coverage area ($t_{56} = 0.84$, $P = 0.40$) or in the low-coverage area ($t_{33} = -0.82$, $P = 0.42$) (Fig. 6). There was also no significant difference in the RTCI per line between the

high- and low-coverage blocks in either the broadcast-baited area (t_{53} = 1.67, P = 0.102 or the cluster-baited area (t_{41} = 1.99, P = 0.053).

The RTCI of 0% recorded in the small 359-ha prefed block in which bait was sown in clusters at 1.0 kg/ha (Fig. 1) was not significantly lower than in Block 2, the most comparably treated block (Fig. 5, t_{31} = −1.19, P = 0.24).

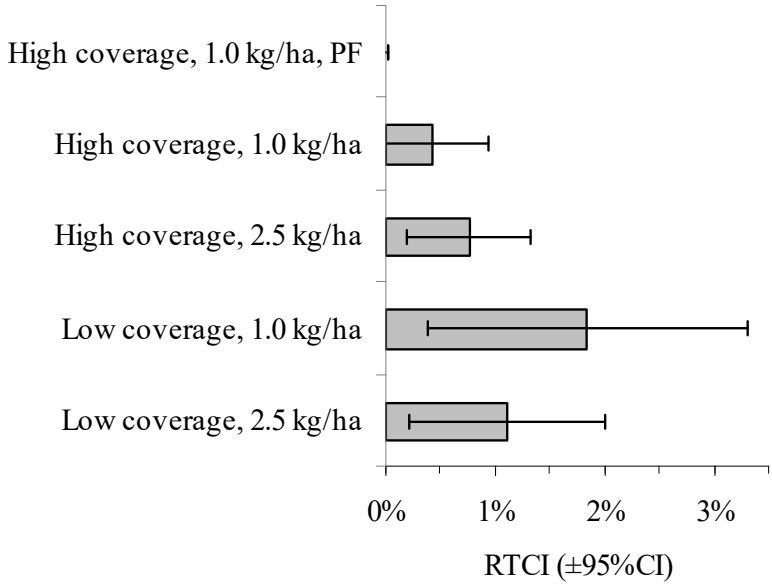

Fig. 6 Residual Trap Catch Indices (RTCI) for the four main treatment blocks and also for the small prefed (PF) block. In the three blocks baited at 1.0 kg/ha, baits were sown in clusters, whereas bait was broadcast in the other two blocks.

5.4 Changes in indices for species other than possums

At least four species (mice, ferrets, rabbits, and hedgehogs) other than possums were detected on CCs, WTs or both, but only mice were detected on more than 5% of cards. A few cards were bitten by an unidentified species (probably goats). No rats were detected at all.

Mouse interference was detected on an average per line of 46% of CCs before control, and 64% after control, but on only 1.1% and 1.3% respectively of the WTs. The apparent increase in CCI appeared largely to be an artefact of the decline in possum interference, as on the 269 cards not bitten by possums before or after control mouse detections were 65% before control and 70% afterward. Overall, there was no evidence of any major reduction activity in mouse activity in any block.

There was no apparent overall change in ferret CCIs (1.2% before control, 1.1% afterward; t_{43} = 0.01, P = 0.99). With WTs, however, the overall interference rates recorded (3.6% before control, 1.9% afterward) were higher than those recorded with CCs, but the halving in WTI after control was not significant (t_{43} = 1.08, P = 0.28).

Rabbit CCIs did not change significantly (1.6% before control, 1.0% afterward; t_{43} = 0.61, P = 0.55)). Rabbit bite marks were recorded on just one WT.

Hedgehog CCIs declined significantly (1.3% before control, 0.1% afterward; $t_{43} = 3.11$, $P = 0.004$)). In Block 1, hedgehog interference was the same before and after control (0.6%), but in the other three blocks none at all were detected after control. No hedgehog bite marks were recorded on WTs.

5.5 Observations of non-target kill

Although station staff had attempted to muster all cattle out of area to be poisoned, some broke back in the westernmost High-Coverage Cluster Block (Block 2) and at least five of these were seen dead after poisoning (R. Mapp, P. Packham, pers. comm.). This block has very little woody vegetation so dead animals were much more easily seen than in the other blocks. Some deer were also seen dead in this block (13 sighted by ground staff, and 18 by the helicopter pilot – with 7–9 of these likely to have been seen by both (R. Mapp, P. Packham, pers. comm.).

A further three dead deer were observed by the pilot and two by ground staff in the High-Coverage Broadcast Block (Block 3). Six live deer were sighted in this block during post-control monitoring (P. Packham, pers. comm.) and 23 live deer were seen in the Low-Coverage Cluster Block (Block 4) in April 2009 (albeit close to the boundaries of the block).

Approximately 20 dead goats were seen in Block 3 (broadcast) and Block 4 (cluster), with some deaths apparently occurring up to a fortnight after the poison was flown (P. Packham, pers. comm.). However, monitoring staff reported seeing many goats alive after the poisoning in both these blocks, which hold the main concentration of feral goats on Molesworth.

Three dead pigs (one pair and one single pig, all about 35-kg weight) were observed by the pilot in the High-Coverage Broadcast Block (Block 3), and one large adult pig was found dead in the High-Coverage Cluster Block (Block 2) (R. Mapp, pers. comm.).

5.6 Variable costs of poisoning

The two helicopters spent a total of 44.6 hours' flying time to deliver and spread the toxic bait over the 17 800 ha poisoned, at a total cost of about $4.79 per hectare. This flying-time cost was partitioned into the time spent getting the helicopters to Molesworth Station, the time spent actually spreading bait, and the time spent reloading the buckets, using estimates of the relative amounts of time required for each activity given the particular helicopter used (and the typical flying speeds during each activity), the estimated length of flight path baited in each block (given the area poisoned and the 130-m flight path spacing), and the different distances between each block and the loading zone.

The estimated cost of the flying time actually spent spreading bait was slightly higher for the 1.0-kg/ha blocks (~$2.06 per hectare) than for the 2.5-kg/ha blocks ($1.68 per hectare; Fig. 5) reflecting the different helicopter used and different flying speeds used. In contrast, the estimated flying cost of reloading was almost 60% lower for the 1.0-kg/ha blocks (~$1.90 per hectare) than for the 2.5-kg/ha blocks (~$4.10 per hectare) simply because the lower sowing rate required fewer reloads per unit area. Obviously the cost of bait was also 60% lower in the 1.0-kg/ha blocks.

Overall, there was a >50% reduction in the combined cost of bait and flying time for the in 1.0kg/ha blocks (Fig. 7). In the small prefed block the estimated costs were similar to those in unprefed 2.5-kg/ha blocks.

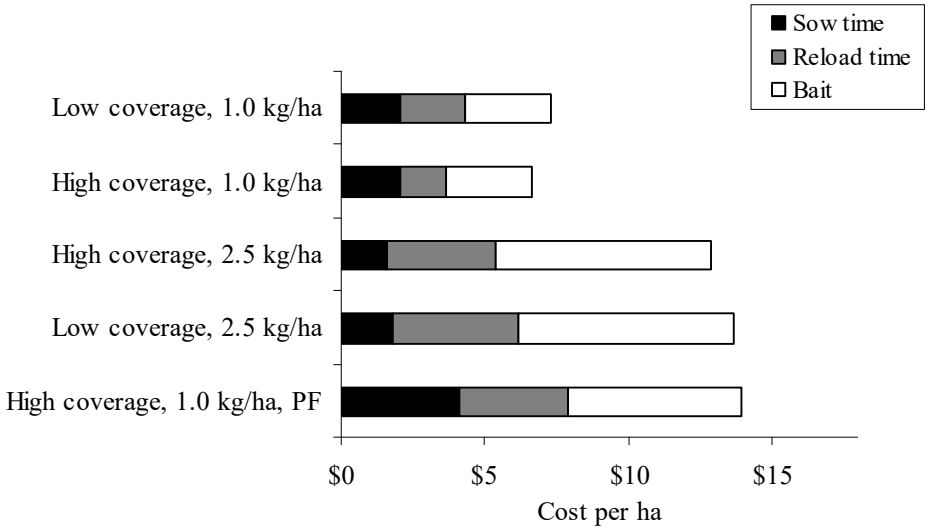

Fig. 7 Estimates of the variable costs of bait and flying time for each for the four main experimental blocks on Molesworth Station (none of which were prefed) and the small prefed (PF) block treated at the same time (see Methods for full description of these treatments). The costs do not include the fixed costs such as planning, consents and approvals, water monitoring, ground staff for reloading, helicopter positioning time, and other such costs, which comprised approximately one-third of the total cost ($7 per hectare). Sow time is the estimated flying time actually sowing bait, while reload time is the flying time spent returning to the loading zone to refill the sowing bucket and then returning to the operational area.

6. Conclusions

6.1 Ability to aerially deliver bait in clusters

It is feasible to aerially sow bait in clusters, at least on flat ground where the helicopter is close to the ground. On steeply sloping undulating terrain, the helicopter typically flies higher altitudes over much of the country, and the combination of factors results in an increase in cluster size to the point where they merge into a more or less continuous strip. Although staff involved in post-control monitoring did not formally measure cluster size, clustering of bait was often evident to them.

There was less fragmentation of bait during sowing with the cluster-sowing bucket than with the broadcasting buckets used, particularly in the calibration trial at Hanmer but also in the main operation. However, field observations indicated that some baits broke apart on impact, especially in the very rocky areas that are common on Molesworth, so there is likely to have still been significant fragmentation in the cluster-sown blocks.

6.2 Flight path spacing

No RB marking was detected on about 10% of the possums trapped halfway between flight paths in the spacing trial. Assuming simplistically that this is a consequence of possums not encountering bait, and also assuming that all possums with home range centres directly under the flight path cannot have avoided encountering bait, this indicates that at worst an average of only 5% of possums might not encounter bait.

However, we think that is probably an overestimate because the only unmarked possums were trapped on the sixth and seventh night after prefeeding, by which time all of the bait had been consumed in some places (by pigs, and possibly rabbits and goats, as well as possums). It is therefore possible that these possums had previously eaten bait, but the resulting marking had disappeared in the days between their eating bait and being trapped. In line with that, many stomachs did not contain measurable amounts of baits and in these possums the marking was often very faint, suggesting it faded quickly.

Given the possibility that up to 5% of possums might not be encountering bait within 7 days at the 140-m flight path spacing, the flight path spacing for the main operation was reduced from the planned 140 m (previously used on Molesworth) to 130 m.

6.3 Efficacy against possums

The reductions in the transformed indices of possum activity are not direct estimates of percent kill because the pre-control assessment period was substantially longer than the post-control period. That will have resulted in greater apparent reductions in activity than the actual reduction in possum numbers. Also, the extent to which the Poisson transformation applied to the raw WTCCIs over- or under-compensated for the inevitable non-linearity of the WTCI–possum-density relationship is not known. For the purposes of this study, however, the relationship between the reduction in activity and the true reduction in possum numbers is assumed to be consistent across blocks.

The actual overall reduction in possums (to an average post-control RTCI of 0.9%) is likely to have exceeded 90%, as a previous trap-catch survey in 2005 (Byrom et al. 2007) recorded a TCI for the then uncontrolled possum population of 9%. As that figure included high-altitude areas that were excluded from the poisoned areas because they contained very few possums, the pre-control TCI for the area poisoned is likely to have been well above 10%, especially in the low-coverage blocks.

All of the RTCIs for those blocks were below the 2% RTCI target often applied by AHB as a performance standard. However, two lines in Block 4 (low-coverage block) nominally caught three possums (although for one of these one of the 'captures' was a trap sprung by a possum on the second night that may have been caught on the third night). This block would therefore have failed a 'no line over two captures' target if that frequently used complementary target had also been imposed.

We had not expected coverage to greatly influence poisoning efficacy, but for each sowing method there were greater reductions in possum activity in the high-coverage blocks than in the respective low-coverage blocks. While that suggests better kills were obtained with

higher coverage, the result is inconclusive because the design was not spatially replicated (i.e. there was effectively only one spatial sample of each of the four combinations of sowing method and coverage).

Overall there was no strong evidence of any difference between sowing methods in either the possum reductions or RTCI. Given the indications of a possible effect of coverage on the possum reductions, the lack of any consistent difference between sowing methods could therefore reflect either similar efficacy with broadcast and cluster sowing, or it could be the product of an interaction between coverage and sowing method, with cluster treatment being more effect than the broadcast treatment in the high-coverage blocks and the reverse in the low-coverage blocks. Such an interaction could reflect some effect on the bait-finding ability of possums in the dense patches of matagouri and other scrubby vegetation that was more common and extensive in the low-coverage blocks than in the high-coverage blocks; it is possible, for example, that in open-habitat sowing, possums more readily found several baits at once when the bait was in clusters than when it was broadcast, but that the reverse occurred in dense scrub.

Whatever the explanation, it is clear that high reductions were obtained with cluster baiting despite the 60% reduction in the amount bait used. Research elsewhere (Brown & Urlich 2005; Coleman et al. 2007) indicates it is likely that prefeeding would have resulted in even higher kills and lower RTCI, and the 0% RTCI recorded in the small prefed cluster-baited block is consistent with that.

6.4 Changes in activity of other species

The poisoning appeared to reduce hedgehog CCIs by 85%, suggesting it had a significant effect on that species. However, there was no evidence of any effect at all on mice, and no clear evidence of any major reduction in rabbit and ferret interference.

Although none of the freshly dead animals seen during post-control monitoring were tested for 1080, it is likely that most if not all had been poisoned. We had hypothesised that the reduced rate at which clustered bait was sown might reduce deer deaths, as Meenken and Sweetapple (2000) did not detect any reduction in an index of deer abundance when bait was sown in high-density strips. However, in the High-Coverage Cluster Block it appears that at least 20 deer were killed and few were seen alive in that block afterward, suggesting a high percentage kill of deer there. One ground-based observer reported finding a ‘string’ of dead deer along a flight path through an area of easy terrain where the bait was tightly clustered and the ground cover very short so that it was easy to see tens of baits within a radius of a few metres. That observation is consistent with our underlying hypothesis that where animals such as deer and cattle need to eat multiple baits (or parts of baits for possums) to be killed, the likelihood of their being poisoned is increased by any factor that increases their ability to quickly find those extra baits.

The much smaller number of deer seen dead in the other cluster block and the larger number of live deer seen there several months later suggests clustered baiting had less effect on deer there. One reason for that might be the much more extensive presence of dense matagouri scrub in which it was usually difficult to see more than one bait at a time. However, that scrub will also have reduced the proportion of dead deer seen by observers.

In relation to Tb control on Molesworth, the killing of deer will have reduced the number of infected deer capable of carrying the disease through time.

6.5 Modelled costs of poisoning

The sowing of bait in clusters at a lower rate had two main effects on the cost of the operation. It reduced the bait cost by about 60%, and reduced the number of times the bucket needed to be reloaded by the same amount. The latter represented a major saving in this operation because the loading zone was a long way from the area being poisoned; but where the loading zone was close to the area to be poisoned this saving would be proportionately smaller.

6.6 Summary

Although none of the four main treatments were replicated, sowing a reduced amount of bait in clusters appeared to have been as effective as when the normal amount of bait is broadcast. That suggest that there is potential to substantially reduce the amount of toxic bait sown during aerial 1080 poisoning. That could either result in large saving in bait costs and sometimes also in flying costs, or those reductions in cost could be used to apply prefeed where that is not normally used. Either option would increase cost-effectiveness.

While further trials are needed to confirm these results, the outcomes are consistent with the hypothesis that possum kill depends partly on how quickly possums can find a second bait after they have encountered toxic bait for the first time (Nugent et al. 2008). As there is no evidence that sowing baits in clusters greatly reduced possum kill, it seems clear that it is not necessary to attain uniform bait coverage to obtain good kills.

7. Recommendations

- The AHB should continue with an already planned series of trials to test the efficacy of sowing smaller than usual amounts of toxic bait in strips or clusters.
- Future aerial possum control operations on Molesworth Station (or in similar unforested habitats) should test the efficacy of even lower amounts of toxic bait with and without a small amount of prefeed. At this time we recommend trialling a regime involving prefeeding in strips using a large number of small non-toxic baits (e.g. 0.5 kg/ha of 2-g baits) followed by strip- or cluster-sown toxic bait also applied at a low rate (e.g. 0.5 kg/ha of 8-g 1080 baits). Preliminary results from a February 2009 trial (G. Morris, unpubl. data) suggest that the flight paths used for prefeeding and for toxic baiting should be closely aligned.

8. Acknowledgements

We thank Mike Perry, Morgan Coleman, Roger Carran, Kev Drew and Grant Morriss (Landcare Research field staff), and Roland Mapp, Chris Brausch, Nigel Young, David Griffiths, Natalie Curnow, Charles Lim, Nyree Fea, and Jeff Lennon (independent contractors). The flying was undertaken by Phil Packham (Amuri Helicopters), whose knowledge of Molesworth and practical experience proved invaluable during this work.

Special thanks to Jim Ward (Molesworth Station) and Colin and Tina Nimmo (Muzzle Station) for the use of their station huts. Andrew Nugent and Peter Sweetapple helped with logisitics and laboratory work, and Jackie Whitford and Christine Bezar commented on and helped edit early drafts of the report.

9. References

Brown KP, Urlich SC 2005. Aerial 1080 operations to maximise biodiversity protection. DOC Research & Development Series 216. Wellington, Department of Conservation.

Byrom A, Nugent G, Yockney I, Poutu N, Whitford J, McKenzie J, Shepherd J, Porphyre T 2007. R-80629. Cost-effective control of Tb in the Northern South Island High Country (NSIHC): Identifying the habitats and vector species requiring control. Landcare Research Contract Report LC0708/033. 85 p.

Coleman JD, Fraser KW, Nugent G 2007. Costs and benefits of pre-feeding for possum control. New Zealand Journal of Zoology 34:185–193.

Meenken D, Sweetapple P 2000. Comparison of red deer and possum kills following aerial 1080 poisoning by broadcast and strip application in the Wainuiomata and Orongorongo catchments, Wellington. Wairarapa Division Report No. 00/22. Wellington Regional Council. 14 p.

Morgan DR 2004. Maximising the effectiveness of aerial 1080 control of possums (*Trichosurus vulpecula*). Unpublished PhD thesis, Lincoln University, Canterbury, New Zealand.

Morgan DR, Thomas MD, Meenken D, Nelson PC 1997. Less 1080 bait usage in aerial operations to control possums. Proceedings of the 50th New Zealand Plant Protection Conference: 391–396.

NPCA 2008a. Possum population monitoring using the Trap-Catch method. Wellington, National Possum Control Agencies. 36 p.

NPCA 2008b. Possum population monitoring using the Wax Tag® method. Wellington, National Possum Control Agencies. 23 p.

Nugent G, Whitford J 2007. R-10652. Relative utility of Tb hosts as sentinels for detecting Tb. Landcare Research Contract Report LC0708/032. 38 p.

Nugent G, Warburton B, Morgan D, Sweetapple P, Clayton R, Thompson C, Coleman M 2008. R-10669. Local elimination: a new strategic approach to large-scale control of small mammal pests. Landcare Research Contract Report LC0708/149. 110 p.

Sweetapple P, Nugent G 2008. R-10681. Tools for mapping and eliminating surviving possums following possum control. Landcare Research Contract Report LC0809/017. 23 p.