SHORT COMMUNICATION

Relative consumption of two commonly used rodenticides in New Zealand

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Abstract: Controlling rodents near municipal areas requires bait that must be housed in purpose-built bait stations to prevent interference from curious people, companion animals, and non-target species. Bait station design is important, but so are the baits themselves. To improve the efficacy of rodent control in municipal areas, we compared the consumption rates of two off-the-shelf rodenticides with the same active ingredients, but with different designs and cereal matrixes (Connovation D-Block® bait and Bell's DITRAC All-Weather BLOX®) in two similarly sized locations to determine whether consumption rates of baits differed. Forty tracking tunnels were deployed pre and post bait deployment to determine the presence of rodents. Rodents ate more of the fragile Connovation D-Block® bait than Bell's DITRAC All-Weather BLOX®. We hypothesise that using both baits in each bait station may deliver a higher kill rate than using a single bait type, thus saving time and money.

Keywords: bait; baiting efficiency; bait station; pest control; rats

Introduction

When laid to control rodents near human habitation, toxic baits cannot be openly broadcast. Rather, toxins must be enclosed in bait stations that are tamper-resistant, designed to prevent baits from being removed, weather-proof, and inaccessible to companion animals and non-target species (Quy 2011). They must also be designed so that the target species will enter and consume the baits (Inglis et al. 1996; Buckle & Prescott 2011). Further, the baits themselves must be manufactured to promote consumption, to minimise decay, reduce by-kill, and to prevent removal from the bait station (Murphy et al. 2014; Clapperton et al. 2015). However, if baits are unpalatable then no matter what bait stations are used or how they are deployed, a control operation will fail and this will result in wasted time, money and resources (Quy et al. 1992).

D-Block® by Connovation and DITRAC All-Weather BLOX® by Bell Laboratories are long-life rodenticides used regularly by central and local government agencies and urban pest controllers in New Zealand. Both rodenticides are cereal-based and include the active ingredient Diphacinone in the bait matrix. Diphacinone is a chronic anticoagulant, meaning the rodents must repeatedly consume bait over several days in order to receive a lethal dose (Gillies et al. 2006). Rodents are specialised gnawers (Cox et al. 2012), and as a result bait blocks are manufactured with multiple gnawing edges to encourage chewing. Each bait has a central hole for securing it to the bait station, thus preventing removal and caching.

We compared the consumption rates of both baits presented to rodents at the same time in a commonly used bait station (here-after called a rat café®). The aim of this study was to determine whether there were different consumption rates for either bait.

Methods

The study was conducted in spring (August to October) 2014 near Te Rotoruanui-a-Kahumatamomoe (Rotorua). Baits were presented at two sites, the Rotorua Lakes Council Landfill (8 km from downtown Rotorua; 38˚18′56″ S, 176˚ 23′07″ E; site area 14 ha), and Te Puia, an internationally significant geothermal tourist attraction at the city boundary (5 km from downtown Rotorua; 38˚16′41″ S, 176˚25′10″ E; site area 15 ha). The landfill is highly disturbed with little natural vegetation, and organic and inorganic waste arriving constantly throughout the day. Te Puia has a constant flow of tourists throughout the day, and has little to no organic waste because groundkeepers are present. Te Puia has dense, low-growing (2–3 m) native vegetation dominated by mānuka (*Leptospermum scoparium*), kānuka (*Kunzea robusta)*, prostrate kānuka (*Kunzea tenuicaulis*) (de Lange 2014) and mingimingi (*Leucopogon fasciculatus*), and is accessible via a network of walking tracks. The two sites are 5 km apart, and the same stream flows through both.

Prior to any toxic bait being distributed, 40 Gotcha® tracking tunnels (containing an ink pad) lured with peanut butter were placed beside buildings, walking tracks, rubbish bins, geothermal warm zones (at Te Puia), near the tip face (at the landfill), and along prominent animal runs. Although systematically placed in lines, a true grid was not used because of health and safety requirements, site features, and daily movements of people. The mean distance between each tunnel was 78 m (range 50–105 m; n = 40). Tunnels were checked for tracks on ten nights over three weeks. At each inspection, cards with animal tracks were recorded and replaced, undisturbed cards were left *in situ*, and peanut butter was replenished as needed. During the post-toxic baiting, the tracking tunnels were placed in the same locations with checks conducted on seven nights over two weeks.

One rat café® (an opaque plastic-moulded bait station designed by Connovation Ltd. to hold at least 4 bait blocks) was placed close to each of the 40 tracking tunnels at each site after the first week of tracking tunnel monitoring. To reduce any potential neophobic effects (Barnett 2009; Modlinska et al. 2015), baits were deployed in the cafés when the monitoring work ended two weeks later. Baits were checked daily and replaced as needed on three consecutive days for the following five weeks. Each bait was weighed before it was inserted into each café. All partially eaten baits were weighed and replaced immediately when found. Any baits remaining after three days were removed for the intervening four days of each week so only fresh bait was used. Partially consumed baits were discarded off-site.

The baits used were: DITRAC All-Weather BLOX® (Bell), manufactured by Bell Industries (USA), and D-Block® (Conn), manufactured by Connovation Ltd (New Zealand). Bell is a square bait with multiple gnawing edges, contains inert flavours and enhancers, and has a small amount of paraffin for waterproofing. Conn is triangular, contains food grade ingredients and is also coated with waterproof wax. Both baits are: dyed green to deter non-target species, use a concentration of 0.05 g kg^{-1} of diphacinone as the active anticoagulant ingredient, are mould and moisture resistant (designed as long-life), are of similar weight, are biodegradable with no persistent residues, and have a hole in the centre to prevent bait caching or transference of bait residue outside the cafés (Pitt et al. 2011).

Two baits of each type were placed into every café (four baits in total). Although similar, the weight of Bell baits was less variable than of Conn baits (combined weight for two baits: Bell, $\bar{x}$ = 57.5 g, range 56–58, n = 200; Conn, $\bar{x}$ = 60.3 g, range 55–67 g, n = 200). However, due to the overall similarity, we did not adjust the data for bait size and analysed raw consumption weights. The baits were not assayed as these are sold as commercial rodenticides. We refer to baits as being "eaten" whether or not they were fully consumed.

A single bait was placed on the 4 metal pins (115–125 g in total for the four baits) within each café for five (weeks) × 3 (days) = 15 times. The pins were numbered 1–4 and a random number generator was used to assign the position of each bait. Overall, there were 600 opportunities for rodents to eat either or both bait types at each study site. For analyses of the *number* of baits eaten, the 600 overnight exposures were used because baits were replaced every day (if eaten). These counts were analysed separately for site, using chi-square. For analyses of the *amount* of bait consumed and trends in consumption through time, the data were adjusted by: (1) summing the total amount of each bait type consumed during a week in a café; and (2) eliminating cafés that were never visited (12 and 7 stations respectively were rejected from the landfill and Te Puia sites).

The data were analysed using SPSS® Version 23. A multiple regression analysis was run using the enter method, with bait type and site as binary nominal predictor variables and week as a continuous predictor variable. The amount of bait consumed was the outcome variable. All assumptions of the model were met. The effect of bait type was of primary interest. We predicted decreasing bait consumption in later weeks due to die-off of rats (assuming baits were consumed). No predictions were made about site differences or the specific shapes of the consumption curves due to the different characteristics of the two sites.

A population-level bias is indicated if the proportion of each bait consumed is consistently higher for one bait over the other across cafés. Variation among individual rodents is implied if the proportion of each bait consumed varies across cafés. When the proportions are compared, a consistent bias will deliver a high correlation coefficient; variable consumption of bait types between cafés will deliver a low correlation.

Results

From the pre-baiting tracking cards, we counted 109 mouse (*Mus musculus*), 55 rat (*Rattus norvegicus* and *R. rattus*), and 46 cat (*Felis catus*) tracks at the landfill, and 152 rat, 96 mouse and 11 cat tracks at Te Puia. More *R. norvegicus* were detected, particularly at Te Puia, than *R. rattus.* Most cards had single tracking events, but 36% of the cards (from both sites) had multiple sets of tracks, possibly by the same animal, in which case we counted these footprints as one event. On three occasions at Te Puia and one occasion at the landfill we recorded rat and mice tracks on the same card. Cats could not enter the tunnels, but paw marks gave evidence of their presence. During the post-baiting, 11 rat, six mouse and no cat tracks were counted on the cards at the landfill; one rat, one mouse and no cats were recorded at Te Puia.

Measured as *number* of baits eaten, significantly more Conn baits than Bell baits were eaten in the cafés. *Landfill*: Conn, 218 of 600; Bell, 86 of 600 (χ^2 = 76.8, P < 0.001). *Te Puia*: Conn, 269 of 600; Bell, 63 of 600 (χ^2 = 176.7, P < 0.001). Measured as total amount of bait consumed during a week for any café × week combination in which at least some bait was eaten, more weight of Conn bait than Bell bait was consumed: *Landfill*: Conn, 78.1 g ± SD 50.55, n = 85; Bell, 43.4 g ± 36.37, n = 38. *Te Puia*: Conn, 69.9 g ± 37.45, n = 109; Bell, 31.1 g ± 26.67, n = 38. These summary values excluded any café × week combination in which no bait was consumed, so are a subset of the data used in the more detailed analysis presented below. There, the zero values were included for all cafés where there was consumption of a bait on at least one occasion in any of the five weeks of data capture, enabling analysis of the amount eaten through time. Baits were eaten at least once at 28 landfill and 33 Te Puia cafés respectively, determining the sample size for each site.

Consumption across the five weeks declined as expected, showing a similar pattern for both baits at both locations. At both sites, consumption of both baits initially increased in weeks 1–2, and then declined (Fig. 1).

The analysis of bait consumption through time produced a significant regression model, $F_{3,606}$ = 86.75, P < 0.001, adjusted R^2 = 0.30, suggesting that at least one of the variables is a significant predictor of consumption. Taken together, the three predictors accounted for 30% of the variance in consumption.

Bait type was the strongest predictor of consumption, B = −37.47, 95% CI [−43.22, −31.73], β = −0.44, P < 0.001, and week was also a significant predictor, B = −10.09, 95% CI [−12.12, −8.06], β = −0.33, p < .001. Site was not a significant predictor, *p* = 0.32 (Table 1).

The analysis indicates that the bait type Conn was consumed at significantly higher rates, *M* = 46.75, 95% CI [41.17, 51.55], than the bait type Bell, *M* = 9.28, 95% CI [6.66, 11.90], t = −12.81, P < 0.001. The analysis also indicates a decline of 10.1 g in the amount of bait consumed each week, t = −9.75, P < 0.001.

The generally higher consumption of Conn over Bell baits was not apparent in every analysis. We explored the bait type that was eaten more (= dominant) in individual cafés in which both types were eaten during one week. Conn and Bell were equally dominant at the landfill in week 1 (ratio Conn

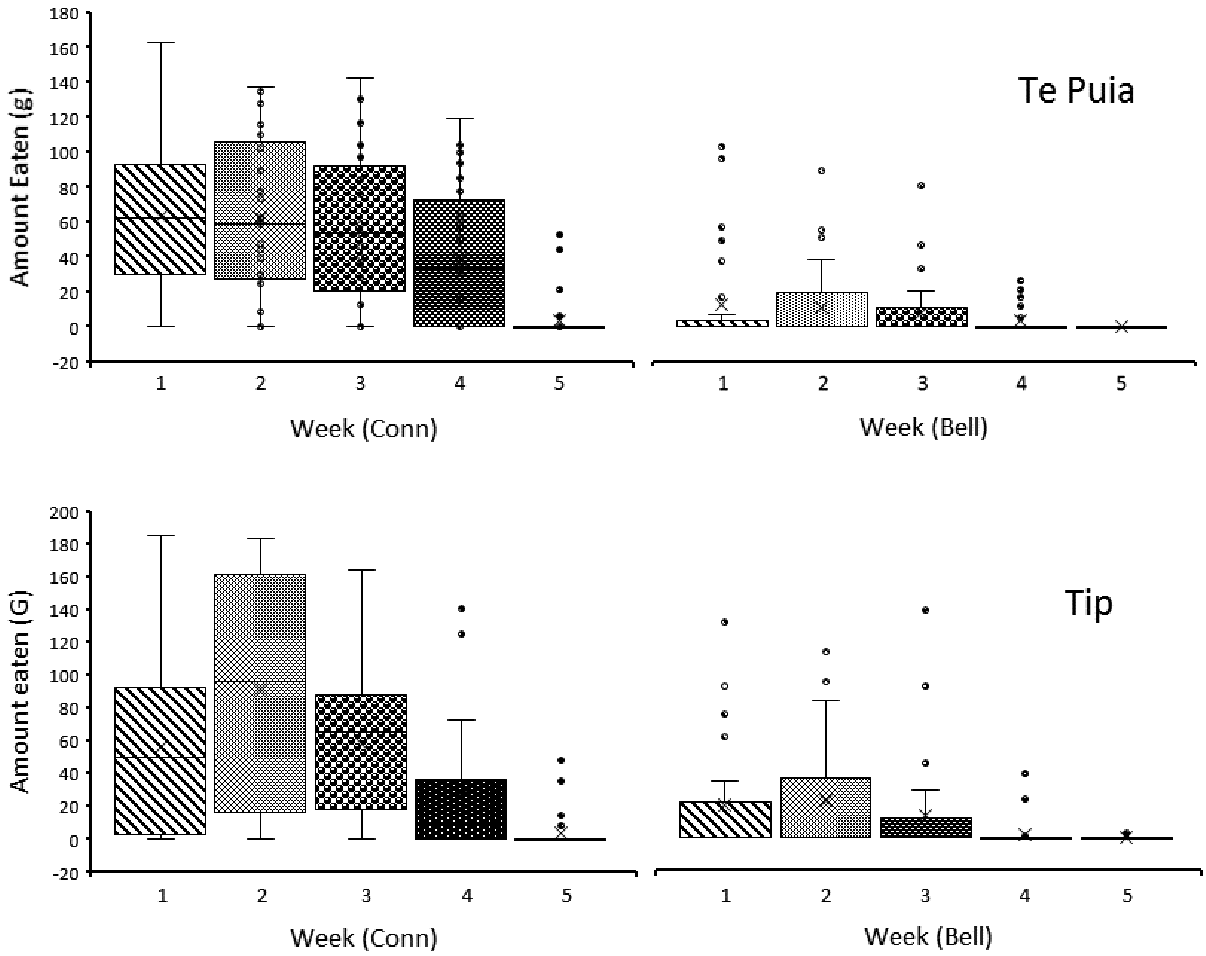

Figure 1. Box and whisker plots of amount of two types of bait taken at two sites in Rotorua: Te Puia and the landfill (Tip).

Table 1. Values of the coefficients produced by the multiple regression analysis.

	B	SE B	β	t	p
Constant	119.01	7.17		16.59	<0.001
Site	−2.94	2.94	−0.03	−1.00	0.32
Bait	−37.47	2.93	−0.44	−12.81	<0.001
Week	−10.09	1.03	−0.33	−9.75	<0.001

dominant: Bell dominant; 3:3), after which Conn became consistently dominant (ratios for weeks 2 to 5 respectively; 7:1, 9:1, 2:0, 1:0). The totals (22:5) indicate that Conn was eventually eaten more, but that bias took a week to appear. At Te Puia, for 38 cafés at which both baits were eaten during a week, Conn was consistently dominant (ratio 37:1).

For both sites combined, all of the Conn bait was consumed on 38 occasions, whereas all of the Bell bait was consumed on three occasions. At the landfill, consumption of the two baits across cafés within a week was not highly correlated, with no clear pattern. Pearson's correlation coefficients (r) were, respectively for weeks 1–4: 0.06, −0.07, 0.28, and 0.14 (too few data were available for week 5). None of these correlations are significant at $P = 0.05$. At Te Puia, for weeks 1–4, the coefficients were: 0.41, 0.62, 0.60, and 0.31. All were strongly positive and the first three are significant at $P < 0.05$. For the landfill site, these results indicate variability in proportion of each bait consumed at each café. At Te Puia, consumption was consistently of Conn over Bell baits.

Discussion

The baits and cafés in this trial were standard 'off-the-shelf' commercial rodenticides and equipment, used by many pest control agencies in New Zealand. The study clearly shows that rodents ate more Connovation bait than Bell bait. More Bell than Connovation bait was eaten in only a small proportion of cafés.

Connovation and Bell baits are made from similar materials. However, more Connovation bait may have been consumed because it was more fragile, making it easier to gnaw even though the Bell baits had more gnawing edges (Bell Laboratories 2017; Cox et al. 2012). We saw little or no bait residue in the rat cafés, indicating that the crumbs and fragments were eaten. If fragility aids rodents in consuming more bait, then this design feature might be key to encouraging increased bait uptake in future.

For both baits, the initial amount of bait consumed was high but began to decline after 6–9 days of exposure, perhaps because more dominant rodents take the toxins first and more submissive rodents enter the bait stations as the dominants succumb to the baits (Dubock 1982). In a study on the foraging behaviour of Norway rats towards new foods and bait stations, Inglis et al. (1996) found that although males and females ate the same amount of food, the females had many short foraging sessions while the males fed for longer but did not visit the bait stations as often. The design of the rat café with its internal baffles precludes more than one rat accessing the bait at a time, possibly preventing rodents from feeding for sustained periods of time (Pitt et al. 2011). This limitation could be overcome by using a two-way PVC pipe (or submarine-design) so two rats can access the bait concurrently, thus reducing any conflict (Kleman and Pelz 2006). Even so, this submarine-design still prevents group feeding behaviour (Quy 2011).

No bait loss was recorded at either site on the last few nights. The low occurrence of rodents in our post-baiting monitoring indicates that five weeks of baiting achieved high kill rates, even in the landfill that regularly received inputs of organic waste.

There were several key differences between the two study sites that could have influenced the patterns of bait uptake. At Te Puia, rodents experience less disturbance, lower resourcing, fewer cats and a more natural environment relative to the landfill. Quy et al. (1992) reported a failed control operation because large amounts of alternative food were available at the baiting site. However, the pattern of consumption of baits was similar at both sites despite the differences in resourcing, indicating that baiting as a control mechanism is robust even if resourcing is variable.

While cats were detected during the pre-baiting phase, no cats were recorded during the post bait phase. It is possible that cats were reduced at the landfill by secondary poisoning. Cats may also have restricted the ability of rodents to access cafés at the landfill. These issues acting together likely explain the higher residual density of rats post-baiting at the landfill relative to Te Puia.

In conclusion, if a minority of rodents take an alternative bait when one is available, then the use of two baits could deliver a higher kill rate than for control situations in which only one bait is used. In a future trial, one rat café could be loaded with only Conn bait and another could be loaded with only Bell bait to ascertain if the rodents prefer one bait type over another as inferred by this study. Alternatively, as we found by using both baits within one bait station, the use of two baits may actually hasten rodent control.

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References

Barnett SA 2009. The rat: A study in behaviour. Principles of ethology, and behavioural physiology, displayed mainly in the rat. Chicago, Aldine Publishing Company. 288 p.

Bell Laboratories Product Sheet for DITRAC All-Weather BLOX®. http://www.belllabs.com/bell-labs/product/ca/pest-control/ditrac-all-weather-blox (accessed 7 April 2017).

Buckle AP, Prescott CV 2011. Effects of tamper-resistant bait boxes on bait uptake by Norway rats (*Rattus norvegicus* Berk.). International Journal of Pest Management 57: 77–83.

Clapperton B K, Day TD, Morgan DKJ, Huddart F, Cox N, Matthews LR 2015. Palatability and efficacy to possums and rats of pest control baits containing bird repellents. New Zealand Journal of Zoology 42: 1–15.

Connovation product sheet for D-Blocks®. http://www.connovation.co.nz/vdb/document/91 (accessed on 7 April 2017).

Cox PG, Rayfield EJ, Fagan MJ, Herrel A, Pataky TC, Jeffery N 2012. Functional Evolution of the feeding system in rodents. PLoS ONE 7: e36299.de Lange PJ 2014: A revision of the New Zealand *Kunzea ericoides* (Myrtaceae) complex. Phytokeys 40: 1–185.

Dubock AC 1982. Pulsed baiting – a new technique for high potency, slow-acting rodenticides. In: Marsh, R.E. ed. Proceedings of the 10th Vertebrate Pest Conference, University of California, Davis. Pp 123–136.

Gillies C, Styche A, Bradfield P, Chalmers K, Leach M, Murphy E, Ward-Smith T, Warne R 2006. Diphacinone bait for ground control of rats on mainland conservation land. Science for Conservation 270. Wellington, Department of Conservation.

Inglis IR, Shepherd DS, Smith P, Haynes PJ, Bull DS, Cowan DP, Whitehead D 1996. Foraging behaviour of wild rats (*Rattus norvegicus*) towards new foods and bait containers. Applied Animal Behaviour Science 47: 175–190.

Kleman N, Pelz HJ 2006. The feeding pattern of the Norway rat (*Rattus norvegicus*) in two differently structured habitats on a farm. Applied Animal Behaviour Science, 97: 293–302.

Modlinska K, Stryjek R, Pisula W 2015. Food neophobia in wild and laboratory rats (multi-strain comparison). Behavioural Processes 113: 41–50.

Murphy G, Baker,R, Felix-Thomas A, Fowler M 2014. The influence of bait presentation on bait uptake by mice (*Mus domesticus*) in infested urban domestic dwellings. International Journal of Pest Management 60: 22–32.

Pitt WC, Sugihara RT, Driscoll LC, Vice DS 2011. Physical and behavioural abilities of commensal rodents related to the design of selective rodenticide cafés. International Journal of Pest Management 57: 189–193.

Quy R, Shepherd D, Inglis I 1992. Bait avoidance and effectiveness of anticoagulant rodenticides against warfarin- and difenacoum-resistant populations of Norway rats (*Rattus norvegicus*). Crop Protection 11: 14–20.

Quy R 2011. Review of the use of bait boxes during operations to control Norway rats, *Rattus norvegicus.* London, The Chartered Institute for Environmental Health. 12 p.

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