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Field efficacy of cholecalciferol gel baits for possum (*Trichosurus vulpecula*) control

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Abstract The efficacy of a cholecalciferol gel bait against high-density possum populations was assessed in two replicate field trials conducted in beech forest in the Hopkins Valley. The possum populations were monitored by (i) trap-catch before and after control at both treated and non-treated sites and (ii) recapture of possums tagged during pre-control trap-catch. Control was conducted at each treatment site by presenting a non-toxic gel as a prefeed in mid April, followed a fortnight later by gel bait containing 0.9% cholecalciferol; these baits were checked and replenished at intervals of decreasing frequency (i.e., 1–8 weeks) until late July. Monitoring of interference at bait stations suggested that the population was greatly reduced within the first fortnight of toxic baiting (i.e., by early May). The mean corrected trap-catch reduction at the two treatment sites was 81%, while there was a 100% reduction in the recapture of ear-tagged possums at both treatment sites. This difference was due to an average 68.5% drop in trap-catch at the non-treatment sites, which reduced the effect of the otherwise very large declines (average of 94.1%) in the treatment sites, while the mark/recapture-based estimate was not affected because no tagged possums were caught after control at the treatment sites. The unexpectedly large population reductions in the non-treatment sites are believed to be mainly (possibly entirely) because possums were removed by unauthorised hunters during June, as verified by Department of Conservation staff. Therefore, the effectiveness of the cholecalciferol gel was markedly underestimated by the trap-catch monitoring. Conversely, the 100% reduction assessed by mark/recapture was overestimated because some possums were caught in the treatment sites after control. Consequently, the true reduction achieved by the gel bait was between 81 and 100%, at a cost of about $35/ha. This figure is similar to the cost of using other ground-based control methods, but there is potential for the development of more efficient use of cholecalciferol gel baits, particularly where sustained control at low density is the aim.

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INTRODUCTION

Control of possum (*Trichosurus vulpecula*) populations using poison baits has traditionally used bait formulations such as cereal pellets, carrot, or pastes having a field life of only a few days. This is adequate for "knockdown" operations where the principal aim is to ensure a rapid reduction of possum populations to low density. However, the use of short-lived baits in subsequent "maintenance control" is a strategic weakness because such control is typically applied to any given area for only a few weeks of the year. This leaves no protection at other times from possum-transmitted bovine tuberculosis (Tb), impacts on native flora and fauna, and other forms of damage (Montague 2000). Therefore, baits with a longer field-life are needed to help provide long-term suppression of damage and possum population recovery.

Earlier research (Morgan 2004) assessed the field-life of several long-life baits by (1) sampling baits at 2-monthly intervals from a high-rainfall site at Taramakau Settlement, Westland, (2) estimating bait palatability in trials with captive possums, and (3) measuring bait toxicity by laboratory assays for toxicants. Cholecalciferol gel bait proved the most long-lived bait type, remaining palatable and toxic to possums for at least 26 months. A preliminary field trial along bush-edge in the Kokatahi Valley, Westland, showed that this bait type had considerable potential for long-term suppression of possum populations. Possums' interference with baits, and hence efficacy of the bait, was poor at first because they were placed approximately 2 m above ground, beyond the reach of cattle, but once bait stations were made more conspicuous and accessible to possums, efficacy was improved. This trial suggested that more prolonged use of gel baits presented in this manner may have eventually caused significant declines in the bush-edge possum populations. The potential efficacy of the bait at 5 and 12 months was confirmed by collecting samples in the field and testing them against captive possums. While also having access to their normal diet, captive possums ate large amounts of the gel bait (mean consumption of 5-month gel was 75 g, and of 12-month gel was 45 g). Mean times until death and mean weight loss at death ranged between values similar to those previously recorded for cholecalciferol baits (Morgan & Milne 2002).

Since the earlier part of the study (Morgan 2004) predicted that cholecalciferol gel bait should remain effective for longer than 2 years in the field, this new tool has the potential to achieve "continuous" control rather than the present "pulsed" annual control. Furthermore, because the product is relatively unattractive to non-target species (Morgan 1999), its use offers a means of improving the environmental safety of possum control. However, the product is not yet commercially available because data on field efficacy are required to meet registration requirements. These specify: "replicated field studies should be conducted to confirm the efficacy of a new toxic bait type and baiting strategy as able to kill at least 80% and preferably 90% of the population present" (section 3.4.1.6 in New Zealand Food Safety Authority 2002). This study was therefore conducted to assess effectiveness of cholecalciferol gel bait against possum populations in replicated field trials.

METHODS

Study area

The study was conducted in beech forest in the Hopkins Valley, Canterbury. Four areas were selected (Fig. 1), each with a bush-edge measuring 2 km, and separated by 300–400 m and large creeks to minimise the likelihood of movement of possums between areas. The areas were selected because they met the following requirements: possum population density was considered moderate to high; livestock and ground-dwelling birds (i.e., kiwi and weka) were absent, enabling the use of ground-set traps; and the probability of unauthorised possum hunting (i.e., poaching) or other forms of interference was low. Permits for the trial were then obtained, as required, from the Department of Conservation, Medical Officer of Health, Environmental Risk Management Authority, and the New Zealand Food Safety Authority, and signs were displayed in the area advising the general public of the trial.

Preliminary bait quality assurance and assessment of the suitability of a bait station

Non-toxic and toxic gel bait (containing nominally 0.8% wt:wt cholecalciferol) was prepared by Kiwicare Corporation, Christchurch, New Zealand, for preliminary tests. Palatability of non-toxic gel was assessed in trials using possums captured in North Canterbury and maintained individually in cages at the Landcare Research animal facility, Lincoln, on a diet of fruit, vegetables, and supplementary feed pellets. After being acclimatised to captivity for 4 weeks, 20 caged possums were presented with 100 g of non-toxic gel and 100 g of fresh RS5 cereal pellets (Animal Control Products Ltd, Waimate). Consumption after 16 h (i.e., overnight) was recorded and corrected by the mean change in three 100 g samples of each bait type which were unavailable to possums. Palatability was calculated from each possum's consumption of gel bait expressed as the percentage of total consumption, and a mean value of palatability then calculated. Three random samples of toxic gel bait were assayed for cholecalciferol content. Toxic gel was also tested for palatability using a further 20 possums (as above), and efficacy was assessed from the percentage of animals killed after eating bait. A plastic container (Fig. 2) was identified that was considered suitable for presenting small quantities of gel (100 g) at close spacing in the field. The suitability of these for field use was assessed by presenting bait stations to possums maintained in outdoor pens (5 × 5 m) at the Landcare Research animal facility. The approximate percentage of bait consumed or spilled, and the damage to bait stations over 5 nights were visually assessed. The bait stations were made of PET (polyethylene terephthalate) plastic in two thicknesses (0.25 and 0.4 mm). Bait stations of each thickness, with and without gel bait, were presented to two pairs of penned possums.

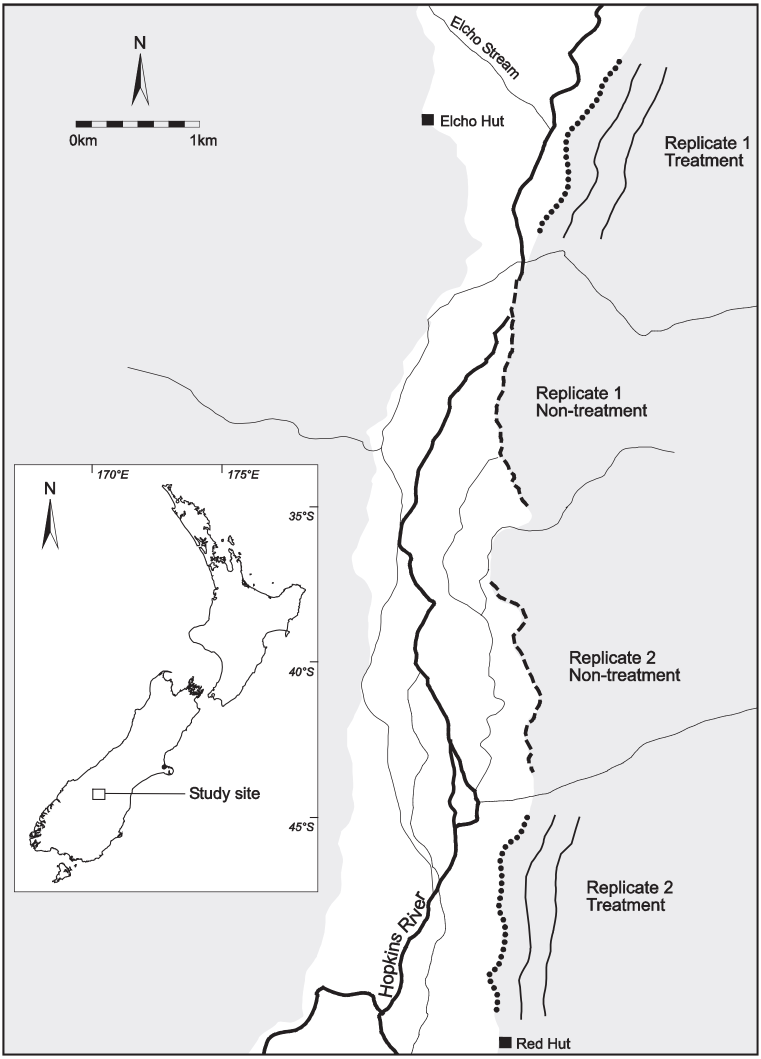

Fig. 1 Map of study site in the Hopkins Valley, South Canterbury. Lines of dots indicate location of monitoring lines and bait stations in treatment areas. Additional lines of bait stations are indicated by solid lines. Dashed lines indicate location of monitoring lines in non-treatment areas.

Population monitoring

An initial trap-catch assessment was conducted along the bush-edge of each of the four sites (i.e., two treatment sites and two non-treatment sites) for 3 nights of 17–19 March 2005. Victor 1 inch hard-catch traps were set along 10 lines of five traps, with traps set approximately 20 m apart, and lines separated by 100 m. To eliminate significant injuries, trap chains were fitted with spring tensioners and trap sites were cleared of obstructions to avoid entanglement. Traps were lured with a blaze of 5:1 flour/icing sugar applied approximately 50 cm vertically up the tree trunk, and set and relured for 3 consecutive, fine nights. All trapped possums were recorded, ear tagged, and released. Post-control monitoring was carried out for the 3 nights of 21–23 July 2005 following the same procedures, except that all possums were killed, and recapture of ear-tagged animals was recorded.

Treatment

The four sites were first divided into two pairs within which treatment and non-treatment were randomly assigned (Fig. 1). At treatment sites, cholecalciferol baits, prepackaged in 100 g quantities in plastic bait stations (see Fig. 2), were deployed by stapling the bait stations to trees 30–40 cm above ground. A photoluminescent lure-tag (Pest Control Research,

Fig. 2 Cholecalciferol gel bait, prepackaged in a plastic bait station being stapled to a tree.

Christchurch) was also stapled to the tree at a height of about 1 m above ground, directly above the bait station. These lures have been shown to increase possum interaction with WaxTag® monitoring devices (Thomas & Maddigan 2004) and were therefore considered likely to increase interaction with the baits. Bait stations and lure-tags were established approximately 20 m apart along the bush-edge, and also along two additional lines (at 25 m spacing) running parallel to the bush-edge at 200 and 400 m perpendicular distance from the bush-edge. This was designed to provide control of both resident possums at the bush-edge and transients moving from within the bush to the bush-edge. Initially, non-toxic baits were deployed as prefeed during 4–6 April 2000. Two weeks later, interference was assessed (check 1) and the baits were replaced with cholecalciferol gel baits which were inspected at successive intervals of 1 week (checks 2–4), 2 weeks (check 5), and 2 months (check 6), so that toxic baits were presented for approximately 3 months. At each check, baits were replaced if less than 20% of bait remained, and the percentage amount of bait removed at each bait station (n = 530) since the last check was estimated visually.

Data analysis

Trap-catch data were analysed using 'PestCalc' version 1.23 (2002) to calculate trap-catches before and after control at each site, and percentage change. (Because possums were released after capture, any that were recaptured during each 3-day trapping session were treated in the same manner that non-target captures are treated by PestCalc: that is, the number of trap-nights was reduced by 0.5 for calculating the trap-catch on the line of each recapture). The proportion of possums ear-tagged before control and then recaptured after control was used to provide a second estimate of percentage change. For both methods, the mean changes in the non-treatment sites were used to correct mean treatment site values enabling estimation of the mean percentage change attributable to treatment (i.e., the mean percentage kill) and its standard error. If no possums had been removed, then similar pre:post ratios for both trap-catch or numbers of tagged possums trapped would be expected in the treatment and non-treatment site of each replicate trial. Therefore:

Expected $Post_t/Pre_t = Post_{nt}/Pre_{nt}$
(where subscripts $_t$ and $_{nt}$ indicate treatment and non-treatment respectively)

and so,

Expected $Post_t = Pre_t \times Post_{nt}/Pre_{nt}$
if the possum population was unaffected.

The kill was therefore estimated for both monitoring methods by:

$$\% \text{ Kill} = ((\text{Expected Post}_t - \text{Post}_t)/\text{Expected Post}_t) \times 100$$

RESULTS

Preliminary bait quality assurance

Preliminary testing indicated that the cholecalciferol gel bait was suitable for use in the field trials. Mean palatability of the non-toxic gel was high at 74.4% (SEM = 10.6%) with consumption by individual possums averaging 54.1 g (SEM = 9.4 g). Three samples of toxic gel showed values of 0.8, 0.98, and 0.94% wt:wt of cholecalciferol; therefore, cholecalciferol concentration on average (i.e., 0.91%) was 14% greater than the nominal concentration. When toxic gel was presented to caged possums, mean palatability was 50.6% (SEM = 15.9%), individual consumption averaged 24.2 g (SEM = 6.9 g), and 85% of possums were killed, most within 4–6 days. This result was considered to be a conservative indication of likely field efficacy due to the simultaneous presentation of RS5 pellets (for palatability assessment), another palatable bait of proven operational performance. Nevertheless, this result indicates a reduction in palatability due to the inclusion of cholecalciferol.

In pen trials of the bait stations, a mean of 70% (SEM = 12.4%) of the gel bait was eaten during the first night and the remainder was eaten over the next 4 nights. About 5 g of gel (i.e., 0.6% of total presented) was noticed as spilt from only one of the eight bait stations presented. Over the 5 nights none of the bait stations of either thickness (with or without gel) was damaged, and the design was therefore considered suitable for the field trial.

Efficacy of cholecalciferol gel

The possum population density along the bush-edge of the study area was high (31–67% trap-catch) before control (Table 1). Reductions in trap-catch exceeding 90% were recorded in the treatment sites of both replicates, but unexpectedly large reductions were also recorded in the non-treatment sites. When these were taken into account (see Data analysis above), the estimated mean kill was 81.3% (SEM = 5.4%).

Ninety-two possums were tagged and released in the treatment sites, and 100 possums in the non-treatment sites (Table 2). Only 15–16% of animals tagged in the non-treatment sites were recaptured. However, no tagged possums were recaptured in the treatment sites, and the estimated mean kill was therefore 100% (SEM = 0%). All recaptures of tagged possums at all stages of the study were recorded at the sites at which they had been initially captured and tagged before control, supporting the assumption that sites were independent.

Bait interference

Most of the non-toxic prefeed bait had been removed when bait stations were inspected after 2 weeks (Fig. 3). On replacing with toxic bait, about 30% was removed at site 1 (replicate 1) and 50% at site 4 (replicate 2) after 1 week; thereafter, removal declined to low levels. The reduced consumption is attributed to:

Table 1 Estimation of percentage kill in each replicate trial based on trap-catch before and after control. Trap-catch is given as the average for 3 nights of the number of possums captured per 100 traps.

		Change recorded in trap-catch			Corrected treatment data and % kill	
		Mean trap-catch				
Replicate	Site	Pre	Post	% reduction	Expected $Post_t$	% kill
1	1 (treated)	31.3	1.3	95.8	10.0	87.0
1	2 (non-treated)	31.4	10.0	68.1		
2	4 (treated)	53.0	4.0	92.5	16.3	75.5
2	3 (non-treated)	67.0	20.6	69.2		

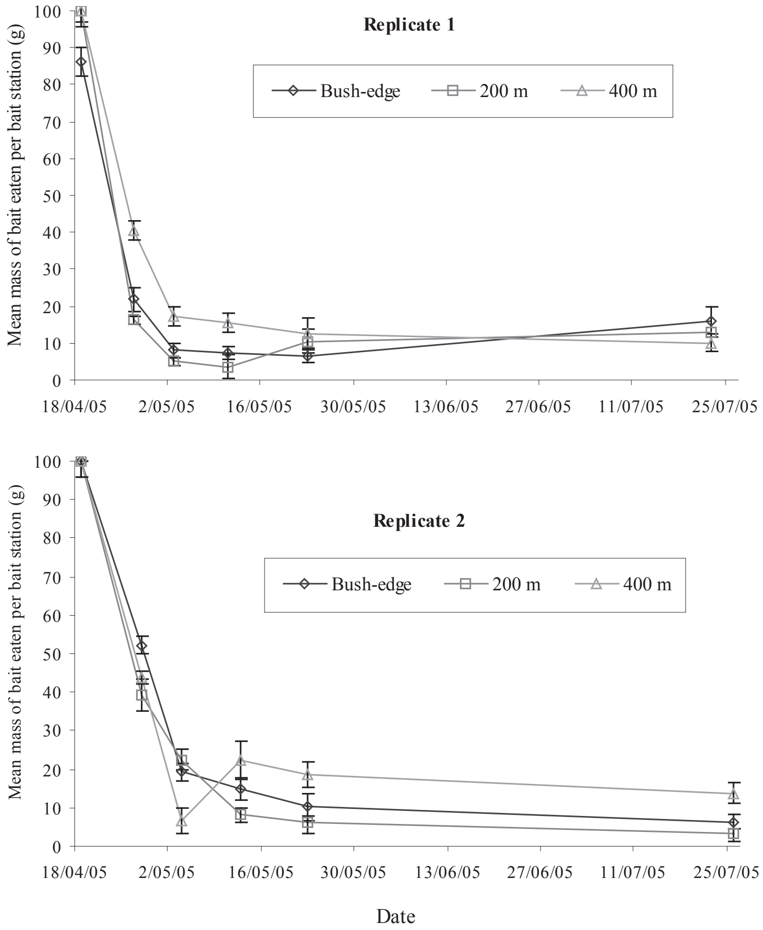

Fig. 3 Mean quantity of bait eaten per bait station (±SE) on three lines in each treatment site. Baits were initially non-toxic (i.e., at 19 April 2005 measurement) and thereafter toxic.

Table 2 Estimation of percentage kill in each replicate trial based on recapture of ear-tagged possums.

		No. of tagged possums			Corrected treatment data and % kill	
Replicate	Site	Tagged (Pre)	Recaptured (Post)	% reduction in capture	Expected $Post_t$	% kill
1	1 (treated)	33	0	100	4.7	100
1	2 (non-treated)	28	4	85.7		
2	4 (treated)	59	0	100	9.8	100
2	3 (non-treated)	72	12	83.3		

(i) possums being killed, (ii) the reduction in appetite that follows after possums ingest cholecalciferol (Morgan & Milne 2002), and (iii) the lower palatability of the toxic bait compared with non-toxic (see above). By the final check, when baits had been exposed for at least 2 months, about one-third had partly detached from bait stations, while at 16 bait stations the gel had become completely detached and was found on the ground. Characteristic tooth marks in the gel indicated that most removal was due to possums, but 56 bait stations showed evidence of removal by rodents (with mouse and rat tooth marks not being clearly distinguishable) of 2–15% of bait when toxic baits were checked after the first week, but not at any later checks. There was no evidence of interference by other non-target species.

DISCUSSION

In these, the first replicated field trials of the efficacy of cholecalciferol gel baits in controlling possum populations, the estimated mean population reductions, by two methods, were 81% (trap-catch) and 100% (mark-recapture). Therefore, the baits achieved the level of efficacy required by the registration standard; that is, reduction of the population by at least 80%. However, the trap-catch based result is likely to have markedly underestimated the actual kill because the large reduction recorded in the non-treatment blocks (i.e., almost 70%) was probably caused (at least in part and possibly entirely) by non-permitted removal of possums in early June along the bush edge in these areas. This poaching, as reported by Department of Conservation staff (M. Beardsley pers. comm.), occurred despite an initial assessment of a low risk of poaching in the area and the posting of information signs in the area. Possum carcasses, from which fur had been plucked, were also found along the bush-edge of the non-treatment sites during post-control monitoring in late July. Poachers did not remove any possums from the treatment sites, probably because the population had already been reduced, as indicated by the bait interference data (Fig. 3). The effectiveness of the cholecalciferol gel was therefore underestimated by the trap-catch monitoring.

In support of this conclusion, population reductions of the size recorded in the non-treatment blocks have not previously been recorded in undisturbed possum populations, except after extreme weather events. For example, possums trapped over a 30-year period in the Orongorongo Valley (Efford 2000) generally fluctuated by ±0–30% over successive 4-month periods, and where this variation was exceeded (only twice), it was attributed to extreme weather, which did not occur during the present study. Furthermore, the normal annual mortality rate for independent possums of 15–20% (Green 1984) is clearly insufficient to account for the decline in trap-catch in the present study, even if it had occurred entirely during the 3-month period between the pre- and post-control monitoring. Since eight possums were caught in the treatment sites after control (from 300 trap-nights), the estimate of 100% reduction given by mark/recapture is clearly an overestimate suggesting, further, that some tagged possums may have been removed from the non-treatment sites. Therefore, the true mean population reduction was between 81 and 100%.

The bait consumption data indicate that the population reduction due to poisoning was achieved within 2 weeks of replacing non-toxic baits with toxic. Thereafter, some further bait removal was recorded throughout the site, and this was probably attributable, in part, to possums immigrating into the area. This is supported by a trend of higher mean consumption, after the initial population decline, on the uppermost (i.e., 400 m) lines of bait stations that would be the first baits encountered by possums moving downhill into the treated areas. The data may also reflect some measurement error. Accurate estimation of the amount of bait eaten at each bait station became progressively more difficult, particularly at the final check, due to, for example, the lower stability of the 100 g gel baits used for this trial result compared with the larger ones previously assessed (i.e., 500 g) in a study of the durability of bait under field conditions (Morgan 2002). The smaller baits were more readily detached from the container when interfered with by possums. This may have resulted in more rapid dehydration and shrinkage of the bait than previously observed; consequently, removal may have been overestimated. Baits that became completely detached and fell to the ground may have been overlooked in the leaf litter, or removed by rats to caches. If the 100 g bait is considered a desirable size for commercial production, some redesign of the bait-station mould is advisable to prevent bait detachment; for example, ridges in the base of the bait station would provide a better surface for adhesion.

Rodents interfered with toxic baits during the first week, but apparently no later. This suggests that either these animals were killed, or they found the bait unpalatable, or they became bait shy after consuming a sublethal quantity. The impact on rodent populations was not assessed in this study, but recent cage trials indicate that palatability to rodents of the present, non-toxic, formulation of gel bait is low (C. O'Connor unpubl. data).

Although the study was designed to assess the level of control that could be achieved using cholecalciferol gel bait rather than identifying "best practice", an indication of its relative efficiency can be inferred. At each treatment site, 265 bait stations were used to control possums over an area of approximately 100 ha (assuming at least 90% of possums within a 100 m distance from bait station lines encounter bait (Thomas et al. 1996)). Since possums consumed 24.2 g of toxic gel bait on average in the preliminary cage trial of toxic gel bait, each bait is likely to provide sufficient to kill four possums. The cost of non-toxic baits is likely to be around $3 and $6 for each toxic bait (M. Carson pers. comm.).

Photo luminescent tags cost 65 cents, so, assuming they can be reused 10 times, an additional 6.5 cents is added per bait station location. Bait stations and tags were deployed at each site in one day by two people, so a labour cost of $1,000 is assumed for two visits. Therefore, the total cost of materials and labour used in prefeeding and a single presentation of toxic bait (i.e., no replacement) is estimated at $35/ha. Since the bait consumption data indicate that population reduction was probably achieved by these two phases of baiting alone, this cost compares favourably with the range of costs ($32–39/ha) estimated for the materials and labour used in four other established ground-based baiting methods (Speedy 2003). However, because gel baits remain palatable and toxic for at least 26 months under field conditions (assuming they do not become detached from bait stations), and because the baits were deployed at a close spacing, there appears to be potential for reducing both the cost of materials and labour in seeking a more efficient baiting strategy. This may also provide for sustained control rather than the pulse of control followed by population recovery achieved by other baiting methods. Furthermore, deployment of cholecalciferol bait for prolonged periods presents lower risks than other bait types because the bait type itself is unattractive or unpalatable to non-target species of concern (Morgan 1999), and incorporation of cholecalciferol offers a further margin of safety towards non-target species relative to other toxins (Eason et al. 2000). It would appear therefore that cholecalciferol gel bait presents a promising new option for achieving long-term control of possum populations.

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