Chew-track-cards: a multiple-species small mammal detection device

Peter Sweetapple*, Graham Nugent

Landcare Research, PO Box 40, Lincoln 7640, New Zealand
*Author for correspondence (Email: sweetapplep@landcareresearch.co.nz)

Published on-line: 30 September 2010

Abstract: Detecting the presence of invasive mammalian pests is expensive, particularly where multiple species of interest are sympatric, yet is key to determining when, where and how much control to do, and the effectiveness of that control. Here we describe the efficacy of a simple new and cheap device, the chew-track-card (CTC), both as a potential tool for simultaneously indexing the relative abundance of sympatric small-mammal pests, and for cheaply and comprehensively mapping the distribution of these pests over large, remote areas. The CTC is an interference device that can record both tooth impressions and the footprints of animals interacting with it. Several studies comparing CTC indices (CTCIs) with established indices of possums and rodents are reported. Possum CTCIs were positively and significantly correlated with established trap-catch indices (TCI), WaxTag® and faecal pellet indices of possum abundance. The relationship between possum CTCI and TCI in seven study sites was always positive and, with adequate sampling, statistically significant, but was also variable, probably due to monitoring protocols differing between trials. Rat CTCIs were also positively correlated to tracking tunnel indices, but these two indices were unrelated for mice. Standard leg-hold trapping cost 29−46 times more per possum detection than for CTCs during a large-scale survey of the Hauhungaroa Range. CTCs are a sensitive and cost-effective means of detecting the presence of small mammalian pests, especially possums and rodents. They also potentially provide a robust tool for indexing low density populations of such pests, particularly possums and rats, although further calibration of CTC indices of pest abundance with standard indices is required. Also, the consequences of interaction between abundant pests, particularly rats, on CTC detection rates, and means to reduce these interactions, need further investigation.

Keywords: detection, pest abundance indices, possums, rodents, tracking tunnels, trap-catch method, waxtags

Introduction

Detecting the presence of pests after control and more generally assessing their abundance is crucial for determining where, when and how much pest control is needed. However, monitoring to do so is often expensive, or at least uses resources that might otherwise be available for actual control. Such costs will be even greater when several species of pests are targeted during control. Multispecies control is increasingly common in native forest ecosystems in New Zealand, where possums (*Trichosurus vulpecula*), ship rats (*Rattus rattus*), stoats (*Mustela erminea*), and mice (*Mus musculus*) are all significant conservation pests (Payton 2000; Sadleir 2000; Cowan 2005; Innes 2005; King & Murphy 2005). Possums are also controlled as agricultural pests because they are vectors for bovine tuberculosis (Coleman & Caley 2000).

Control of some or all of this entire suite of pests is frequently implemented at large scales by aerially poisoning tens of thousands of hectares with sodium fluoroacetate (1080). Aerial 1080 poisoning of forested areas was developed mainly for possum control (Morgan & Hickling 2000). However, such possum control operations can also reduce rat and stoat numbers to very low levels (Innes et al. 1995; Murphy et al. 1999; Sweetapple & Nugent 2006, 2007). Aerial 1080 poisoning is therefore increasingly being deliberately used for multi-species control (e.g. Operation Ark; Elliott & Suggate 2007).

Assessing both the effectiveness of multispecies control and when to reapply such control requires monitoring the abundance of multiple pests. Ideally a single method would be used for all the species of interest, to minimise costs. However, possums are usually monitored using leg-hold traps following a nationally standardised protocol (Trap-Catch Index (TCI); NPCA 2008a), while rodents and stoats are usually monitored using tracking tunnels (e.g. Innes et al. 1995; Brown et al. 1996). The trap-catch method used for possums requires at least four visits and tracking-tunnel assessment of both rodent and stoat numbers requires at least three visits to each device. Traps are heavy (c. 350 g each) and both detection devices (traps and tunnels) are bulky, which constrains the number that can be carried and deployed. Using two different monitoring systems, based on bulky devices that require more than two visits, is expensive, prompting efforts to develop a lower-cost alternative.

One approach has been to use small (lightweight) blocks of wax that animals bite out of curiosity, with the bite mark providing the desired evidence of animal presence. Only two visits are required: one to deploy the device, and the other to collect and 'read' it. The concept evolved from bait interference trials in the 1960s and 1970s (Bamford 1970; Jane 1979, 1981; Bell 1981), and was developed primarily for monitoring possum abundance (Warburton et al. 2004; Ogilvie et al. 2006). It is now been developed as a commercially available product (WaxTag®, Pest Control Research, Christchurch) for that purpose (Thomas et al. 2003; Ogilvie et al. 2006) with an established standardised protocol (NPCA 2008b). Rats (and other species) also leave distinctive bite marks (e.g. McKay & Russell 2005), so the device has potential as a multispecies monitoring device. However, the wax block used is small and can be either totally destroyed by interacting animals (PS pers. obs.), or may have bite marks of initial visitors obscured by the marks left by later visitors. Further, the wax used is unpalatable, so animals are considered unlikely to bite multiple devices – a factor considered likely to make it more consistent as a standardised monitoring tool (M. Thomas, Pest Control Research, pers. comm.). However, managers are sometimes also interested in surveillance to define and map the area(s) occupied by the pest(s), especially at low densities, so that the occupied areas can be targeted for control. For this, a palatable device that maximises sensitivity is preferable.

The need for a low-cost device to delimit ranges, at least for possums, has emerged from the extremely low numbers that can remain after aerial 1080 poisoning (Morgan et al. 2006), and the widespread public antipathy to such poisoning (Hansford 2009) that has spurred efforts to reduce reliance on this tool (Parker 2009). One way of doing that is the so-called 'local elimination' approach (Nugent et al. 2008). Conceptually, the aim is to reduce pest densities to near-zero levels by aerial poisoning, and then prevent population recovery by undertaking systematic surveillance using a low-cost detection device to map the few places where pests still remain. The intention is that those few pests are then targeted (mopped up) using ground methods rather than further aerial poisoning (Nugent et al. 2008). The feasibility of this detect-and-mop-up strategy depends on the availability of a suitable low-cost multi-species device that is both highly sensitive (reliably indicates pest presence wherever pests actually occur, with few false negatives) and highly specific (seldom confuses which pest is present, with few false positives).

In this paper, we describe the efficacy of a new device, the chew-track-card (CTC), both as a potential tool for monitoring the abundance of multiple small-mammal pests and for cheaply and comprehensively mapping the distribution of possums and other small mammalian pests over large tracts of remote terrain. The CTC is an interference device that records tooth impressions and (if required) the footprints of animals interacting with it. It incorporates palatable bait, to maximise sensitivity as a mapping tool. Tracking ink can be added to (1) increase sensitivity to individuals that visit but do not bite the card and (2) aid species identification. We describe the results of a series of field trials undertaken to assess the efficacy of CTCs for detecting and mapping the distribution of possums and rodents.

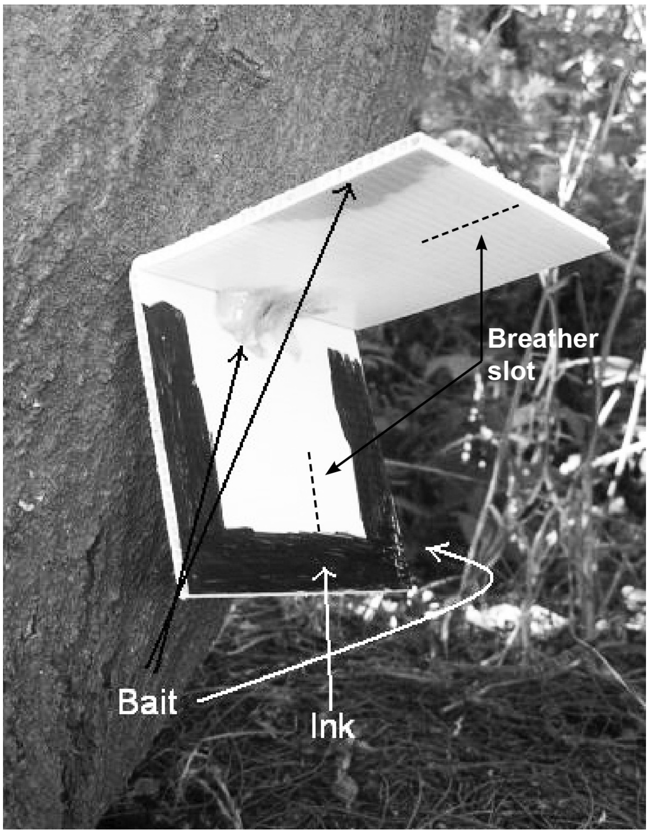

Figure 1. A chew-track-card mounted on a tree. All four corners of the card can be baited if required. The breather slots are necessary only when baits inserted at opposite ends of the same internal channels.

Methods

Chew-track-cards: design and use

CTCs consist of a rectangular piece (90 × 180 mm) of 3-mm white twin-walled polypropylene sheet (e.g. Mulford Plastics, Christchurch, NZ) with the flutes (internal channels) aligned parallel with the 90-mm sides (Fig. 1). Attractant paste (bait) is pressed c. 20 mm into the flutes along c. 50-mm lengths at 1–4 corners of the card. A 50-mm slot, cut along the centre-line, perpendicular to the 90-mm sides, releases airlocks created when baits are applied to both ends of the same flute. Cards are bent into a right-angled shape, mounted on tree trunks or stakes about 200–300 mm above the ground and, when desired, have tracking ink (e.g. Black Track, Pest Control Research, Christchurch, NZ) applied in a 20-mm strip around the perimeter of the lower inside half of the card (Fig. 1). Finally some bait is placed in the apex of the fold, above the inked surface. This design allows four or more different baits to be used, to simultaneously attract multiple species.

Early trials used plain smooth peanut butter as a possum and rodent attractant and a chicken-flavoured jelly-meat cat food as a predator attractant. Later trials (2008–2009) used a 10:2:0.5 mix of smooth peanut butter + icing sugar + ground lucerne pellets (dried alfalfa (*Medicago sativa*) pelletized livestock feed) as the best of a range of possum attractants tested, identified from unpublished pen and field trials. Unbaited CTCs cost c. $0.20 each and materials for two peanut butter-based baits cost c. $0.05 per card.

For logistic convenience CTCs are typically placed at regular intervals along transects, but as yet no standardised spacing, transect length, or interval between deployment and checking has been agreed. This is, in part, because CTCs were initially developed primarily for detecting pest presence rather than assessing relative abundance, although they are increasingly also being used for the latter purpose. However, CTCs are often retrieved and assessed after about 7 days. All retrieved cards were assessed by experienced observers with access to optical equipment (hand lenses) and reference materials including cleaned jaws and skulls and cards bitten by captive animals, to minimise misidentifications and missed detections.

Comparison with other measures of pest abundance

Using data collected incidentally in a number of other projects, we explored the relationship between the rates of interference on CTCs and other measures of pest abundance. The four measures were trap-catch indices of possum abundance, a faecal pellet measure of possum abundance, a tracking-tunnel tracking rate measure of rodent and stoat abundance, and a WaxTag® bite-rate interference measure of possum and rodent abundance. For this, a CTC Index (CTCI) for each species was generated simply by calculating the percentage of CTCs on which interference (tooth impressions, tracks or occasionally fur, scratches or faecal pellets) was recorded per sampling unit (transect or block). As such, the CTCI are not corrected for any difference between studies in the number of days they were available to the pests. Percent indices usually show a curvilinear relationship with animal density (Caughley 1977) so CTCIs were Poisson-transformed to approximate a linear index of density (Hone 1988) as follows:

$$transformed\ CTCI = -\ln(1-p)$$

where p is the proportion of CTCs detecting the target species. Four data points comparing possum trap-catch indices (TCIs) with CTCIs from one study (McKerrow; see below) were excluded because 100% of CTCs were bitten by possums and therefore could not be Poisson-transformed.

In four studies (Molesworth, Landsborough, Isolated Hill, and McKerrow), both CTCIs and standard TCIs (lines of 10 leghold traps at 20-m intervals set on the ground for three fine nights, NPCA 2008a) were determined for 4–20 trial transects or blocks. In two further studies (Whirinaki 2007 and Kumara) CTCIs and a non-standard measure of TCI were obtained. At Whirinaki traps were set at 40-m intervals and at Kumara traps were placed on boards 70 cm off the ground to prevent capture of ground birds. The trial blocks varied in size from a few hundred to a few thousand hectares. CTCIs were measured before TCIs at all sites. Simple linear regression, with CTCI as the dependant variable, was used to test whether there was a positive relationship between the two indices. Sampling units were transects at Kumara and McKerrow, and blocks at the other study sites.

The relative abundance of faecal pellets has also been used as an index of possum abundance (Baddeley 1985). Before experimental possum control trials in 2007 in two podocarp–tawa forests in the central North Island, –Whirinaki and Mokaihaha– possum abundance in 36 blocks (each 100 ha) was monitored with CTCs during winter 2006. Each block was surveyed with 151–170 CTCs placed for c. 2 weeks on four parallel 1-km-long transects spaced 200 m apart. The presence or absence of possum faecal pellets was recorded on a circular (1.14-m radius) plot immediately adjacent to each CTC when cards were removed. Poisson-transformed CTCIs and possum faecal-pellet frequency (FPF; the percentage of plots with faecal pellets present) were correlated, using blocks as sampling units.

Tracking tunnels were paired with CTCs in podocarp–tawa forest at four North Island sites (Kaimai, Mokaihaha, Waimana, Whirinaki) in October 2008 to compare sensitivity of CTCs and tracking tunnels to rodents. Two 2.7-km transects at least 1 km apart were established at all sites, each with 36 sets of both devices placed side by side at 200-m intervals and run for four nights. CTCs were baited with peanut butter + icing sugar + lucerne as above and tunnels were baited with peanut butter and salted rabbit meat. For each species, the percentage of the tracking tunnels tracked over the four nights (TTI) was compared with untransformed CTCIs, using correlations and paired t-tests, with transects as sampling units.

Finally we also compared CTCIs and a WaxTag® index (WTIs), using data obtained from aerial poisoning trials in the south-eastern portion of Molesworth Station, Marlborough (42º12’ S, 173º20’ E), in spring 2008. The devices were deployed over c. 18 000 ha of montane–subalpine grassland and shrubland, with 44 transects along which 20–23 pairs (one CTC, one WaxTag®) of devices were placed at 20-m intervals. The CTCs and WaxTag®s (both coloured orange) were placed c. 5 m apart and pinned to the ground with aluminium pegs. CTCs were baited with the possum bait and ‘carnivore’ bait, comprising ground Purina One chicken-flavoured cat food and canola oil. Pre-control transects were deployed for 44–51 days and post-control transects for 10–20 days, with the long pre-control interval a consequence of delays in the poisoning operation. Frequency of possum interference was calculated for the two devices on all 44 transects both before and after poisoning, and was compared between devices using correlations and paired t-tests.

Utility as a mapping tool

To assess the practicality, efficacy and cost-effectiveness of CTCs as a tool for mapping the distribution and abundance of possums and other mammalian pests after intensive 1080 poisoning, a series of CTC surveys were conducted in 19 000 ha of podocarp–hardwood forest in the central and southern Hauhungaroa Range, central North Island (38º42’ S, 175º35’ E) between 2005 and 2008. The area was aerially poisoned in winter 2005, as part of a large (88 000 ha) operation primarily targeted at possums (Coleman et al. 2007). The operation was highly effective. In the 19 000-ha study area, only two possums were caught during post-poison trap-catch monitoring (TCI = 0.06%, n = 106 traplines, 3180 trap-nights; S. Littlefair, Qualmons, Taupo, pers. comm.). Simulation modelling (Ramsey et al. 2005) suggests that the trap-catch index of 0.06% (0.06 possums captured per 100 trap-nights) equates to an actual density of 0.01 possum ha^{-1}.

In the period 4–9 months after poisoning, CTCs were used to survey c. 80% of the study area (2992 cards placed at 50-m intervals on 27 parallel transects spaced 1 km apart, total transect length = 150 km). Cards were left for 6–7 nights before being checked. The study area was divided into five sub-blocks, primarily for logistical purposes.

Four of the five blocks were resurveyed 25–36 months after control, using 2599 CTCs deployed in a similar way, but with the parallel east–west transects all moved 250 m northward to target areas not sampled in the initial survey.

Effect on CTCI of between-species interference

Detection rates of a range of pests were compared on cards that detected or did not detect a second pest species during the Hauhungaroa trials to investigate between-species interactions at chew-track-cards. For example the ratio of possum detection rate on cards with and without rat sign (detection ratio) was calculated. Detection rates were compared using 2×2 contingency tables. The relationship between possum–rat detection ratios and rat abundance was determined by regressing detection ratios against rat CTCIs from different blocks and years.

Results

Small-mammal interference sign on chew-track-cards

All of the small-mammal pest species commonly encountered in New Zealand forests produced distinctive tooth impressions on CTCs. Possums extensively crushed card margins to a depth of c. 20–30 mm, and/or produced clear, narrow, slightly curved incisor-pair impressions c. 6 mm wide (Fig. 2a, b) but rarely cut or perforated the card surface. Rats frequently gnawed away large portions of cards leaving jagged edges and/or incisor-pair perforations c. 2 mm wide (Fig. 2c, d). Mice cut small nicks or gnawed away portions of one surface of baited areas, leaving numerous tiny (c. 0.5 mm wide) tooth impressions along the chewed edge (Fig. 3a). Mice also cleanly removed c. 5 mm of bait from the ends of baited channels, sometimes without leaving tooth impressions. Stoats produced highly variable numbers of 1-mm-wide canine perforations within c. 10–20 mm of the card margins (Fig. 3b) and hedgehogs (*Erinaceus europaeus*) left slightly elongated small (1–2 mm wide) canine perforations on one side of the cards and blunt incisor-pair impressions c. 4 mm wide on the opposite surface (Fig. 3c, d). Field staff easily distinguished between possum, rodent and carnivore tooth impressions. A hand lens was sometimes required to differentiate between rats and mice when gnawing was light, but these two species could always be separated by an experienced observer. Indistinct impressions were rarely unidentifiable (< c. 1% of detections) and may sometimes have been produced by accidental damage to the cards.

Ink tracks were frequently smeared but the width of 'toe-stripes' (c. 1 or 2 mm wide for mice and rats, respectively) were diagnostic for rodents. Clear prints were also occasionally produced by rats, stoats, hedgehogs and, particularly, mice.

Detection was primarily from tooth impressions, or a combination of ink tracks and tooth impressions, although some detections were only from ink tracks, particularly for mice (Table 1). Other forest-dwelling vertebrate species occasionally detected were pigs (*Sus scrofa*), goats (*Capra hircus*), cats (*Felis catus*), kea (*Nestor notabilis*) and weka (*Gallirallus australis*). Rabbits (*Oryctolagus cuniculus*), ferrets (*Mustela furo*) and dogs (*Canis familiaris*) have also been identified from tooth impressions on CTCs placed in unforested habitats (PS unpubl. data).

Not all possums detected by CTCs left tooth impressions or ink footprints. During the two Hauhungaroa Range surveys (combined total of 125 possum detections), possums were detected by only fur or scratch marks on two occasions. Likewise, rodents, particularly rats, frequently left faecal pellets on top of CTCs, which aided species detection and identification.

Comparison with other measures of pest abundance

Possum CTCIs were always positively correlated to TCIs, although only weakly in some of the trials with low samples sizes (Table 2). The relationship (regression slope) varied markedly between studies but this may reflect varying monitoring protocols used for both CTC and traps. The two

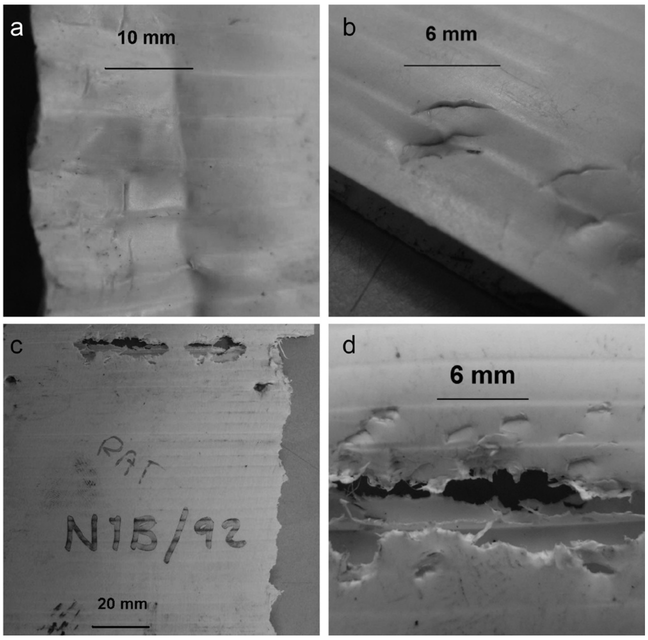

Figure 2. Chew-track-cards showing possum bite marks (a & b) and rat bite marks (c & d).

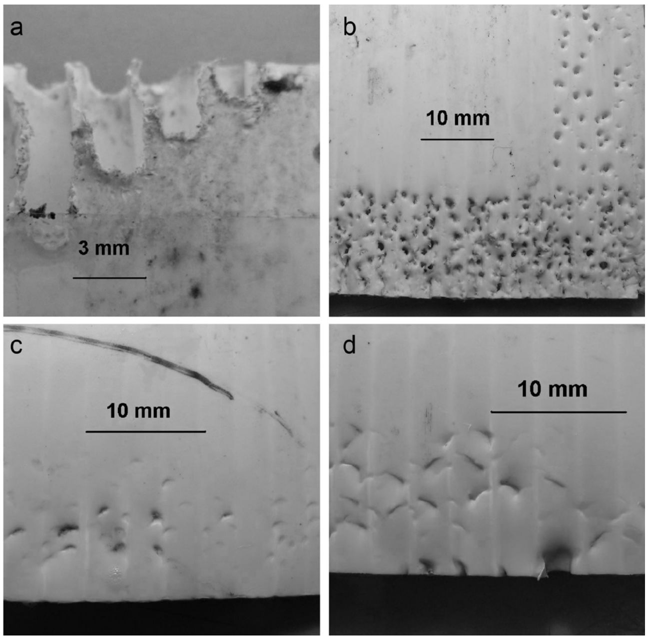

Figure 3. Chew-track-cards showing mouse gnawing (a), stoat canine tooth impressions (b) and hedgehog canine (c) and mandibular incisor (d) impressions.

Table 1. Frequency of detection on chew-track-cards of a range of mammalian pests, and the percentage of those detections that recorded only ink tracks or tooth impressions. Data are from the 2005/06 Hauhungaroa survey. *This one possum left scratch marks on the inked surface.

Species	N	Detection frequency (%)	Percentage of detections with only ink tracks	Percentage of detections with only tooth impressions
Hedgehog	2992	2.4	5.5	45.9
Mouse	2992	60.1	23.9	5.9
Possum	2992	1.5	2.3*	47.7
Rat	2992	44.3	8.0	4.2
Stoat	2992	0.27	11.1	62.5

Table 2. Possum data from six studies comparing regressions of Poisson-transformed trap-catch index on Poisson-transformed chew-track-card index. The national possum trap-catch protocol (NPCA 2008a) was followed in studies 4–7 only. Chew-track-card deployment periods varied between studies from 6 to 24 nights as indicated below the study name. Linear regression line slope (a), *y*-axis intercept (b), and regression statistics (R^2, *P*-value) are shown. Mean untransformed rat CTCI recorded on the same cards as possum CTCIs are also shown. Where data include pre- and post-control results from aerial 1080 operations (Whirinaki, Molesworth, Landsborough, Isolated Hill) only pre-control rat data are shown.

Study	Lines/blocks (*N*)	a	b	R^2	*P*	Mean rat CTCI
1. Whirinaki North 2007 (40-m TCI, 7-day CTCI)	10	1.32	−0.05	0.79	<0.001	53.3%
2. Whirinaki South 2007 (40-m TCI, 7-day CTCI)	10	3.78	−0.02	0.77	<0.001	51.8%
3. Kumara 2008 (Raised set TCI, 7-day CTCI)	12	6.46	0.04	0.68	<0.001	92.3%
4. Molesworth 2009 (10–20-day CTCI)	4	12.80	−0.03	0.74	0.091	0.0%
5. Landsborough 2009 (16–24-day CTCI)	6	10.27	0.02	0.61	0.066	3.2%
6. Isolated Hill 2009 (7-day CTCI)	4	12.64	0.07	0.23	0.71	27.8%
7. McKerrow 2008 (6-day CTCI)	16	4.88	15.70	0.63	<0.001	0.6%

studies with the longest CTC deployment had steep regression slopes (10.27 and 12.8). However, the regression slope for Isolated Hill, where cards were out for just 7 days, was also high at 12.64, but may be erroneous due to a small sample size and a limited range of possum abundance encountered (0.6–4.8% RTCI). A modest regression slope of 3.78 at Whirinaki South probably reflects a wider trap-spacing than in other areas, resulting in higher RTCIs than expected under standard 20-m spacing. Whirinaki North, with a regression slope of just 1.32, stands out as markedly different from areas with comparable survey protocols. Frequent cyanide poisoning by local possum-fur harvesters in this easily accessible block, leading to significant CTC shyness, is thought to be responsible for this result. In the only study with adequate sampling in which standard TCIs (i.e. as per NPCA 2008a) were compared with 6-day CTCIs (McKerrow), the regression slope was 4.9 and the relationship strong.

The CTCI-to-RTCI ratio for possums was unrelated to the abundance of rats as measured by CTCs (R^2 = 0.08, *P* = 0.272; Table 2). However, a trial rat-repellent bait was used in conjunction with the standard possum bait in CTCs in the only study with high rat indices (Kumara) and, therefore, may have reduced the potential impact of rat interference on possum detection rates there.

Possum CTCIs at Whirinaki and Mokaihaha were strongly and positively correlated to possum faecal pellets frequency on 1.14-m-radius plots (R^2 = 0.82, *P* < 0.001; Fig. 4).

Rat detection rates on CTCs were positively correlated with those from tracking tunnels (R^2 = 0.57, *P* = 0.03; Fig. 5a) with weak evidence that rates were higher on CTCs than in tracking tunnels (CTCs = 0.39, tunnels = 0.29, paired *t*-test t_7 = 2.19, *P* = 0.065). Mouse detections on CTCs and in tracking tunnels were not correlated (R^2 = 0.004, *P* = 0.89; Fig. 5b) but were recorded 3.4 times more frequently on the former (paired *t*-test: t_7 = 3.69, *P* = 0.008).

In the 2008 Molesworth study, possum CTCIs were also positively correlated with the frequency of possum detection on WaxTags®, both before and after possum control, with the relationship strongest before control due to the greater range of possum abundance sampled then (Fig. 6). After Poisson transforming the raw data to account for device saturation at high detection rates, possum CTCIs were 2.1 and 2.0 times higher than WTIs before and after possum control, respectively (paired *t*-test before control: t_{43} = 5.65, *P* < 0.001, after control: t_{43} = 2.64, *P* = 0.01). Both monitoring devices occasionally failed to detect possums, as on 6 of 44 transects possums were detected by one device but not the other during post-control monitoring. No such examples occurred during pre-control monitoring. These failure-to-detect rates were not significantly different at 6.7% and 11.4% of lines where possums were detected for CTCs and WaxTags®, respectively (2×2 contingency table: χ_1^2 = 0.21, *P* = 0.65).

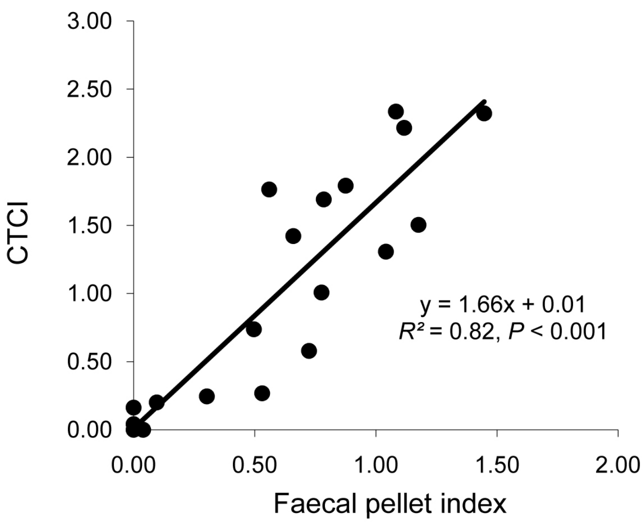

Figure 4. Correlation between possum detection frequency on chew-track-cards and possum faecal pellet frequency on 1.14-m-radius plots at Whirinaki and Mokaihaha in 2006. Raw data are Poisson-transformed to approximate a linear index (Hone 1988).

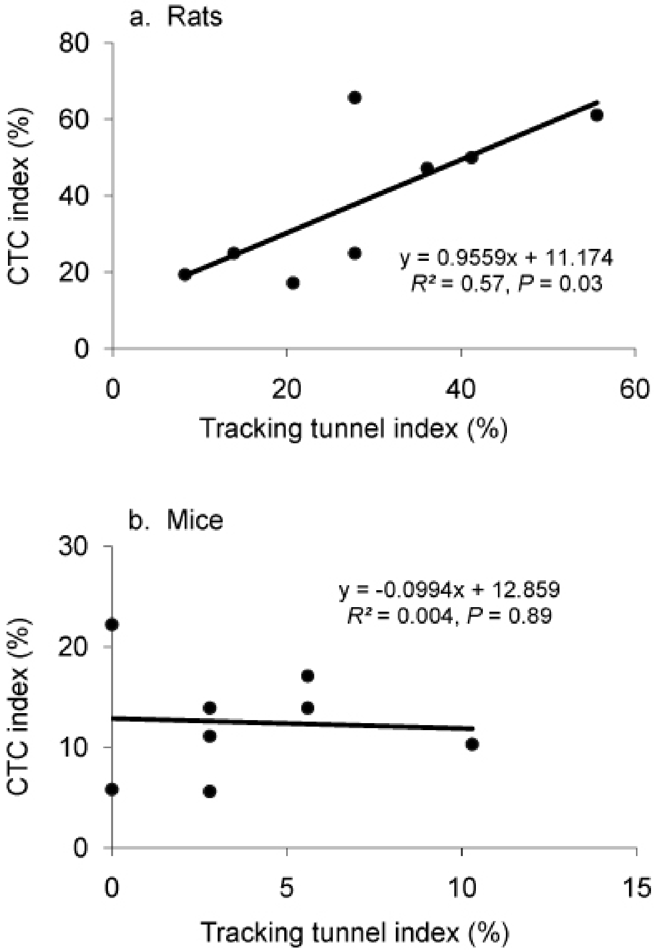

Figure 5. Correlations between 4-day detection frequency on chew-track-cards and tracking tunnels for rats and mice.

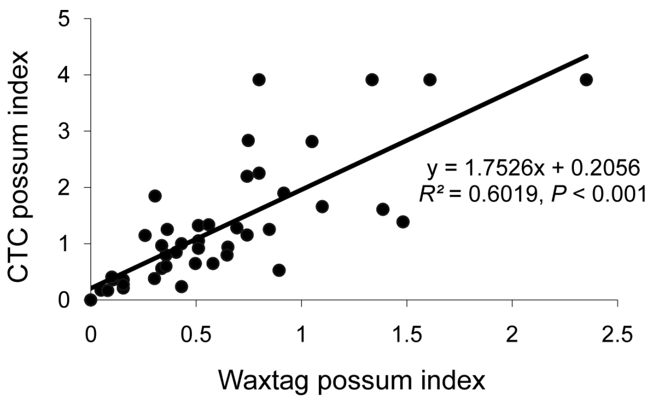

Figure 6. Correlation between possum detection frequency on chew-track-cards and Waxtags® at Molesworth Station in spring 2008. Data are Poisson-transformed to approximate a linear index (Hone 1988).

Very few mice were detected on WaxTags® (1.2%) compared with CTCs (58.9%) at Molesworth (pre- and post-control results combined, 2×2 contingency table: $\chi_1^2 = 1366$, $P < 0.001$), indicating that unbaited WaxTags® are not a sensitive monitoring tool for mice.

Utility as a mapping tool

Possums were recorded on 44 (1.47%) of the 2992 CTCs deployed in the initial CTC survey of the Hauhungaroa Range 4–9 months after the 2005 poisoning. These detections occurred within 28 clusters of activity, a cluster being designated as possum interference or sign detected on a card or group of cards that were at least 150 m from other possum-positive cards, indicating that there were between 28 and 44 possums detected (0.19–0.29 possum km^{-1} of transect). This is more than twice the detection rate during the post-control leg-hold trapping within c. one month of control, with two possums detected (captures) on a total length of 21.2 km of traplines (0.09 detection km^{-1}).

Cost of CTC surveys

Field crews were able to establish 3–4 km of CTC transect each per day, in remote terrain and all seasons, at an on-transect rate of 1 km and 20 devices every 60–90 minutes. At a labour cost of NZ$260 per day (2005 dollars and pay rates), a factor of 1.2 for travel and other such non-productive time, $110 per kilometre for materials and travel, total costs for the CTC survey were $266–355 per kilometre. This gives costs of $907–1,209 per detection and $1,425–1,900 per detected cluster for the 2005/06 Hauhungaroa survey.

Multiple species detection interactions

Individual CTC cards frequently detected more than one species; during the 2005/06 Hauhungaroa survey two and three species were simultaneously detected on 23.6 and 0.5% of cards, respectively. There are strong indications that when a CTC is interfered with by one species (particularly rats) it affects the likelihood that that CTC will detect other species. For example, rat interference on cards at Hauhungaroa was associated with lower detection rates of other species. During the 2005/06 Hauhungaroa survey, when rat abundance was moderate (44% of cards detected rats), hedgehog, mouse and possum detection rates on cards that also detected rats were only 27–55% of those recorded from cards without rat interference (Table 3). There were no significant detection interactions between non-rat species, with the possible exception of a positive interaction between stoats and mice, although there were insufficient stoat data to test this interaction (Table 3). The degree of negative interaction between the detection of possums and rats was correlated with overall rat abundance (Fig. 7). At the highest rat detection rates (c. 90% of cards), possum detections were c. 10-fold lower on rat-detecting CTCs than on CTCs that did not detect rats (Fig. 7).

Likewise, as another example, no mice at all were detected at Isolated Hill on 30 CTCs that had been bitten by possums and rats, whereas they were detected on 29.7% of 84 CTCs that detected neither rats nor possums ($\chi^2_1 = 11.44$, $P < 0.001$).

Discussion

The ideal surveillance or monitoring tool for assessing the abundance of multiple species of small mammals should be

(1) highly sensitive in its ability to detect all of the species of interest, (2) highly specific in accurately and simultaneously identifying the presence of particular species, (3) not prone to major biases, and (4) cheap and easy to deploy. Unfortunately, no such tool exists. However, CTCs, and their wax block precursor, show promise in fulfilling some of these requirements. The degree to which they are able to do so depends on the context in which they are used, and on the surveillance or monitoring goals.

CTCs appear to be a sensitive tool for detecting rats and possums, and also mice where rats are rare, compared with other available tools. They can also detect many other species, but do so only rarely. It is unclear whether that is a consequence of the rarity of species such as stoats in most of the areas in which the trials summarised here were conducted, or low sensitivity to those species (or both). Several species can be detected simultaneously on the same CTC. This feature is enhanced by the large detection surface area, the two modes of detection, and the ability to apply at least four different baits to separate parts of the card, each one targeting a different species. The addition of tracking ink was particularly useful for detecting mice (Table 1). To date we have primarily focused on baits to attract possums, which being peanut-butter based are also very attractive to rodents. Work on stable species-specific baits is needed to increase sensitivity of CTCs to carnivores.

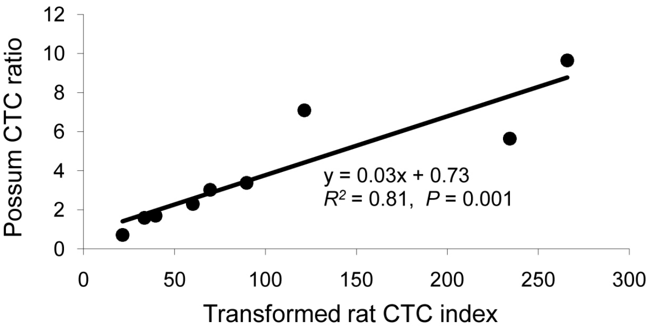

Figure 7. Relationship between possum CTCI ratio (possum detection frequencies on chew-track-cards (CTCs) without rat sign divided by possum frequency on CTCs with rat sign) for a range of Poisson-transformed rat interference rates. Rat-interference and possum-CTCI-ratio data were square-root-transformed prior to regression analysis to normalise residuals. Back-transformed values are plotted. Sample units are blocks (five from first survey and four from second survey).

CTCs appear to be as sensitive, or more so, at detecting possums as leg-hold traps. In the first Hauhungaroa CTC survey, at least 28 possums were detected along 150 km of CTC transect compared with just two along 21 km of trapline. Adding an assumed mean recapture distance of 160 m (the figure recorded in a 2005 study at Purerora, 25 km to the north; D. Morgan Landcare Research, Lincoln, pers. comm.) to each end of each trap and CTC line indicates a minimum of 0.19 possums were detected per kilometre of CTC transect compared with 0.036 possums detected per kilometre of trapline. This five-fold difference appears too great to be explained by any bias downward in the trapping estimate as a consequence of it having being conducted a few weeks rather than months after the poisoning operation, as observed elsewhere (Nugent et al. 2010). Accordingly, the per-possum cost of detection with leg-hold traps at Hauhungaroa ($41,720, estimated from cost-per-line data; S. Littlefair, Qualmons, Taupo) was 22−46 times more than with CTCs ($907−1,900).

In designing CTCs, palatable bait was included specifically in an attempt to maximise detection sensitivity. This is in contrast to WaxTags®, which are deliberately made to be unpalatable, to minimise the number of different devices that an individual animal might bite (M. Thomas, Pest Control Research, Christchurch, pers. comm.). Although in the Molesworth study possum-detection frequency on CTCs was nearly double that of WaxTags® (Fig. 6), it is unclear whether that reflects detection of more possums or simply a greater mean number of detections per possum, as levels of false-negatives (failures to detect) were statistically similar for both devices. Because multiple detections of the same possum result in more rapid saturation of the CTCI as possum numbers increase, CTCs will be less useful than WTs for monitoring possum populations where numbers are moderate or high. Where possum numbers are very low, however, CTCs appear likely to be more sensitive. One solution to multiple detection of the same animal is simply to space CTCs more widely, so that the distance between them is just beyond the normal home-range diameter for the species (c. 160−225 m; derived from home-range sizes in Cowan (2005)), although this is likely to be at the cost of lower detection probabilities.

Detection probabilities using CTCs are required to determine if the absence of detections provides reliable evidence of pest absence. These have not been measured for any species. However, one study recorded (by DNA extraction from chewed CTCs) that 77−93% of individual possums captured in leg-hold traps had bitten CTCs deployed at the trap sites for 4 nights prior to trapping (PS unpubl. data).

Table 3. Ratio of detection rates for species X on cards that did and did not detect species Y during the 2005/06 Hauhungaroa survey. Ratios close to one indicate little interaction between the detectability of pairs of species. Numbers in parenthesises are total number of detections from all cards. Statistical significance is indicated (** $P < 0.01$, * $P < 0.05$, NS not significant at the 95% level), after Bonferonni adjustments for multiple comparisons (multiplying the P-value by the number of tests in each column), for 2×2 contingency tables of the presence or absence of species X and Y interference. Insufficient data were available to test comparisons for stoats.

Species X	Species Y				
	Hedgehog	Mouse	Possum	Rat	Stoat
Hedgehog (74)		0.80 NS	0.92 NS	0.27**	0.0
Mouse (1818)			1.12 NS	0.55**	1.46
Possum (44)				0.40*	0.0
Rat (1356)					0.49
Stoat (9)					

This demonstrated that most possums would bite a CTC if they encountered one.

CTCs appear as sensitive, or more so, to the presence of rodents as tracking tunnels. CTCIs were as high as or higher than TTIs in podocarp forest (Fig. 5). Markedly higher mouse detection rates, however, clearly indicate that CTCs are more sensitive than tracking tunnels to the presence of mice, at least in the presence of rats, which were ubiquitous across the eight podocarp–tawa study sites. Relative sensitivity of CTCs to mice was even greater in comparison to WaxTags® at Molesworth Station. Mice were detected 50 times more frequently on CTCs there than on WaxTags®. However, WaxTags® may be sensitive to mice in some habitats as high mouse indices have been recorded with them elsewhere (M. Thomas, Pest Control Research, Christchurch, pers. comm.).

The interference recorded on CTCs is usually readily assigned to a particular species, making them usefully species-specific (PS pers. obs.). However, there can be uncertainty where bite and track marks are faint, or where species with similar sized teeth and jaws are involved (e.g. young rats and large mice). A more common problem is that detection of one species is affected by the detection of a second species (e.g. possums and rats; Table 3 & Fig. 7). This affects both sensitivity and specificity, and can therefore result in bias if the CTCI is being used as a measure of animal abundance. We are uncertain as to the mechanism of this interaction, but removal of bait by the first visitor reducing the attractiveness of CTCs to subsequent visitors is likely. A strong depression in mouse detectability due to behavioural modification in the presence of abundant rats, as recorded elsewhere (Brown et al. 1996; Sweetapple & Nugent 2005), is probably also involved in the detection interaction of rats and mice on CTCs. The extent of these biases can be explored by comparing CTCIs between subsets of CTCs – those with and without interference sign of the second species of interest – although this will not determine which species is excluding which. The significant negative interaction between rats and three other species but not any non-rat pairs of species (Table 3) strongly implicates rats as the dominant species in these interactions. Current work to develop a bait-type unpalatable to rats, for inclusion on CTCs, may remedy this apparent problem.

The complexity of two- or three-way pest interactions potentially undermines confidence in using CTCIs to accurately measure change in pest abundance. However, the lack of significance between rat abundance and the possum CTCI-RTCI relationship suggests either that (1) rats do not markedly influence possum detection on CTCs relative to traps, (2) the trial rat-repellent bait used at Kumara was effective at preventing rat-exclusion of possums at CTCs, (3) the variable survey protocols across the study sites masked rat-possum interference, or (4) some combination of all three. Furthermore, this problem of between-species effects largely disappears for all species when the abundance of both main obscurers in forests (possums and rats) is reduced to near-zero levels. This is the case after (for example) aerial 1080 poisoning, and is the context for which CTCs were developed.

Use of CTCIs for assessing abundance and/or changes in abundance of pests rests on the assumption that the index is somehow related to pest density. At one extreme that must be true, as (false positives aside) where there are no pests, there can be no detection. For possums and rats, CTCIs are positively related to other indices of relative pest abundance, although our data suggest the relationship may be variable for possums. It is not clear how much of that variability reflects sampling error in CTCIs and how much reflects sampling error in TCI estimates, as the trials to date have had relatively small sample sizes and did not use consistent protocols (see Table 2). Trap-catch indices are considered to be more-or-less linearly related to possum density up to about 20% TCI (Forsyth et al. 2005; Ramsey et al. 2005); therefore, further calibration using standardised protocols for both CTCs and traps should clarify the reliability of CTCs for indexing possum abundance, at least at low possum densities.

Mouse detection rates on CTCs were unrelated to those in tracking tunnels, but were markedly higher on CTCs (Fig. 5b). The lack of correlation for mice between the two devices is not surprising given that mouse tracking in tunnels is unrelated to measures of absolute mouse abundance (Ruscoe et al. 2001). Further work is required to determine if CTCs provide a reliable index of mouse abundance.

Their apparent sensitivity to possums and rodents indicate the utility of CTCs for monitoring low-density populations of these pests, but probably limits their usefulness when these pests are abundant. A continuous variable, e.g. scoring the intensity of pest interaction on CTCs, instead of the simple presence/absence score (used in this study), enhances the utility of an indices for monitoring abundance pests (Engeman 2005). However, many individually housed captive possums heavily chewed CTCs on their first encounter (PS unpublished data). If such behaviour is typical of wild possums then a continuous variable will be of limited value for monitoring possums with CTCs. A shorter deployment time than used in this study (one or two nights) may be a better option for monitoring abundant pests. Trials where cards are assessed daily under a range of pest densities are required to quantify this.

A major prompt for the development of CTCs (and Waxtags® before them) was to reduce the cost of possum monitoring. Since the mid-1990s, TCIs based on leg-hold trapping have been the primary monitoring tool used in possum management. However, it is expensive, primarily because the nationally standardised protocol stipulates daily servicing for three fine nights; that is, at least four visits to each trap site (NPCA 2008a). Adding to that, the traps are spaced closely together (20-m spacing) so that, at very low density, capture of a possum greatly reduces the likelihood that any neighbouring traps will also catch possums. In contrast, CTCs (and Waxtags®) require only two visits, and in at least some of the CTCI surveys wider spacings were used (e.g. 50-m spacing for the Hauhungaroa surveys). TCIs therefore contain little extra information about possum abundance relative to CTCIs in terms of the effort and cost of collecting it. Adding to this the CTCs are smaller, lighter, and inexpensive and have proven to be easy to deploy (20 devices on 1 km of transect per hour in untracked forested terrain). Thus, in the Hauhungaroa surveys, the cost per possum detection was at least 20 times higher with traps than with CTCs, although the survey designs were not directly comparable. We estimate from field experience that trapping for three nights using a similar protocol to the Hauhungaroa area-wide CTC surveys (i.e. traps every 50 m along transects spanning the entire area) would cost about three times as much as CTC transects.

Conclusions

CTCs show promise as a tool for efficiently monitoring the distribution and abundance of possums, rats, and mice in New Zealand forest when the densities of pests are very low, particularly in extensive tracts of remote and difficult terrain.

They are low cost, compact, light weight, easy to deploy, sensitive to possums and rodents while also capable of detecting a wide range of other species, and are easy to interpret with minimal training. High sensitivity undermines their utility as a tool for monitoring high density pest populations, but they appear well suited to (1) comparing possum and rodent densities after large-scale aerial poisoning and (2) identifying (mapping) areas where pests still occur after control so that further control can be focused at these site.

Acknowledgements

Many people assisted with the extensive fieldwork, particularly Chris Brausch, Caroline Thomson and Ivor Yockney. Phil Cowan, Christine Bezar and two anonymous reviewers commented on drafts of the manuscript. This work was undertaken with funding from the Animal Health Board and the New Zealand Foundation for Research, Science and Technology.

References

Baddeley C 1985. Assessment of wild animal abundance. FRI Bulletin 106. Forest Research Institute. 46 p.

Bamford J 1970. Evaluating opossum poisoning operations by interference with non-toxic baits. Proceedings of the New Zealand Ecological Society 17: 118–125.

Bell DJ 1981. Estimating the density of possums *Trichosurus vulpecula*. In: Bell BD ed. Proceedings of the First Symposium on Marsupials in New Zealand. Zoology Publications from Victoria University of Wellington 74. Pp. 177–182.

Brown KP, Moller H, Innes J, Alterio N 1996. Calibration of tunnel tracking rates to estimate relative abundance of ship rats (*Rattus rattus*) and mice (*Mus musculus*) in a New Zealand forest. New Zealand Journal of Ecology 20*:* 271–275.

Caughley, G. 1977: Analysis of vertebrate populations. John Wiley, New York, USA. 234 p.

Coleman J, Caley P 2000. Possums as a reservoir of bovine Tb. In: Montague TL ed. The brushtail possum: Biology, impact and management of an introduced marsupial. Lincoln, Manaaki Whenua Press. Pp. 92–104.

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

Cowan PE 2005. Brushtail possum. In*:* King CM ed. The handbook of New Zealand mammals. 2nd edn. Melbourne, Oxford University Press. Pp. 56–80.

Elliott G, Suggate R 2007. Operation Ark: three year progress report. Public report. Christchurch, Department of Conservation, Southern Regional Office. 83 p.

Engeman RM 2005. Indexing principles and a widely applicable paradigm for indexing animal populations. Wildlife Research 32: 203-210.

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

Hansford D 2009. 1080. New Zealand Geographic 97: 52–63.

Hone J 1988. Feral pig rooting in a mountain forest and woodland: distribution, abundance and relationships with environmental variables. Australian Journal of Ecology 13: 393–400.

Innes JG 2005. Ship rat. In*:* King CM ed. The handbook of New Zealand mammals. 2nd edn. Melbourne, Oxford University Press. Pp. 187–203.

Innes J, Warburton B, Williams D, Speed H, Bradfield P 1995. Large-scale poisoning of ship rats (*Rattus rattus*) in indigenous forests of the North Island, New Zealand. New Zealand Journal of Ecology 19: 5–17.

Jane GT 1979. Opossum density assessment using the bait interference method. New Zealand Journal of Forestry 24: 61–66.

Jane GT 1981. Application of the Poisson model to the bait interference method of possum *Trichosurus vulpecula* assessment. In: Bell BD ed. Proceedings of the First Symposium on Marsupials in New Zealand. Zoology Publications from Victoria University of Wellington 74. Pp. 185–195.

King CM, Murphy EC 2005. Stoat. In*:* King CM ed. The handbook of New Zealand mammals. 2nd edn. Melbourne, Oxford University Press. Pp. 261–287.

McKay J, Russell J 2005. Eradication of ship rats from Goat Island April–October 2005. University of Auckland contract report to the Department of Conservation. 13 p. (accessed at www.conservationevidence.com/Attachments/242_2.pdf on 19 April 2010).

Morgan D, Hickling G, 2000. Techniques used for poisoning possums. In: Montague TL ed. The brushtail possum: Biology, impact and management of an introduced marsupial. Lincoln, Manaaki Whenua Press. Pp. 143–153.

Morgan D, Nugent G, Warburton B 2006. Benefits and feasibility of local elimination of possum populations. Wildlife Research 33: 605–614.

Murphy EC, Robbins L, Young, JB, Dowding JE 1999. Secondary poisoning of stoats after an aerial 1080 poison operation in Pureora Forest, New Zealand. New Zealand Journal of Ecology 23: 175–182.

Nugent G, Morgan DR, Sweetapple P, Warburton B 2008. Developing strategy and tools for the local elimination of multiple pest species. In: Witmer GW, Pitt WC, Fagerstone KA eds Managing vertebrate invasive species. Proceedings of an international symposium, 2007. Fort Collins, CO, National Wildlife Research Center. Pp. 410–417.

Nugent G, Whitford J, Sweetapple P, Duncan R, Holland P 2010. Effect of one-hit control on the density of possums (*Trichosurus vulpecula*) and their impacts on native forest. Science for Conservation 304. 86 p.

NPCA 2008a. Protocol for possum population monitoring using the trap-catch method. Wellington, National Possums Control Agencies. 34 p.

NPCA 2008b. Possum population monitoring using the Waxtag® method. Wellington, National Possum Control Agencies. 21 p.

Ogilvie SC, Paterson AM, Ross JG, Thomas MD 2006. Improving techniques for the WaxTag® possum (*Trichosurus vulpecula*) monitoring index. New Zealand Plant Protection 59: 28–33.

Parker W 2009. Moving forward with the complex issues of 1080. Kararehe Kino Vertebrate Pest Research 14: 4–5.

Payton I 2000. Damage to native forests. In: Montague TL ed. The brushtail possum: Biology, impact and management of an introduced marsupial. Lincoln, Manaaki Whenua

Press. Pp. 111–125.
Ramsey D, Efford M, Ball S, Nugent G 2005. The evaluation of indices of animal abundance using spatial simulation of animal trapping. Wildlife Research 32: 229–237.
Ruscoe WA, Goldsmith R, Choquenot D 2001. A comparison of population estimates and abundance indices for house mice inhabiting beech forests in New Zealand. Wildlife Research 28: 173–178.
Sadleir R 2000. Evidence of possums as predators of native animals. In: Montague TL ed. The brushtail possum: Biology, impact and management of an introduced marsupial. Lincoln, Manaaki Whenua Press. Pp. 126–131.
Sweetapple P, Nugent G 2005. When the rats are away the mice do play! Kararehe Kino Vertebrate Pest Research 6: 9–10.

Editorial Board Member: John Parkes
Received 1 April 2010; accepted 15 September 2010

Sweetapple P, Nugent G 2006. Effect of reduced possum density on rodent and stoat abundance in podocarp–hardwood forests. DOC Research and Development Series 231. Wellington, Department of Conservation. 25 p.
Sweetapple PJ, Nugent G 2007. Ship rat demography and diet following possum control in a mixed podocarp–hardwood forest. New Zealand Journal of Ecology 31: 186–201.
Sweetapple P, Nugent G 2009. Replacing repeat aerial 1080 baiting for possums by ground-based detection and mop-up. Kararehe Kino Vertebrate Pest Research 14: 18–19.
Thomas MD, Brown JA, Maddigan FW, Sessions LA 2003. Comparison of trap-catch and bait interference methods for estimating possum densities. New Zealand Plant Protection 56: 81-85.
Warburton B, Barker R, Coleman M 2004. Evaluation of two relative-abundance indices to monitor brushtail possums in New Zealand. Wildlife Research 31: 397–401.