Animal Health Board Project No. R-10681

Tools for Mapping and Eliminating Surviving Possums Following Possum Control

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Landcare Research
Manaaki Whenua

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DATE: September 2008

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Landcare Research Contract Report: LC0809/017

DOI: https://doi.org/ 10.7931/66s7-7c19

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Summary

Project and Client

A series of trials to develop a low-cost detection device for mapping the distribution of possums surviving control operations were undertaken by Landcare Research, Lincoln, for the Animal Health Board (AHB), between August 2007 and September 2008. This work involved optimising possum-palatability of baits for use on a new detection device (chew-track cards) and determining the percentage of possums in a low density population that are detected by this device.

Objectives

To develop a low-cost but highly sensitive detection device for reliably mapping the distribution of possums (and other small mammals) surviving control, by:

- Pen and field testing refinements to a new detection device (the chew-track card) to maximise its sensitivity to possums
- Systematically mapping the distribution of surviving possum foci following a large-scale control operation, and determining if chew-track cards can reliably and cost-effectively detect all possums present at such foci

Methods

- Pen trials with captive possums were undertaken to optimise palatability to possums of bait suitable for use with coreflute chew-track cards (CTCs). We initially compared possum preferences for white flour, wholemeal flour and peanut-butter-based baits, with and without the inclusion of 20% icing sugar. We then compared the palatability of the two most preferred bases when lured with one of seven lures (aniseed oil, curry powder, orange oil, raspberry essence, honey, fresh clover, mealworms), firstly when presented in bulk, and then the six most promising combinations when incorporated into CTCs.
- The two most promising base–lure combinations from the pen trials were field tested in CTCs on wild possums at Craigieburn, mid-Canterbury. Both baits were trialled with and without the addition of photoluminescent tags.
- The best-performing bait from the Craigieburn field trial was used in CTCs to survey 500 ha of the eastern Hauhungaroa Range in autumn 2008 to detect possums in a low-density population resulting from pest control in winter 2005. More intensive chew-track card grids were then established at centres of initial possum detection, with DNA recovered from the subsequent possum-chewed cards. DNA from possums leg-hold-trapped on the same grids was compared with that from the CTCs to estimate both CTC sensitivity to possums and possum trappability.

Results

- Honey and fresh clover, both in peanut butter with icing sugar, were the baits most preferred by captive possums, when presented in CTCs.
- Wild possums preferred fresh-clover-lured over honey-lured CTCs. Addition of photoluminescent tags made no significant difference to possum detection rates.
- Chew-track cards detected an estimated 80–93% of possums present during the Hauhungaroa field trial. Possum trappability was estimated at 44%.

Recommendations

- Chew-track cards are recommended as an efficient tool for mapping the distribution of possums surviving control. We recommend CTCs be baited with fresh or dried clover or ground lucerne pellets added to smooth peanut butter and 20% icing sugar at the rate of 10% (wt/wt wet weight equivalent).
- Further research is needed to fully overcome the downward bias caused by rat interference.
- Lower-cost alternatives to leg-hold trapping for mopping up residual clusters of possums should be developed and field-tested. The alternatives should include approaches that enable possums to be recovered for Tb necropsy as well as poison-based methods that do not.

1. Introduction

A series of trials to develop a low-cost detection device for mapping the distribution of possums surviving control operations were undertaken by Landcare Research, Lincoln, for the Animal Health Board (AHB), between August 2007 and September 2008. This work involved optimising possum-palatability of baits for use on a new detection device (chew-track cards) and determining the percentage of possums in a low density population that are detected by this device.

2. Background

The effectiveness of broad-scale possum control is now usually so high that it may be possible, with appropriate follow-up tools and strategies, to cost-effectively achieve local eradication of possums over large tracts of land. This requires the development of two tools, one to locate the few foci of surviving possums, and a second to eliminate all surviving possums at these foci.

One option for locating survivors is the residual trap catch (RTC) technique. However, the purpose of RTC surveys is to quantify possum abundance in terms of a whole-area overall mean density by random sampling of a very small portion of the operational area. RTC surveys are not designed to characterise possum distribution per se, and are an inefficient way of mapping possum distribution because the leg-hold traps are bulky, heavy, and (most importantly) require daily visits. Without an affordable mapping tool that is able to provide high confidence that few or no clusters of possums remain undetected, managers are generally forced by the precautionary principle to repeatedly apply blanket control to the whole area. This is expensive, and wastes resources applying control to areas with no possums. This study therefore aims to provide the AHB with a reliable mapping device and sampling strategy principally for possums, but potentially useable for all or most small mammal pests, to cost-effectively identify areas for targeted pest mop-up following large-scale possum control.

The mapping tool proposed is an adaptation of ‘use interference’ indices to estimate possum presence and abundance. To overcome the limitations of leg-hold trapping, a monitoring system using wax blocks was developed by Landcare Research (and is now commercially available in the form of WaxTags® from Pest Control Research). Possums (and other species) chew these small unpalatable blocks when first encountered, and the resulting bite marks are usually sufficiently species-specific to confirm the presence of at least one of the particular species at that location. As these are lightweight and do not require daily visits, they provide similar or greater sensitivity compared with leg-hold trapping at greatly reduced cost. Two potential limitations of WaxTags® are:

- Less than perfect sensitivity (100% detection) because detection is dependent on interference with an unlured and unpalatable device.

- Lack of ‘specificity’ where bite marks of one species have been obscured by a large number of bites by other species (most commonly rats), or the entire wax block is destroyed by excessive biting.

We have developed a new device, the chew-track card (CTC), as a low-cost means of mapping multiple species, which further develops the device interference concept. The major enhancements relative to wax blocks are: (1) use of palatable bait/lure to increase the likelihood that cautious feeders will want to investigate and bite the device; (2) larger size and more durable detection surface, to reduce the chance that bite marks by sometimes abundant species such as rats will obliterate possum bite marks; (3) addition of a tracking pad as part of the device, both to increase detection of cautious feeders and to increase the ability to distinguish between species where the bite marks are ambiguous; and (4) use of more than one bait type to broaden the attractiveness to a wide suite of small mammals.

Results from large-scale field-testing of CTCs over 15 000 ha in the Hauhungaroa Range in 2005/06 show much higher efficiency than RTC monitoring (45 times as many possums detected per field day than RTC monitoring), and very high detection rates for rats and mice (Nugent et al. 2008). Hedgehogs and stoats were also detected. An operational pilot trial on Mt Maungatautari using chew cards without the tracking pad component showed three times higher detection rates for rats with chew cards than with wax tags (C. Speedy, unpubl. data), presumably reflecting the use of a palatable bait. However, that same trial showed even higher detection rates for rats on ground-based tracking pads than on the tree-set chew cards. Overall, previous work demonstrated the clear potential of CTCs as a low-cost sensitive detection tool for simultaneously detecting the whole suite of common small mammals (e.g. possums, stoats, rats, mice) over large areas. Trials to date have used plain peanut butter as a possum attractant, but no investigations as to optimal bait formulation or direct measurements of sensitivity to possums or other species have been undertaken.

This study therefore aimed to refine CTCs. A series of bait palatability trials were undertaken with captive and wild possums to optimise CTC attractiveness to possums. A second aim of the study was to determine in the field the sensitivity of CTCs in detecting all isolated possums.

3. Objectives

To develop a low-cost but highly sensitive detection device for reliably mapping the distribution of possums (and other small mammals) surviving control, by:

- Pen and field testing refinements to a new detection device (the chew-track card) to maximise its sensitivity to possums
- Systematically mapping the distribution of surviving possum foci following a large-scale control operation, and determining if chew-track cards can reliably and cost-effectively detect all possums present at such foci

4. Methods

4.1 Chew-track card description

Chew-track cards consist of pieces of 3-mm white coreflute plastic (90 ×180 mm), with palatable baits pressed into the flutes (internal channels: 3 × 3 mm) that run across the width of the card. Bait is applied to at least two 5-cm sections of the card, which is then folded along the mid-line and mounted on a tree c. 20 cm above the ground using a flat-headed nail (Fig. 1). Bait can be applied to all four corners after making a 5-cm incision at right angles to the flutes between the two corners at each end of the card. This prevents an airlock developing and expelling bait when applying a second bait directly opposite the first bait. If desired tracking ink is applied to a 2-cm strip around the inside lower border of the card and bait is smeared onto the card inside surface near the fold apex (Fig. 1). Pest species detection is primarily achieved by identification of tooth impressions created as an animal attempts to extract the bait from inside the flutes, and secondly by footprints resulting from contact with the ink. Although tracking ink and more than one type of bait are recommended for multiple species detection, no ink and only possum-specific baits were applied to cards throughout the study, as the aim was primarily to detect possums, and previous work had demonstrated that ink was of little practical use for detecting possums. Different baiting strategies to reduce rat interference with possum sign, a significant problem in the presence of abundant rats (Nugent et al. 2008), were informally trialled during the field trials.

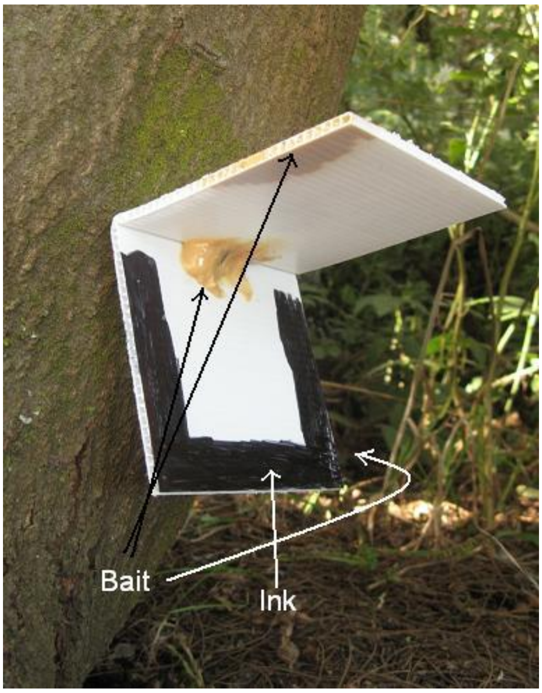

Fig. 1 Tree-mounted and baited chew-track card showing placement of bait and tracking ink.

4.2 Bait development

Pen trials

Baits comprised a base matrix, made into a paste to permit easy penetration of the card flutes, to which lures were added. Optimising palatability to captive possums of baits for use in CTCs was investigated in three steps. Initially six bases were trialled in bulk feeding trials from which two bases were then selected. Next, 14 base×lure combinations were trialled in bulk feeding trials to select six combinations for the third step. Lastly the palatability of these six baits was compared when presented in CTCs. All trials were conducted in outside pens (3 × 3 m) with rye grass ground cover, housing a single possum acclimatised to captivity and with access to its normal diet of cereal pellets, apples and water.

Smooth peanut butter and flour dough (canola oil added to white or wholemeal flour at the rate of 500 ml/kg) were selected as base materials known to be highly palatable to possums and having suitable texture and stability to incorporate lures and be applied to coreflute plastic. These bases were fed in bulk to captive possums with and without the addition of 20% by weight icing sugar. Small quantities of canola oil or water were added as required to the peanut-butter and flour baits, respectively, to standardise bait consistency.

Triplets of bases were presented to 15 possums on each of 2 nights so that each possum was presented with all six bases. Combinations and order of presentation were randomly allocated. About 200 g of each base was placed in plastic pots fixed at 20-cm intervals on a sheltered board. The total weights of the pot and contents were recorded at the start and end of each night to calculate, by subtraction, the wet-weight of bait consumed. The 200 g per bait was sufficient to satiate all possums. Weight of bait consumed was analysed using multiple ANOVA with possum number, the presence or absence of icing sugar, and base material as categorical factors.

The two most palatable base matrices from the first pen trial were used in the next trial, where one of seven lures was added to the bases, producing 14 different baits for palatability comparison. Four lures – orange oil, aniseed oil, raspberry essence, and curry powder – were selected from amongst those identified as the most attractive and palatable to possums in previous studies (Morgan 1990; Morgan et al. 1995). Cinnamon oil, although performing well in these studies, was not included as this is the most commonly used lure in possum-control operations and possums surviving these operations may therefore be cinnamon shy. The lures were supplied by Formula Foods, Christchurch, and were added to the bases at the rate of 10 ml/kg (1%). Odours that are familiar to possums may be more appropriate as lures (Todd et al. 1998) so the remaining three lures (fresh clover foliage, Hollands brand ‘rich native bush’ honey, mealworms) were selected to represent the highly preferred natural foods pasture herbs, flowers and invertebrates (Nugent et al. 2000). These ‘natural’ foods were added to bait bases, after first blending the clover or mealworms to a paste, at the rate of 10% by weight. Two baits were presented to each of 14 possums on each of 6 nights along with an unlured control of either peanut butter and icing sugar or white flour and icing sugar, alternated between pens and nights. Baits were systematically selected so that one flour- and one peanut-butter-based bait was presented to each possum every night, with the combinations changed daily to present all possums with 12 of the 14 baits, in different combinations, over the 6 nights. Wet-weight consumption of each bait and control was recorded as in the first trial, and then bait-consumption weights were divided by the amount consumed of its control. Finally this ratio was $\log_e$-transformed. The resulting consumption score was analysed using multiple ANOVA with control, base, and lure as factors.

The final pen trial compared, when applied to CTCs, the three most preferred peanut-butter and flour-based baits (6 baits in total) from the second trial. Fifteen individually-housed possums were presented with nine baited cards on three successive nights. Three cards were baited with a control (unlured peanut butter) and the remainder were baited with one of two lured baits (three cards of each). Baits were allocated to possums as for the second trial, so that each bait was presented once to each possum, but in different combinations. Single treatment three-card clusters were placed on unsheltered posts within the pens. Intensity of possum chewing on each card was scored on an eight-point scale, giving a total maximum possible score of 24 for each three-card set each night. Each three-card score for the two bait treatments was divided by its control score, then $\log_e$-transformed. These data were then analysed using a simple one-way ANOVA, with means tested by pairwise comparisons following Bonferroni adjustments for multiple comparisons.

Field trial

The two bait formulations identified in the pen trials as most attractive to captive possums when applied to CTCs (honey or clover in a peanut-butter/icing-sugar paste) were used in field trials to determine their relative attractiveness to wild possums. Forty 10-device transects, at least 200 m apart, were checked after two fine nights in mountain beech (*Nothofagus solandri* var. *cliffortioides*) forest at Craigieburn, mid-Canterbury, in January 2008. The two treatments were randomly assigned to transects (20 transects of each). To test whether they increased detection rates of possums, photoluminescent tags (50 × 10 mm; supplied by Ecoglo, Christchurch) were placed immediately above CTCs on 14 randomly selected transects (7 of each treatment).

Percent device interference by possums, and mice, was arcsin-square-root transformed to normalise error variance, then analysed using ANOVA, to compare possum and mouse (separately) detection rates between the three treatments, and to assess the effect on detection rates of using photoluminescent tags.

4.3 Field testing possum detectability

The detectability, trappability and distribution of possums surviving possum control were determined in a three-stage trial in podocarp–hardwood forest bordering farmland in the south-eastern Hauhungaroa Range, in March-April 2008. Possums in the study area were controlled in August 2005, reducing possum abundance to extremely low densities (Nugent et al. 2008). Firstly the area was surveyed using CTCs, then detected possum foci were CTC-surveyed using grids of card, from which possum DNA was extracted from possum-chewed cards. Finally these grids were leg-hold-trapped and captured possums genotyped.

Chew-track-card surveys

A 500-ha block (4 km × 1–2 km) was surveyed using CTCs baited with the highest ranking bait from the bait-development field trial, and on a separate portion of the card a liquid bait prepared from a 50:50 mix of this bait and canola oil. Trials elsewhere have demonstrated that such baiting of cards reduces destructive interference by rats while remaining attractive to possums (unpubl. data). CTCs were placed at c. 50-m intervals at sites of best sign, on transects spaced 250 m apart (totalling 473 cards along 22.7 km of transect), in March and April 2008 (Fig. 2), and left for 7 nights.

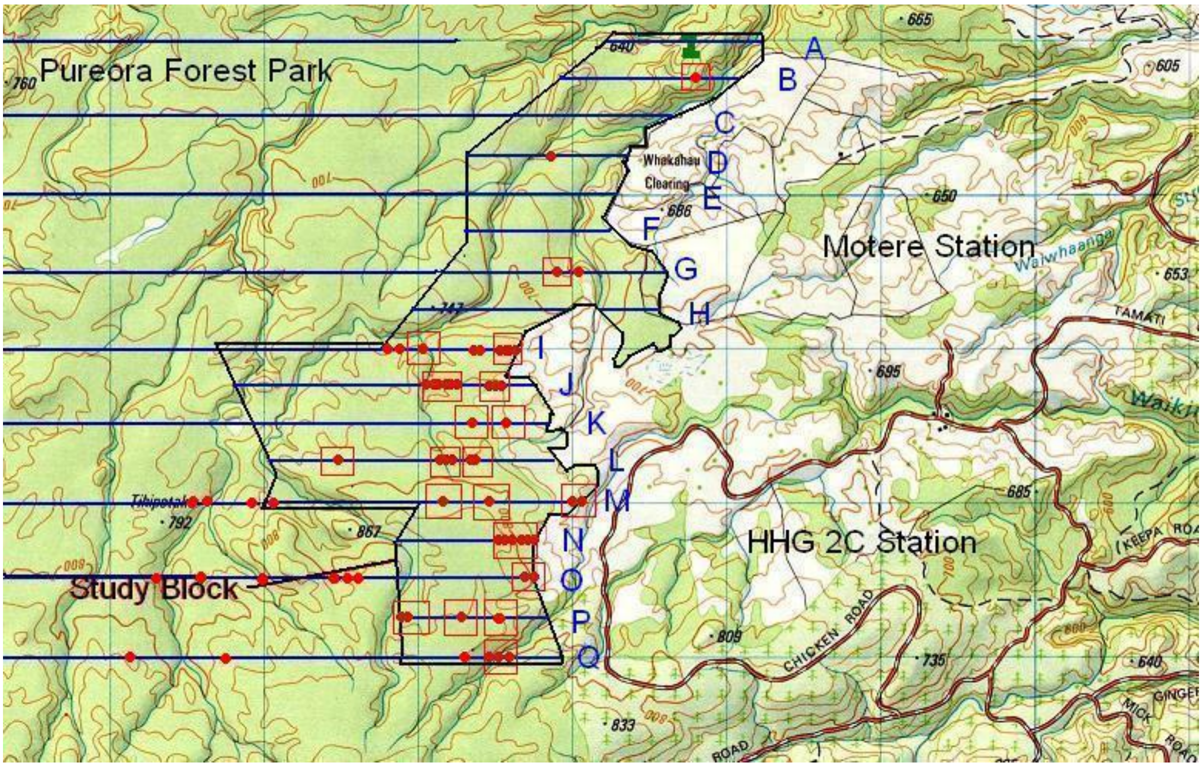

Fig. 2 Hauhungoroa study block, showing surveyed transects (heavy blue lines), possum detection sites (red dots) and CTCs and trapping grids (red squares). Transects and possum detections within the study block were measured in March-April 2008, but those to the west of the study block were measured in June 2008 under a separate project.

Grids of chew-track cards at 50 × 50-m spacing were established at 20 possum foci (25 cards at 18 foci and 35 cards at two large foci on lines J and N; Fig. 2). Nine grids were established within 1 day of the initial survey being completed, while the remaining 11 grids were established, for logistical reasons, about 3 weeks later. All grid cards had Velcro dots (hooks and loops) added to the inside surface of the liquid-baited portion of the card to help recover possum DNA. Grid cards were deployed for 4 nights before scoring and removal. Possum-chewed cards were swabbed with Whatman FTA® DNA fixing paper (Whatman Inc. USA), which was retained along with possum-chewed parts of the card and Velcro for later genotyping. DNA analysis used the same seven markers used in previous possum DNA studies (Morgan et al. 2007). All CTC monitoring was undertaken during fine weather.

Leg-hold trapping

Leg-hold traps were set at each grid-card site, under a standard flour blaze, immediately after assessment of grid cards. CTCs were also left in place to retain a luring device should all flour lure be removed by rats. Captured possums were killed and necropsied for the presence of Tb lesions, and an ear was taken for genotyping. After three fine nights traps were shifted a few metres and reset in shallow pits and covered with a light layer of litter. One-half of these concealed traps were set against a tree as before, beneath a flour blaze and CTC, and the remainder were set on runs or open areas and lured with a chew card and piece of flour-coated apple hanging 30 cm above the trap. Concealed traps were run for three fine nights in an attempt to capture trap-shy possums, if present. The proportion of trapped possums whose DNA was captured by CTC was used as an estimated of the CTC-detectability of possums, and a Petersen mark and recapture estimate (Bailey’s formula in Caughley 1980) was used to estimate trappability of possums (possums marked by DNA capture on CTCs and recaptured in traps).

5. Results

5.1 Bait development

Pen trials

Captive possums ate more white-flour-based baits and less wholemeal-flour-based baits than peanut-butter-based baits ($F_{2,72}$ = 16.9, P < 0.001, Fig. 3), and ate more of the bait with 20% icing sugar than without ($F_{1,72}$ = 6.3, P < 0.001, Fig. 3).

In the second pen trial we therefore used white flour & icing sugar and peanut butter & icing sugar bases separately with each of seven lures and with no lure. Again possums ate more of the flour bait than peanut butter bait ($F_{1,146}$ = 11.7, P = 0.001). Possums also ate more lured bait than unlured bait (Mann–Whitney test: χ^2_1 = 16.48, P < 0.001). They consumed an average of 7.4 and 19.3 g of unlured baits compared with 18.4 and 33.7 g of lured baits for peanut butter and flour baits, respectively. Preference for individual lures was dependent on the bait base (base–lure interaction term; $F_{6,146}$ = 2.6, P = 0.020). Although clover was the highest ranked lure for both bait bases, preference ranking for all other lures was very different for the two base types (Fig. 4).

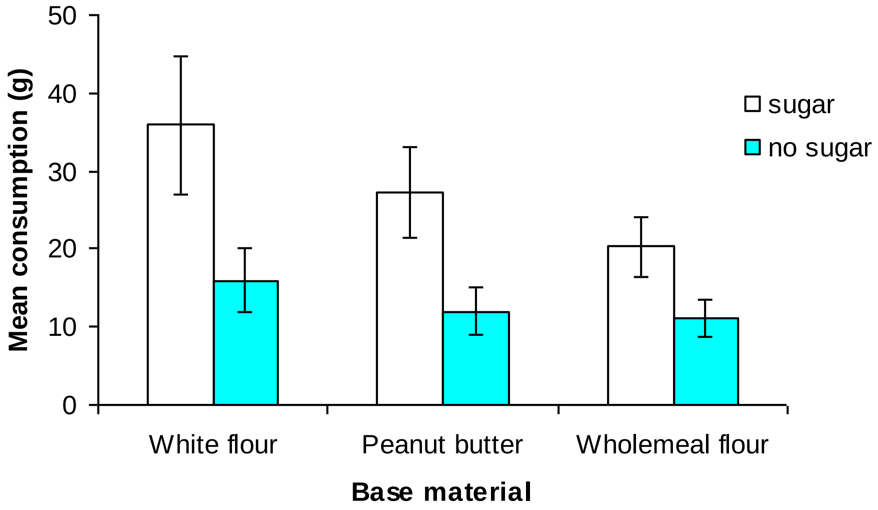

Fig. 3 Mean consumption of three unlured baits, with and without the addition of 20% icing sugar, fed to 15 captive possums at Lincoln, August 2007. Error bars are 95% confidence limits.

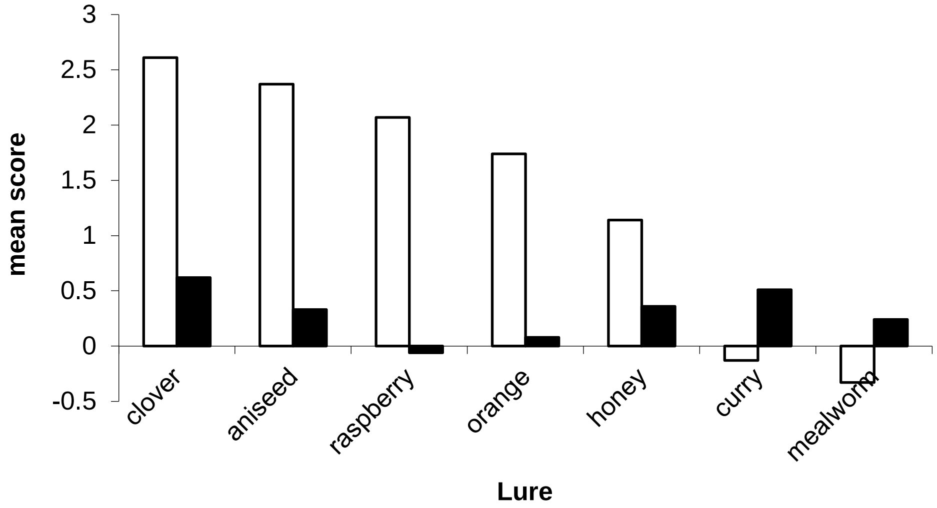

Fig. 4 Mean scores for amounts of baits consumed by 14 captive possums at Lincoln, August 2007. White bars are flour-based baits and black bars are peanut-butter-based baits.

In the absence of a consistent lure ranking, the three best for each base type were used in the final pen trial. All cards other than two baited with raspberry lure were bitten by possums. The index of possum chewing differed significantly between the six bait types ($F_{5,84} = 9.9$, $P < 0.001$). In contrast to the previous two trials, all peanut butter baits were more attractive to possums than the flour baits, with honey and clover in peanut butter the two highest ranked baits (Fig. 5).

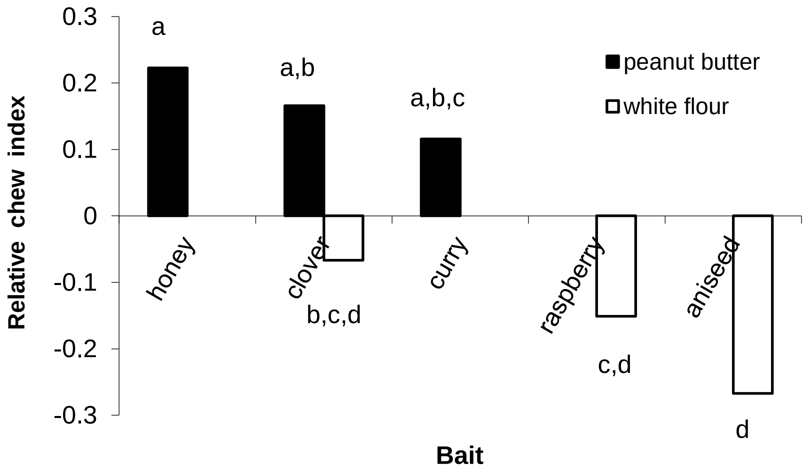

Fig. 5 Relative intensity of chewing by captive possums on chew-track cards baited with six different baits. Baits comprised peanut butter or white flour dough, both with 20% icing sugar, to which one of five lures was added. Bars headed with common letters are not significantly different as tested by pairwise comparisons with Bonferroni adjustments.

Field testing of baits and photoluminescent tags

The two bait treatments (200 of each device) compared in the Craigieburn field trial were: (1) CTCs baited with honey-lured peanut butter/icing sugar; (2) CTCs baited with clover-lured peanut butter & icing sugar. Overall, possums bit 51% of clover CTCs and 32% of honey CTCs, with the difference being significant (Wald test: χ^2_1 = 5.39, *P* = 0.02; Fig. 6a).

Photoluminescent tags (N = 140) had little impact on possum detection rates ($F_{1,59}$ = 0.45, *P* = 0.503) with overall detection rates of 45% and 42% recorded for devices with and without tags, respectively, and the apparent interaction between photoluminescent tags and detection device (Fig. 6a) was not significant (Wald test: χ^2_1 = 0.06, *P* = 0.81).

Mice were detected by c. 12% of both honey- and clover-lured CTCs (Wald test: χ^2_1 = 0.001, *P* = 0.99), with weak evidence that the addition of photoluminescent tags reduced mouse detection rates (Wald test: χ^2_1 = 3.48, *P* = 0.062; Fig. 6b). In addition to mice, hedgehogs and kea were also detected on 1% and 2%, respectively, of CTCs.

No rats or stoats were detected by either device, presumably because there were few of either present and because there was no stoat-specific attractant used

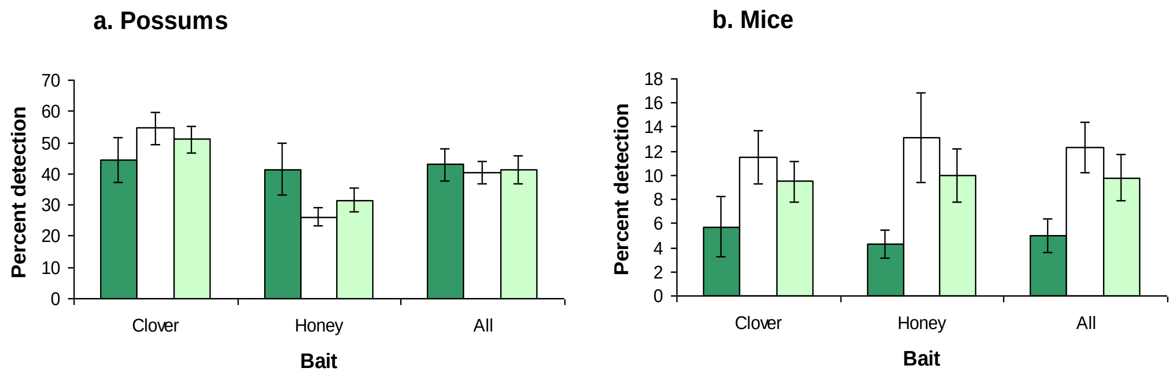

Fig. 6 Percent detection of (a) possums and (b) mice by clover and honey-lured chew-track cards. Dark green, white and light green bars are devices without and with photoluminescent tags and both combined, respectively. Error bars are standard errors.

5.2 Possum detectability field trial

Overall rats were detected on 29% of CTCs. Possum detections were significantly lower (47% of expected detections estimated by contingency table) on cards chewed by rats (χ^2_1 = 6.6, *P* = 0.01). Baiting a portion of the CTCs with a liquid, oil-based bait was partially successful at providing a surface that possums would bite without interference from rats. Of 51 possum-chewed cards, possums bit 33 on the liquid-baited sections, while only 23 of 129 rat-chewed cards had (light) rat biting on this section. Of seven cards bitten by both rats and possums three were bitten by possums on the peanut-butter sections, and all were bitten on the liquid-baited part of the card.

Overall possums had chewed 51 (11.1%) of the 470 CTCs after 7 days. Of the 25 foci of possum detections, 21 were located within a 200 ha area at the southern end of the study block (Fig. 2).

Of the 20 foci resurveyed using a grid of CTCs, possums were detected at 16 (80%), with a total of 58 cards chewed. For the nine foci resurveyed immediately after the initial detection, possums were detected at all but one, whereas of the 11 not resurveyed until 3–4 weeks, possums were detected at only eight.

Standard trapping of these 20 grids immediately after the CTC resurvey resulted in 17 possum captures and 2 escapes over the first three nights. Only one further possum was caught over the next three nights despite switching to concealed traps.

No possums were captured (or escaped) at eight of the grids. These comprised two of the grids with no CTC detections during resurvey, but also six of those with CTC redetections. For all eight of these grids, there were a total of 21 CTC detections from 40 cards during the initial survey (i.e. from sites along the central east–west transects through the centre of the resurvey grids) but just four CTC detections from these same sites during the CTC-resurveys. Four of the resurvey grids only detected possum at their outer edges. This indicates reduced possum activity at the initial detection foci centres during the subsequent CTC resurveys.

For 55 chewed CTCs submitted for DNA recovery, no DNA at all was recovered from 13, and only incomplete genotypes were recovered from a further 16, while a further 11 cards had more than two alleles for some markers, indicating interference by more than one possum. It is not possible to separate genotypes from such mixed samples. Only 15 of the CTCs produced full unmixed genotypes, representing 11 unique genotypes. Given these 15 CTCs represented just 27% of the chewed CTCs, we could at best have detected only about a quarter (27%) of the individual possums even if they had all bitten cards.

Tissue or fur from the 18 captured possums and two escapes produced 19 unique genotypes (one tissue sample from a trapped possum was lost). Four (21%) matched CTC genotypes. This is lower than the maximum of 27% expected (see preceding paragraph), with the 21%:27% ratio suggesting 77% of trapped possums were detected by CTCs.

Alternatively, applying the 11:15 ratio of unique genotypes to the number of full CTC genotypes to the total of 58 chewed CTCs suggests that 42 different possums chewed CTCs on the 20 card grids. Using the 11 unique CTC genotypes as a marked sample, and the 18 trapped possums as a recapture sample, the four recaptures indicate 45 possums were present on trapping grids. Taken together, these estimates suggest a 93% (42/45) sensitivity of CTCs to possums on the grids.

Both estimates might be biased high, because three grids that returned full genotypes for all possum-chewed cards detected just three of six possums captured on those grids. This, however, ignores the possibility that the unmarked possums may have chewed cards on other grids that failed to capture their genotypes. For example, one adult female was identified from five (and possibly eight) sites over 7 days, up to 400 m apart, spread across two adjacent grids.

Possum trappability over 6 nights was lower than the above estimates of chew-track card sensitivity. Including the two escapes, only 20 (44%) of the 45 possums estimated to be present were trapped. This drops to 40% if the two escapes are excluded.

No possums had visible Tb lesions.

6. Conclusions

6.1 Bait development trials

Cafeteria-style feeding trials tend to accentuate differences in palatability between the trial foods (D. Morgan, Landcare Research, pers. comm.). The large differences in bait consumption across foods all known to be highly palatable to possums (Fig. 3, 4) may reflect, therefore, only minor differences in palatability. The differences in attractiveness of baits were much smaller when presented in CTCs, presumably because the total quantity available was far less likely to have satiated the possums. We therefore consider the CTC results (Fig. 5) provided the most realistic of our measures of the relative attractiveness of the various baits.

Adding icing sugar increased attractiveness, as did adding clover and honey. Clover was present in small quantities in the trial pens, so the attractiveness of clover is consistent with Todd et al.'s (1998, 2000) suggestion that familiar odours make better lures. Clover may not be available in the wild, but it may produce odours similar to a wide range of herbs, most of which are preferred by wild possums (Nugent et al. 2000). Honey in peanut butter ranked the highest in the second pen trial. While honey itself may have been unfamiliar to captive possums it may have provided odours similar to flowers (also a preferred food source of wild possums) they had previously encountered.

Captive possums exhibited complex preferences for the various baits presented, with interactions between bait bases and lures (Fig. 4), and more importantly, baits and presentation method (Fig. 4 & 5). Whereas the top five flour-based baits outranked all the peanut butter-based baits when presented in bulk, all three peanut-butter baits ranked ahead of the three flour baits presented in CTCs.

Although the complex interactions between the effects of bases and lures on consumption rates by captive possums created some uncertainty about which baits were most attractive, it is clear that lured baits with either base were better than unlured baits. Peanut butter is the most practically convenient base, and was more attractive to possums than flour-based baits when presented in CTCs, so peanut butter with either honey or clover (the two highest ranked lured baits in the CTC-presentation-to-captive-possums trial) was pragmatically selected for the field trial.

Wild possums in mountain beech forest at Craigieburn preferred clover-lured bait (Fig. 6a). The difference may reflect possum familiarity, because clover (*Trifolium* spp.), lotus (*Lotus pedunculatus*) and other herbs are not uncommon in forest clearings and at forest margins, whereas sources of nectar from which bush honey would originate are absent at Craigieburn. Whatever the cause, the difference indicates clearly that lures can have a big effect on detection rates.

Fresh clover was the best lure in the field but its use has practical problems. It is not commercially available, and has a limited shelf life at room temperature (P.S. pers. obs.). Dried lucerne pellets may provide a longer lasting commercially available solution. Preliminary trials suggest that peanut butter containing rehydrated ground lucerne is at least as attractive as peanut butter lured with fresh clover (unpubl. data). If used, dried clover or lucerne pellets should be finely ground and added to the peanut butter-icing sugar mix at a rate of 10% by volume.

The addition of photoluminescent tags to baited detection devices did not significantly alter detection rates of possums at Craigieburn. In contrast, Ogilvie et al. (2006a) recorded 70% more possum bites on unbaited WaxTags® with photoluminescent tags than those without. However, photoluminescent lures were less attractive to possums than standard flour blazes that are applied to trees during trapping operations (Ogilvie et al. 2006b). The difference may therefore simply reflect low attractiveness of unlured or unbaited devices. Our results suggest the additional expense ($0.80/unit from Pest Control Research, Christchurch) and effort of using photoluminescent tags is not warranted, but more work is needed to confirm that.

The Craigieburn trial did, however, suggest that mice are deterred from CTCs by the addition of photoluminescent tags.

6.2 Possum detectability and trappability

Rat interference significantly reduces possum detection rates on CTCs (Nugent et al. 2008) and rats have been abundant in the Hauhungaroa Range since possum control was initiated in 1994 (Sweetapple & Nugent 2007, Nugent et al. 2008). Possum detection rates were 53% lower on the subset of cards chewed by rats (section 5.2). It is unlikely that this is a reflection of local competitive suppression of rat abundance by possums (e.g. Sweetapple & Nugent 2007) because possum densities in the study area were too low to affect a significant competitive pressure. Rather, lower possum detection rates on rat-chewed cards probably reflect competitive or behavioural exclusion between possums and rats on the cards. Baiting a portion of each CTC with liquid bait probably reduce this bias as only 35% of possum-chewed cards were not bitten on liquid-baited sections, which rats only occasionally lightly chewed. Given the 29% overall rat-detection rate, we estimate that the observed possum-detection rate (11.1%) would have increased at most to about 12.8% ($11.1\times(1+0.29\times0.53)$) if rats had somehow been excluded. The increase would be smaller if some of this bias was due to possum excluding rats from cards. The small size of this rat effect, and the likelihood that most possums will have had 2–5 cards within their range, suggests it would have had little or no impact on the total number of possum foci detected.

Possums were apparently very mobile during the Hauhungaroa trial. Four CTC grids failed to detect possums where they had previously been detected on a single transect through their middle, and eight subsequent trapping grids caught no possums. The one possum that was detected at more than three locations had a range length of at least 400 m over just 7 days. High mobility of possums had been inferred from a range of data during previous surveys of low-density possums in the Hauhungaroa Range (Nugent et al. 2008), but may have been enhanced during the current study because it was undertaken in March and April, during the main possum breeding season (Fletcher & Selwood 2000).

Recovery DNA from possum-chewed CTCs is an important breakthrough because it potentially opens the door to affordable mark–recapture estimation of possum density even at extremely low densities when conventional capture and recapture becomes prohibitively expensive. Possum DNA has also been successfully extracted from chewed Waxtags® (Vargas et al. 2009). However, in this first attempt, the recovery rate was low with just 27% returning full unmixed genotypes (47% when mixed genotypes are included). Ways of increasing the recovery rate and avoiding mixing are in development.

The impact of the low recovery rate on our detectability estimates depends on whether there was a link between the probability of leaving a full genetic fingerprint and the number of cards an individual chewed. A positive bias would lead to an underestimate of detectability. The 11 genotyped possums from the CTC grid cards were detected on a mean of 1.36 cards. The estimated 42 possums that chewed grid cards (section 5.2) chewed a mean of 1.38 cards, suggesting little bias. Against this, the three grids that returned full genotypes for all possum-chewed cards detected just three of six possums captured on those grids, but the non-CTC-genotyped possums caught on those grids may have chewed cards on other grids that failed to return usable genotypes. At worst the detection rate was only 50% (3/6), but our best estimate is 93%. Regardless of whether the low recovery resulted in a systematic bias the resulting low sample sizes has reduced the robustness of our estimates of possum detectability. Improvements in the DNA recovery rate from CTCs will be necessary before good estimates of possum numbers can be made using these methods.

Even at 50% detectability, clustering of possums into breeding groups (Nugent at al 2008) means that most foci would be detected (e.g. 75% of 2-possum foci and 87.5% of 3-possum foci). If individual detectability was 80% nearly all (≥96%) foci with more than one possum would be detected. A repeat survey would increase this latter detection probability to >99.8%. Ninety-six percent of single possum foci, if any existed, would be detected by two surveys.

Once detected, such foci can be targeted for mop-up control. Establishing 4-ha (200 × 200 m) mop-up grids around all 25 foci detected would have covered only 100 ha (25%) of the 500 ha surveyed. For the south-eastern-most 200 ha, a high percentage of the area would have required mop up, but for the other 300 ha only 5% would have required targeting. Alternatively the latter area could have been left for several years before it became a concern with respect to the potential for sustaining Tb transmission.

The mop-up tool used here fore research purposes was inefficient. Possum trappability was relatively low with an estimated 40% of those present caught in leg-hold traps over 6 nights. Fine weather prevailed throughout most of the trapping, with only one night of heavy rain, on which traps were closed down. All but one of the 20 trap-grid possums were detected on the first three nights; therefore, it would seem that most trappable possums were captured, unless concealed traps have markedly lower intrinsic capture rates than standard-set traps. Similar levels of trappability of possums at one point in time were recorded by Morgan et al. (2007), who also found that apparently untrappable possums eventually become trappable within a few months. Therefore, a series of trapping sessions over a period of several months should be able to remove most possums. The 25-trap grids used during the Hauhungaroa field trial caught an average of 1.36 possums over 3 nights (data from only those 8 grids that were surveyed immediately following the initial foci detection). Nine-trap grids at 50 × 50-m spacings that were used to mop up possums in earlier Hauhungaroa trials (within 18 months of the current study) caught 1.29 possums per grid over 3 nights (Nugent et al. 2008). There was little apparent gain therefore, from using larger trapping grids in the current study.

A puzzling feature of these results is the low possum trappability compared with the apparent large number of possums that chewed CTCs. This suggests that traps were either inefficient or many possums were trap shy. The lack of trapping success with concealed traps does not support either of these possibilities. If traps were inefficient then nightly trap rates should have declined more slowly, and concealed traps should have at least partly overcome trap shyness, unless shyness was related to flour-lure. One other possible explanation is that due to mobility, many possums had moved off the grids by the time trapping commenced, and these were not balanced by a reciprocal inflow of possums because most foci were isolated in possum-free terrain.

In summary the high detectability of possums with CTCs is good news for managers wanting to undertake post-control detection and mop-up of surviving possums. Most possums, and virtually all foci of more than one possum, can be detected. Detection surveys for large remote areas can be undertaken using transects spaced at 500-m intervals, for $5.00/ha (Nugent et al. 2008). The optimal spacing of transects for detection of low-density possums is one of the aims of work planned for 2009/10. Cost of trapping or other methods of possum mop-up are dependent on the density and distribution of the possum population, but was achieved for $6.00/ha in one recent operation over 1600 ha in the Hauhungaroa Range (Nugent et al. 2008) using leg-hold trapping over 3 nights. The high detectability of possums with CTCs suggests that much higher rates of possum removal may be achieved than during a one-off short-duration trapping session given suitable tools and approaches, perhaps with toxins associated with or incorporated into CTCs, with or without trapping.

None of the 18 possums necropsied had detectable Tb. Given the estimated total number of possums present (45), this indicates 40% probability Tb is absent from possums. Overall possum density is estimated to be <0.1 possum per hectare. Assuming then that possum density was 0.05 per hectare after control in 2005 and possum Tb prevalence was 5%, a recently developed spatial model (Nugent & Whitford 2008) predicts the probability of Tb failing to persist for at least 3 years at 77%. Based on that, this single survey alone provides >86% confidence of Tb freedom. Two such surveys would increase that probability to >98%. We conclude that where control has successfully reduced possum numbers to near-zero levels, detection surveys provide a highly cost-effective way of targeting mop-up control to prevent population increase and/or also a highly cost-effective way of quantifying the likelihood possums are free of Tb.

7. Recommendations

- Chew-track cards are recommended as an efficient tool for mapping the distribution of possums surviving control. We recommend CTCs be baited with fresh or dried clover or lucerne pellets added to smooth peanut butter and 20% icing sugar at the rate of 10% (wt/wt wet weight equivalent).
- Further research is needed to fully overcome the downward bias caused by rat interference.
- Lower-cost alternatives to leg-hold trapping for mopping up residual clusters of possums should be developed and field-tested. The alternatives should include approaches that enable possums to be recovered for Tb necropsy as well as poison-based methods that do not.

8. Acknowledgements

We thank Chris Brausch, Marcus Bridge, John Williamson for assistance with field work, Karen Washbourn for assistance with the pen trials, Dave Morgan for comments on the draft report and Christine Bezar for editing and formatting the text.

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