Bait station preferences of ship rats

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DOC RESEARCH & DEVELOPMENT SERIES 271

Published by
Science & Technical Publishing
Department of Conservation
PO Box 10-420
Wellington, New Zealand

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.
Individual contributions to the series are first released on the departmental website in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are also listed in our catalogue on the website, refer www.doc.govt.nz under Publications, then Science and Research.

ISSN 1176-8886
ISBN 978-0-478-14205-1 (hardcopy)
ISBN 978-0-478-14206-8 (web PDF)

This is a client report commissioned by Research, Development & Improvement Division and funded from the Science Advice Fund. It was prepared for publication by Science & Technical Publishing; editing and layout by Geoff Gregory. Publication was approved by the Chief Scientist (Research, Development & Improvement Division), Department of Conservation, Wellington, New Zealand.

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Landcare Research, PO Box 40, Lincoln 7640, New Zealand

Email: spurre@landcareresearch.co.nz

ABSTRACT

Department of Conservation (DOC) surveillance programmes to detect rodent invasions on rodent-free islands currently involve observation of rodent interference with toxic baits in bait stations. Different DOC Conservancies use different types of bait station. We monitored the behavioural responses of 24 wild-caught captive ship rats (*Rattus rattus*) to four currently used bait station types; yellow plastic pipe, wooden box ('rat motel'), wooden tunnel, and white plastic Philproof bait stations. The bait stations contained non-toxic bait similar to the toxic bait used in surveillance programmes. More than 75% of the rats entered the yellow plastic pipe, wooden box, and wooden tunnel bait stations, but fewer than 10% entered the Philproof bait stations. Rats ate bait from the first three bait station types but not from the latter. The average amount of bait eaten per night by the rats that ate bait (0.8 g) was not enough for a lethal dose for 50% of the population if the baits had contained 20 ppm, or even 50 ppm, brodifacoum. On the basis of these results, DOC should use yellow plastic pipe, wooden box, or wooden tunnel bait stations rather than Philproof bait stations for surveillance for ship rats. However, other bait station types and the responses of kiore (*R. exulans*) and house mouse (*Mus musculus*) to different bait stations should be tested before any final decision is made on the best type to use in multi-species rodent surveillance programmes.

Keywords: bait stations, ship rats, *Rattus rattus*, reinvasion, rodents, preferences, surveillance

Spurr, E.B.; Morriss, G.A.; Turner, J.; O'Connor, C.E.; Fisher, P. 2007: Bait station preferences of ship rats. *DOC Research & Development Series 271*. Department of Conservation, Wellington. 21 p.

1. Introduction

Introduced rodents have been eradicated from more than 90 of New Zealand's offshore islands (Towns & Broome 2003). The Department of Conservation (DOC) has a mandate to protect many of these islands from rodent reinvasion. To do this it needs to be able both to detect an invasion and undertake effective control once an invasion is detected or suspected. Bait stations containing toxic bait, periodically checked for bait interference, are used for the detection and control of rodents on large islands, where it is not easy to cover the island with a grid of detection devices, and also on remote islands, where early detection of an invasion is not easy and toxic baits might kill invading rodents before they become established (DOC island biosecurity best practice manual, version 2.0, September 2006). The type of bait station used in any individual surveillance programme has mostly been based on personal human preference rather than on a rigorous assessment of rodent preference. A workshop in 2001 recommended that bait station design be tested for acceptability to all rodent species (Dilks & Towns 2002). In a recent study, we measured the behavioural responses of Norway rats (*Rattus norvegicus*) to four currently used bait station types, and recommended the two most suitable for this species (Spurr et al. 2006). However, the responses of other introduced rodents, viz. ship rat (*R. rattus*), kiore (*R. exulans*), and house mouse (*Mus musculus*), to different bait station types need to be tested before any final recommendation can be made on the 'best' bait station type for use in multi-species rodent surveillance programmes. This investigation assessed the behavioural responses of ship rats to four different bait station types, using experimental protocols similar to those used for Norway rats.

2. Objective

To identify the most suitable of the available bait stations to use for ship rat surveillance for island protection, by determining the initial behavioural responses of wild-caught ship rats to four bait station types currently used by DOC.

3. Methods

Twenty-four ship rats (6 males, 18 females) were caught near human habitation or in forests in Canterbury and the West Coast, and brought into an indoor temperature-controlled room at the Landcare Research animal facility. The rats were housed individually in solid metal cages with slats in the top, and a nest box attached to one side (as described in the Landcare Research Animal Facility Quality Manual SOP 3.2). The rats were acclimatised for at least 30 days prior to testing, until their body weights stabilised or at least did not decrease (as required by SOP 1.3). During acclimatisation, they had free access to rat and mouse pellets (Weston Animal Nutrition, Rangiora), and water was available at all times. Supplementary food (e.g. a piece of fruit or cat biscuits) was provided occasionally. The rats were weighed when first brought into captivity, then approximately weekly, and also immediately before testing. The average weight of rats when first tested was 138 g (range 100–223 g).

We tested the responses of rats to four different bait station types currently used by DOC (see Fig. 1):

- Yellow plastic Novacoil drainpipe, 1 m long × 100 mm internal diameter, open at each end, similar to that used on various offshore islands and on the mainland (Thomas & Taylor 1988, 2002; Taylor & Thomas 1989, 1993; Moors et al. 1992; Innes et al. 1995; Lovegrove et al. 2002). In our previous trial, this bait station type was readily used by Norway rats (Spurr et al. 2006). It has been considered the 'gold' standard among bait stations but is now little used.

Figure 1. Bait station types as set up for testing ship rat preference (left to right, top then bottom): yellow plastic pipe, wooden box (or 'motel'), wooden tunnel, and white plastic Philproof bait station.

- Wooden box, commonly known as the 'rat hotel' or 'rat motel' (Dilks & Towns 2002), 530 mm square × 140 mm high internally, with four 55-mm-diameter entrances, one on each side, currently used by Nelson and Southland Conservancies. It was readily used by Norway rats in our previous trial (Spurr et al. 2006).
- Wooden tunnel, 600 mm long × 140 mm wide × 140 mm high internally, with an approximately 40 × 60 mm opening in the wire mesh at both ends, currently used by most Conservancies as a cover for predator traps (see http://www.predatortraps.com/downloads/doc%20200%20setting%20instructions.pdf). It was not tested in our previous trial with Norway rats (Spurr et al. 2006).
- White plastic Philproof mini bait station (Philproof Pest Control Products, Hamilton, http://www.philproof.co.nz), approximately 300 mm long × 140 mm wide × 80 mm high internally, with a single 30 × 130 mm entrance, originally designed for brushtail possum (*Trichosurus vulpecula*) control but currently used for both possum and rodent control by several Conservancies (e.g. Gillies 2002). This bait station type was located 200 mm above ground, as is standard DOC practice and recommended by the manufacturer. It was not tested in our previous trial with Norway rats (Spurr et al. 2006).

Three bait stations of each type were supplied by DOC. All had been used in the field previously, so were 'weathered', but had not been used recently, so were not highly scented. The three bait stations were used in rotation so at least 4 days (and up to 10 days) elapsed before the same bait station was used again. Each bait station type was tested separately, at approximately the same location (against a wall) in an outdoor observation pen (10 × 5 × 2 m). The bait stations were baited with fresh, non-toxic, Pestoff® Rodent Bait Block (which would normally contain 20 ppm brodifacoum) similar to the type of toxic bait used in island rodent surveillance programmes. At the request of DOC, the bait was unsecured (i.e. not tied) inside the bait stations.

To mimic the situation of an invading rat exploring a new area—rather than a new bait station being placed within a rat's existing territory—test rats were transferred individually from the indoor temperature-controlled room to a randomly selected outdoor observation pen (i.e. they had no acclimatisation to the new pen). Overnight exposure to bait stations was repeated four times for each rat, at about 2-weekly intervals from mid-April to early June 2006. Each time, the rats were presented with a different bait station type, in random order, in a crossover design (exactly the same as in Spurr et al. 2006). That is, each of the 24 rats was allocated randomly to one of the 24 possible permutations of the sequence of presentation of the four bait station types over the four nights. In total, there were 96 rat test-nights. Three outdoor observation pens were available, and three of each rat's four test-nights were in different outdoor pens (i.e. new environments), but the fourth test-night was in the same pen as the first test-night. The interval between the first and fourth test-nights was about 6 weeks, which we deemed sufficient for the fourth test to be considered as being done in a new environment. It was certainly a new environment compared with the indoor temperature-controlled room where the rats were housed between tests. The possible effect of rat scent in the pens from rats tested the previous night is acknowledged, but unknown, and would have been similar for each bait station type.

The rats were transferred to the outdoor observation pens in their individual metal nest boxes at approximately 1600 hours, and the entrance was then opened and left open overnight. Two additional nest boxes were placed in each pen, one on the ground and one about 1.5 m above ground. Normal laboratory rat food (rat and mouse pellets) was scattered around the pens. Thus, the rats were free to explore the unfamiliar outdoor observation pen containing familiar food and an unfamiliar bait station housing unfamiliar non-toxic bait, similar to the situation they would encounter during an island invasion. Furthermore, they were not stressed from being forcibly removed from their 'home'. However, unlike an island invasion situation, they had familiar cover (their individual nest boxes). After the rats left their nest box, they spent time exploring the pen, especially the periphery. Unlike Norway rats in our previous study (Spurr et al. 2006), they did not dig underground burrows. Instead, most were found in the above-ground nest boxes next morning. They were recaptured and returned to the indoor temperature-controlled room at approximately 0900 hours.

The observation pens had overhead 300 W halogen bulbs (low white light) for night-time observation, an observation hut with a one-way window, and a video camera and time-lapse video recorder. The activity and behaviour of each rat in response to the presentation of each bait station was recorded on a long-play videotape. Each videotape was replayed and reviewed on a large-screen TV. For each rat, we recorded behavioural responses to the bait station, including time to first approach (since first leaving the nest box), time to first entry, duration of first entry, and frequency and duration of subsequent entries. We also calculated the amount of bait eaten overnight (from the weight of bait put out minus that of bait remaining, corrected for change in weight of baits not eaten by rats).

'Time to first approach' and 'time to first entry' data were analysed using 'survival' analysis (i.e. survival of the behaviour, not the animal) and the generalised linear models (GLM) procedures in the statistical package 'R' (version 2.1.1, 2005, http://www.R-project.org). On 30 of the 96 rat test-nights, rats had not entered the bait station by the end of the experiment (i.e. within about 17 hours), so time to first entry was 'censored', and a censoring indicator vector was created to signify whether the value was the actual time to first entry or the minimum time to first entry (Crawley 2002). The minimum time to first entry was given as 18 hours; i.e. observations were censored at 18 hours. The censoring indicator is a binary variable where 0 = censored (the behaviour was not observed) and 1 = uncensored (the behaviour was observed). The censoring variable was the dependent variable in a GLM with Poisson errors and the log of elapsed time was an offset. The analysis calculated the mean time to first entry from the survival rate of the observed and censored times to first entry. When a large proportion of observations are censored, as in our measurements of time to first entry, the mean is beyond the maximum value measured. Thus, without censoring, the mean time to first entry would have been greatly underestimated. Even with censoring, it was probably still underestimated because ship rats are nocturnal and most likely would not have attempted to enter bait stations for the next 9–12 hours after the end of our experiment.

Other data were analysed using the GLM procedure in 'R', with the appropriate error structure. Models were fitted to investigate differences between the bait station types, using the rat behaviours described above as the response variables and individual rats as a block variable. We also checked for residual effects of previous bait station type (or no previous station) on the behavioural responses of rats to the bait stations.

4. Results

All rats left their nest boxes in the observation pens and explored their surroundings increasingly over time.

4.1 TIME TO FIRST APPROACH A BAIT STATION

The time taken by rats to first approach a bait station after leaving the nest box was not affected by bait station type ($F_{3, 65} = 1.364$, $P = 0.252$) (Fig. 2). However, it was affected by previous exposure to bait stations ($F_{4, 61} = 4.889$, $P < 0.001$) (Fig. 3). Rats took significantly longer to approach a bait station on first exposure (i.e. with no previous exposure to any type of bait station).

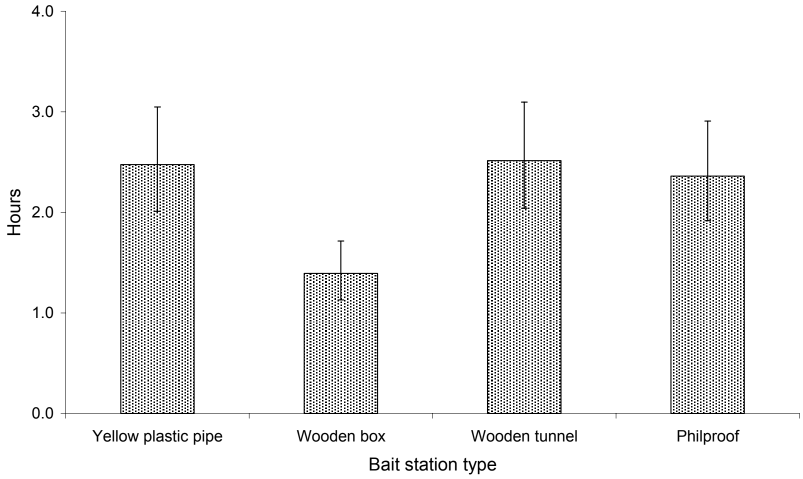


Figure 2.
Time to first approach a bait station (mean ± SE).

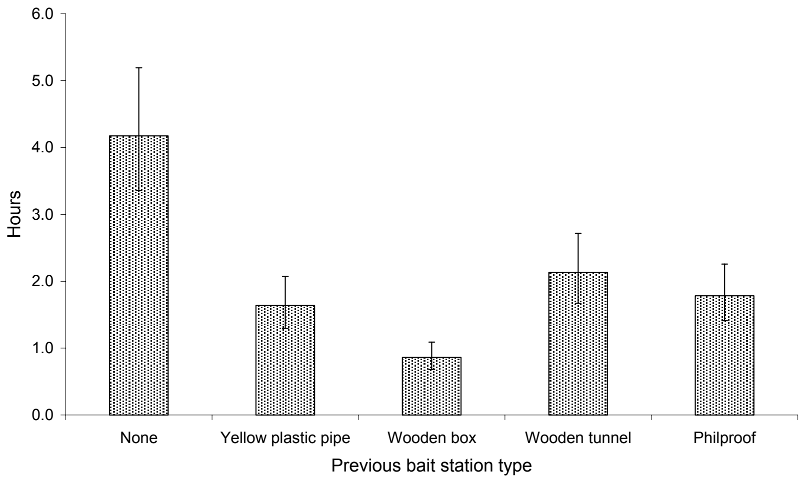


Figure 3.
Time to first approach a bait station (average of all types) in relation to bait station type exposed to in previous trials (mean ± SE).

4.2 TIME TO FIRST ENTER A BAIT STATION

The time taken by rats to enter a bait station after leaving the nest box (or the estimated time to first entry for the 30 occasions that rats had not entered before recording stopped) was significantly affected by bait station type ($F_{3, 63} = 32.176$, $P < 0.001$). Rats took longer to enter Philproof bait stations than the other bait station types tested (Fig. 4). They also took longer to enter bait stations (average of all types) on first exposure than after previous exposure to bait stations (of any type) ($F_{4, 59} = 4.491$, $P = 0.001$) (Fig. 5).

Figure 4.
Time to first enter a bait station (mean ± SE).

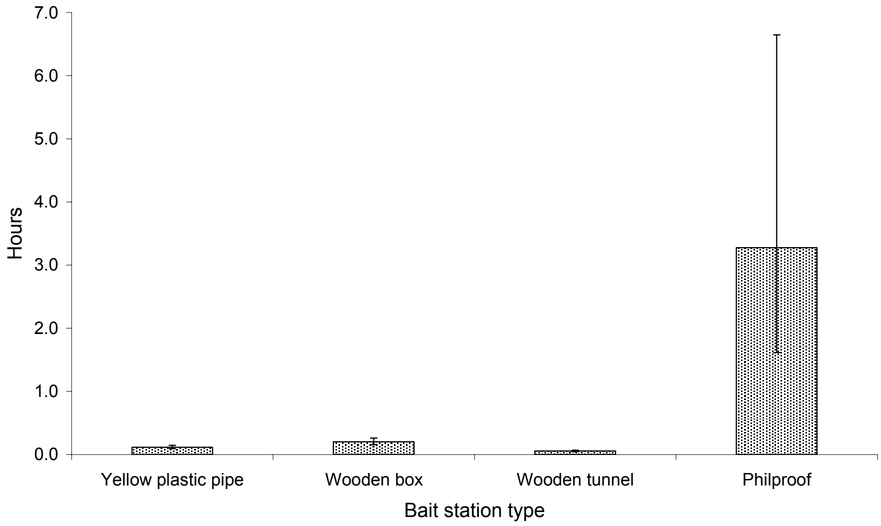
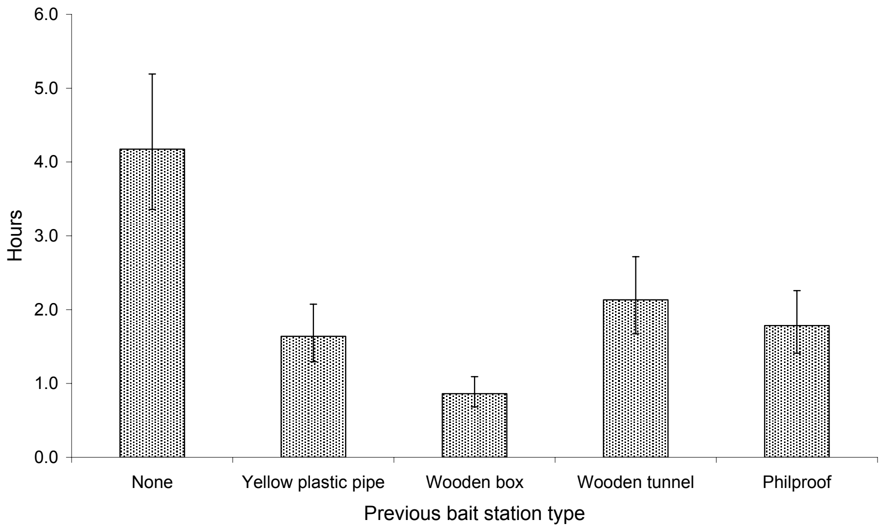


Figure 5.
Time to first enter a bait station (average of all types) in relation to bait station type exposed to in previous trials (mean ± SE)



4.3 PROPORTION OF RATS ENTERING BAIT STATIONS

The proportion of rats that entered a bait station was significantly affected by bait station type ($\chi^2_3 = 84.119$, $P < 0.001$) and by previous exposure to other bait stations ($\chi^2_4 = 15.277$, $P = 0.004$). Proportionately fewer rats entered Philproof bait stations (Fig. 6), and fewer entered bait stations (average of all types) on first exposure than after previous exposure to bait stations (Fig. 7). Only about 50% of the rats entered a bait station on the first night of testing (all bait station types combined).

Figure 6.
Proportion of rats entering a bait station (mean ± SE).

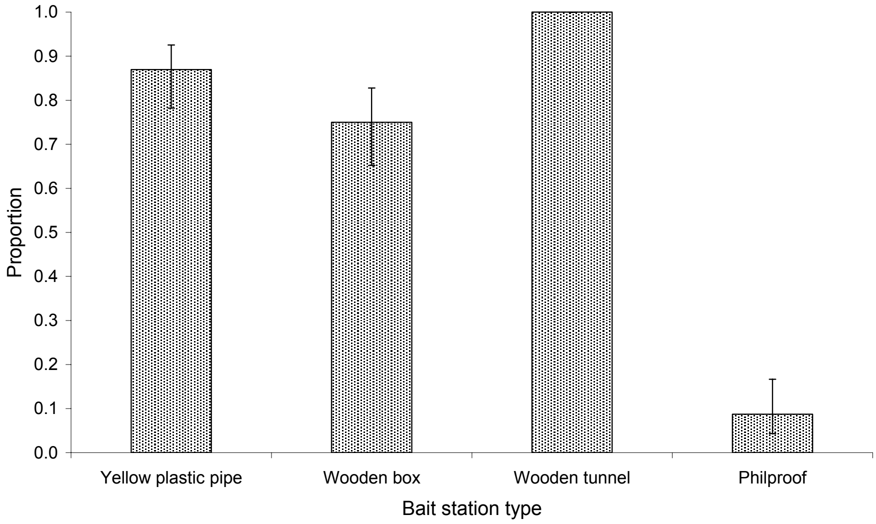
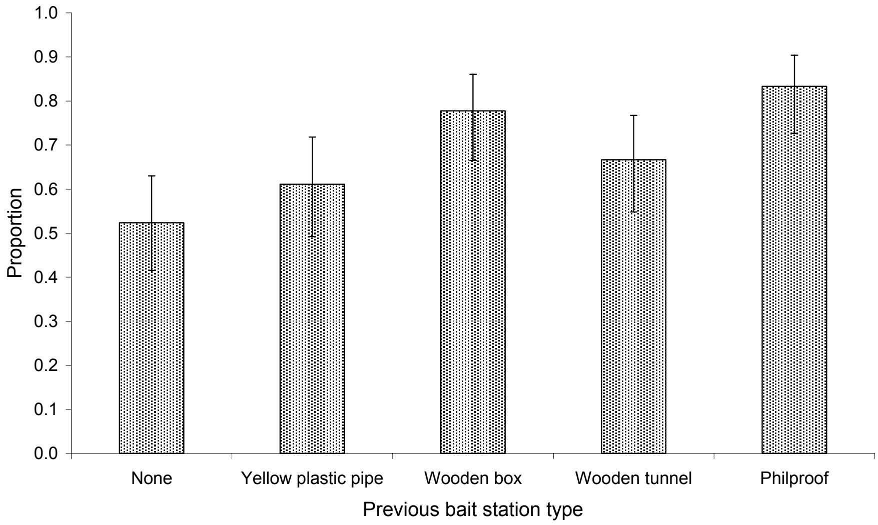


Figure 7.
Proportion of rats entering a bait station (average of all types) in relation to bait station type exposed to in previous trials (mean ± SE).



4.4 DURATION OF FIRST ENTRY

The length of time that rats remained in a bait station after first entry was significantly affected by bait station type ($F_{3, 33}$ = 17.343, P < 0.001) (Fig. 8) but not by previous exposure to other bait stations ($F_{4, 29}$ = 0.459, P = 0.765) (Fig. 9). Rats stayed significantly longer in the wooden box bait stations than in any of the other bait station types tested.

4.5 NUMBER OF ENTRIES

The number of times that rats entered a bait station ranged from 0 to 108 per night, or 0 to 23 excluding entries of less than one second, such as when rats simply 'ran through' bait stations. The number of entries of more than 1 s duration was significantly affected by bait station type ($F_{3, 60}$ = 41.643, P < 0.001) and previous exposure to bait stations ($F_{4, 58}$ = 3.691, P = 0.009). Rats entered wooden tunnel bait stations significantly more often and Philproof bait stations significantly less often than the other bait station types tested (Fig. 10). They also entered bait stations (average of all types) significantly less often on first exposure than after previous exposure to bait stations (Fig. 11).

Figure 8.
Duration of first entry into a bait station (mean ± SE).

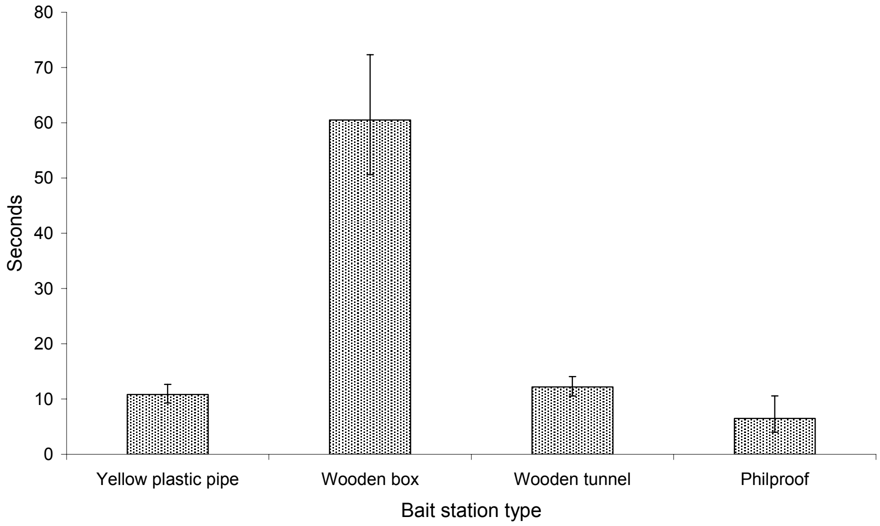


Figure 9.
Duration of first entry into a bait station (average of all types) in relation to bait station type exposed to in previous trials (mean ± SE).

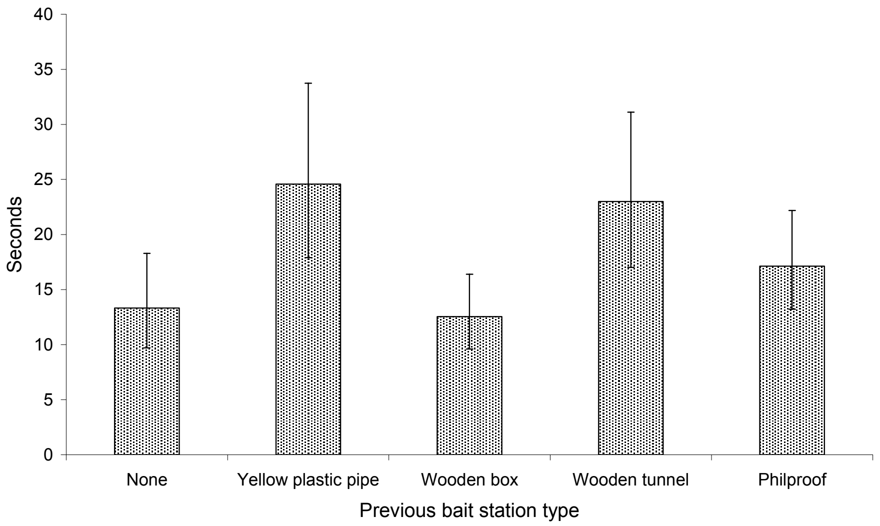


Figure 10. Number of entries into a bait station (mean ± SE).

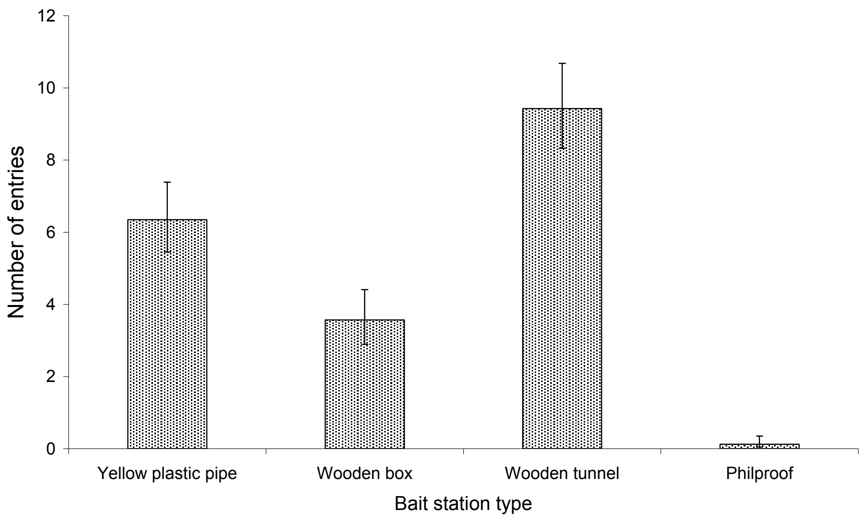
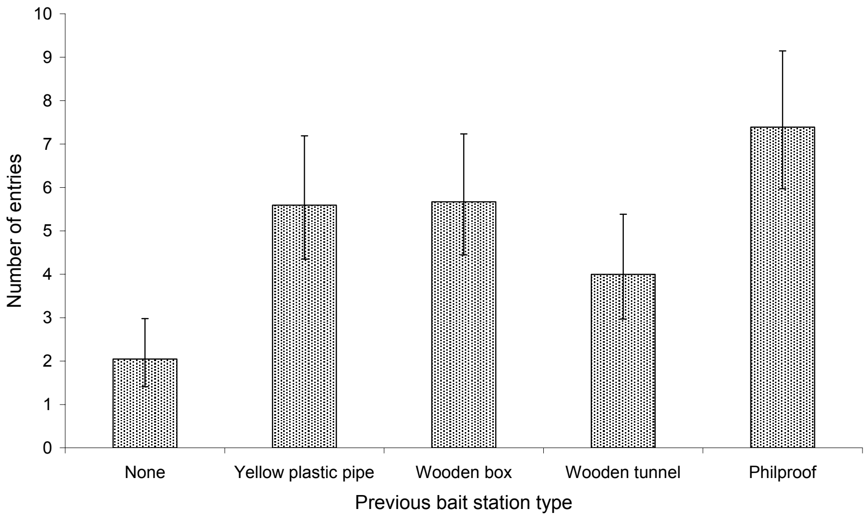


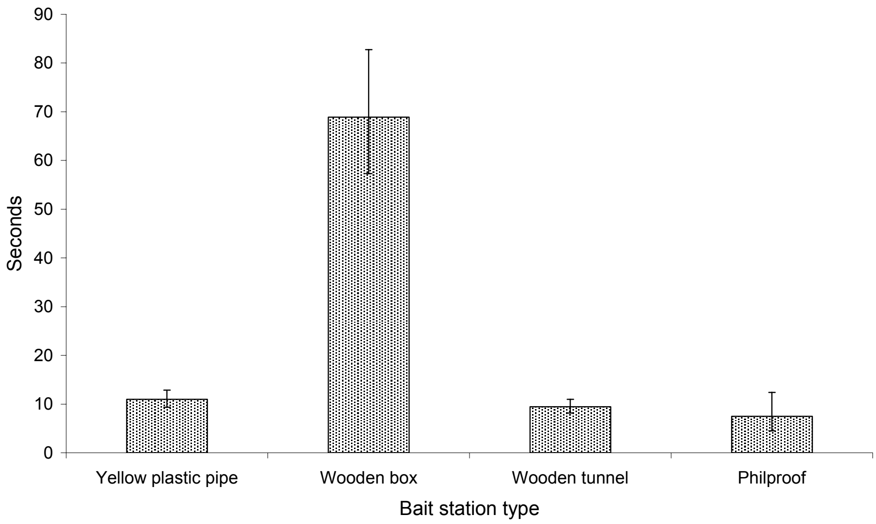
Figure 11. Number of entries into a bait station (average of all types) in relation to bait station type exposed to in previous trials (mean ± SE).



4.6 DURATION OF ALL ENTRIES

The average duration of all entries into a bait station (excluding those less than one second) was significantly affected by bait station type ($F_{3, 33}$ = 26.742, P < 0.001) and by previous exposure to other bait stations ($F_{4, 29}$ = 3.043, P = 0.033). Rats remained in wooden box bait stations significantly longer than in the other bait station types tested (Fig. 12). They also remained in bait stations (average of all types) longer after previous exposure to yellow plastic pipe than after previous exposure to other bait station types (Fig. 13).

Figure 12. Average duration of all entries into a bait station (mean ± SE).



4.7 PROPORTION EATING BAIT

The proportion of those rats entering bait stations that ate bait was significantly affected by bait station type (χ^2_3 = 11.494, P = 0.009). No rats ate bait from Philproof bait stations (Fig. 14). The proportion of rats entering bait stations that ate bait was also affected by previous exposure to bait stations (χ^2_4 = 34.648, P < 0.001). Fewer rats ate bait when they had no previous exposure to bait stations (Fig. 15). Seven rats (one male, six females) did not eat bait from any of the bait stations over the four nights of testing.

Figure 13.
Average duration of all entries into a bait station in relation to bait station type exposed to in previous trials (mean ± SE).

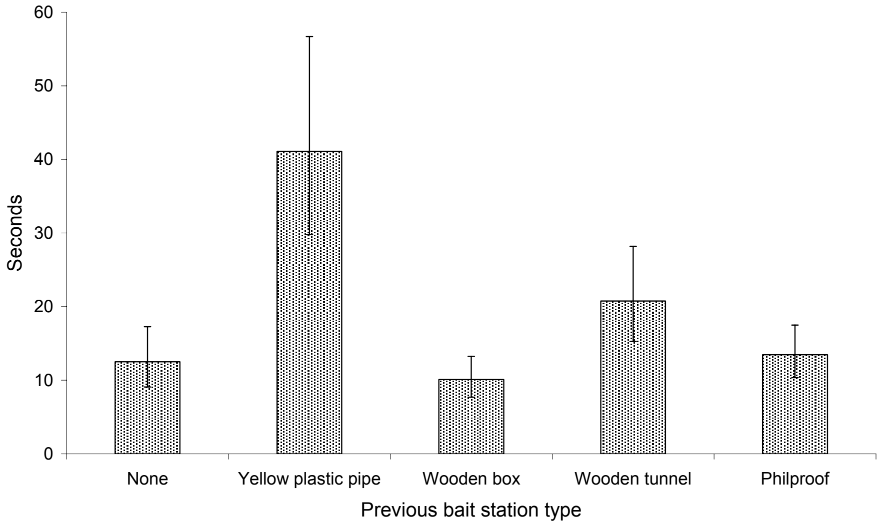


Figure 14.
Proportion of rats entering a bait station that ate bait (mean ± SE).

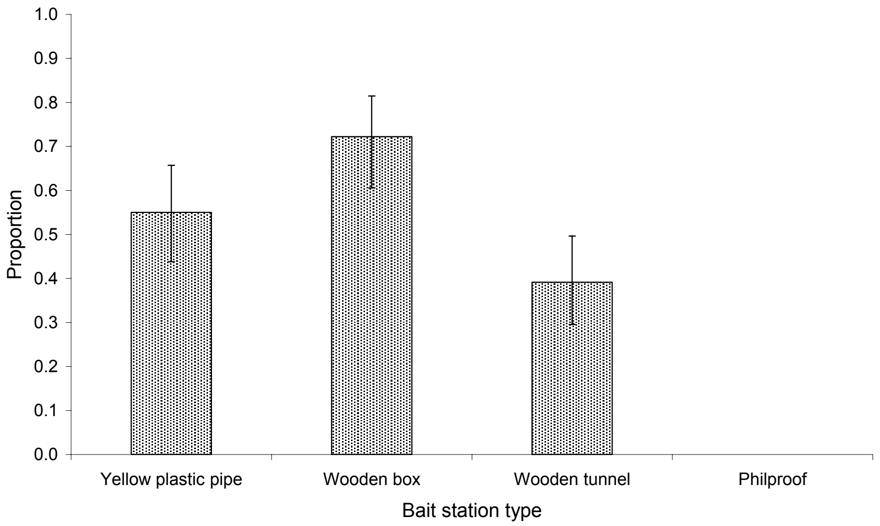
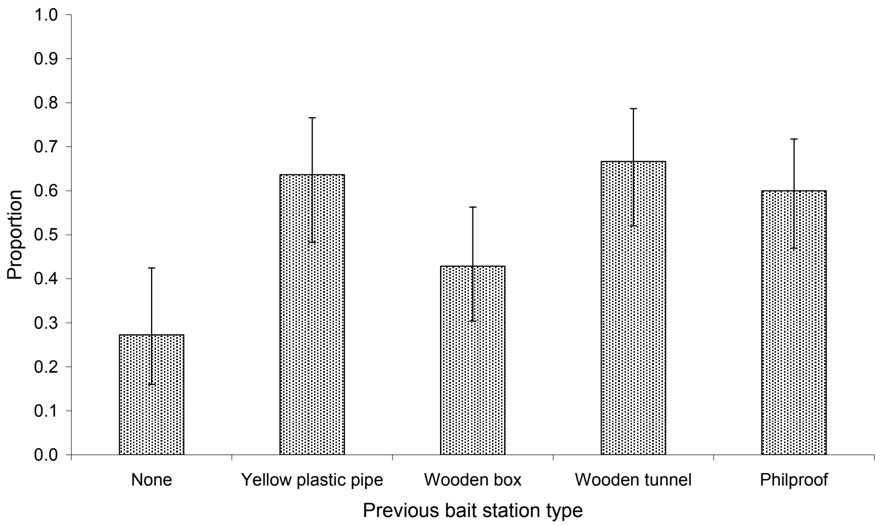


Figure 15.
Proportion of rats entering a bait station that ate bait in relation to bait station type exposed to in previous trials (mean ± SE).



4.8 AMOUNT OF BAIT EATEN

The amount of bait eaten by rats was affected by bait station type ($F_{3, 69} = 4.270$, $P = 0.008$) but not by previous exposure to bait stations ($F_{4, 65} = 2.433$, $P = 0.056$). No bait was eaten from Philproof bait stations (Fig. 16). The amount of bait eaten by rats that ate bait was not significantly affected by bait station type ($F_{2, 10} = 1.623$, $P = 0.273$). On average, rats that ate bait ate 0.8 g per night (range < 0.1–5.4 g, $n = 33$). More than 5 g of bait was eaten on only one occasion. Despite not being secured, bait was removed by only one rat and taken to its next box.

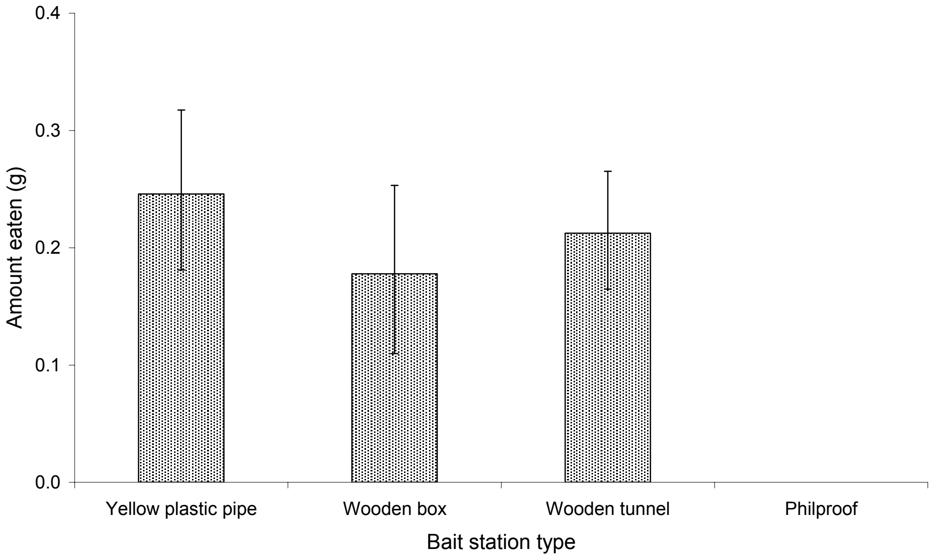


Figure 16. Amount of bait eaten by rats that entered a bait station and ate bait (mean ± SE).

5. Discussion

Yellow plastic pipe bait stations had (with wooden box and wooden tunnel bait stations) the equal highest proportion of rats eating bait, and equal highest amount of bait eaten. They are known to be readily entered by both ship rats (Taylor 1984) and Norway rats (Thomas & Taylor 1988, 2002; Taylor & Thomas 1989, 1993; Innes et al. 1995; Lovegrove et al. 2002; Spurr et al. 2006).

Wooden box ('rat motel') bait stations had the longest duration of entry by rats, equal highest proportion of rats eating bait, and equal highest amount of bait eaten. Although rats spent longer in wooden box bait stations they did not enter them any sooner than the other bait station types (except Philproof) and did not eat any more bait. The wooden box bait stations were also readily entered by Norway rats (Spurr et al. 2006).

Wooden tunnel bait stations had the highest number of entries by rats, but most of these were of short duration (i.e. rats simply running through them). Along with wooden box and yellow plastic pipe bait stations, they had the equal highest proportion of rats eating bait and equal highest amount of bait eaten.

Philproof bait stations had the longest time to entry by rats, lowest proportion of rats entering, lowest number of repeat entries, equal lowest duration of entry, lowest proportion of rats eating bait, and lowest amount of bait eaten. This bait station type was the only one of the four tested that was raised above ground and also had only one entrance. Philproof Pest Control Products also manufactures a specific rodent bait station, which can be pinned to the ground instead of attached above ground (see http://get.to/philproof), but we did not test this. Nevertheless, raised Philproof bait stations have been used successfully to reduce established, high-density, ship rat populations (e.g. Bennett et al. 2002; Gillies 2002; Lovegrove et al. 2002). Thus, our result is perhaps surprising. However, if the rats in our trial had been exposed to Philproof bait stations for more than one night they may have eventually entered them. Howard (1987) noted that it may take several weeks for ship rats to enter a bait station (of any type) for the first time. If our trials had run for more than one night, the proportion of rats entering bait stations, the number of repeat entries, and the total amount of bait eaten may have increased for other bait station types too.

The critical parameters for rat surveillance and control are the proportion of rats entering bait stations and eating bait, the number of repeat entries resulting in eating bait, and the total amount of bait eaten. As noted above, no rats ate bait from the Philproof bait stations. However, there was no significant difference in the proportion of rats that ate bait from the yellow plastic pipe, wooden box, and wooden tunnel bait stations. Rats entered wooden tunnel bait stations significantly more often than the other bait station types, but did not eat significantly more bait. Mostly, the rats simply ran right through the wooden tunnel bait stations. The average amount of bait eaten per rat in one night by those rats that ate bait (0.8 g) was not enough for a lethal dose, whether the bait had contained the 20 ppm brodifacoum it normally would, or 50 ppm brodifacoum as some bait types do. Based on an acute LD_{50} (lethal dose to 50% of the population) of 0.46 mg brodifacoum per kg body weight for ship rats (O'Connor & Booth 2001), a large (200 g) ship rat would need to eat 4.6 g of bait containing 20 ppm brodifacoum, or 1.8 g of bait containing 50 ppm brodifacoum, on average, for a lethal dose. On the basis of the present results, this could be achieved after about 6 nights' feeding on 20 ppm bait or 3 nights' feeding on 50 ppm bait. Smaller rats would need to eat less bait, larger rats more. However, based on the published acute LD_{50}, half the rats would survive eating these amounts. Unfortunately, the acute LD_{99} (lethal dose to 99% of the population) is not known. Because some invading rats may enter a bait station and eat bait only once, it would be ideal if they could obtain a lethal dose of toxicant in a single feeding of bait. This would be more likely if the bait contained 50 ppm than 20 ppm brodifacoum.

Previous exposure to another bait station, of any type, significantly reduced the time taken by rats to enter bait stations and increased the proportion of rats entering. This is similar to neophobia (avoidance of a strange object in a familiar environment) except that the pens were not a familiar environment. Neophobia to bait stations has been found in other studies (e.g. Kaukeinen 1987; Moors et al. 1992; Inglis et al. 1996). As a consequence of neophobia, some rats may not enter bait stations on first encounter (Howard 1987), and some may never enter bait stations. Moors et al. (1992) noted that ship rats are less wary than Norway rats toward strange objects such as bait stations. In our trials, however, ship rats appeared to be more wary than Norway rats (e.g. they took longer to approach bait stations and longer to enter them, and ate less bait). However, our Norway rats came from pigsties and poultry pens on local farms and may have been more accustomed to a changing environment (see also Inglis et al. 1996). Previous exposure to bait stations increased the proportion of rats eating bait once they entered a bait station, but not the amount of bait eaten.

Bait station design has been considered to affect both whether rodents enter bait stations and their consumption of bait, but has seldom been investigated (Inglis et al. 1996; Corrigan & Collins 2004a, b; Clapperton 2006). For example, Kaukeinen (1987) evaluated eight bait station designs for Norway rats and found they showed the greatest delays in utilising stations that had more complex, internal baffles. Howard (1987) noted that bait stations should be large enough for rats to be comfortable in while eating the bait. Monro & Dennis (1988) tested 10 different bait station designs for Norway rats and suggested that the ideal bait station should be large in size, made of plastic rather than metal, and have a straight see-through entrance tunnel from which the bait is directly accessible. Volfová & Stejskal (2003a, b) tested six different bait station designs for house mice and found the mice preferred the largest bait station tested. These researchers suggested that, when introduced into a new environment, mice probably search not only for food but also for a safe shelter in proximity to the food (i.e. 'bed and breakfast'). Corrigan & Collins (2004a, b) compared two bait station designs for house mice, and considered various aspects of bait station design such as size (height and volume), shape, internal structure, construction material, colour, and number, size, and position of openings all potentially important.

A lot of previous research on bait station design overseas has been to meet US Environmental Protection Agency standards (e.g. to be tamper-proof). However, a number of researchers and commercial bait station manufacturers overseas are currently investigating aspects of design of bait station to make them more effective for rodent control (or at least for Norway rat and house mouse control), and DOC should at least keep a watching brief on the outcomes of these investigations. DOC may also consider funding a systematic investigation of bait station design of its own, relevant to New Zealand conditions, at least for ship rats and kiore.

Thomas & Taylor (2002) noted that there is a need to improve bait station design to exclude non-target species and limit the entry of toxicants into the environment. Non-target species reported to have consumed baits from rodent bait stations and spread toxicants into the environment include invertebrates (Craddock 2003) and lizards (Hoare & Hare 2006). This is potentially a problem where bait stations are left baited for considerable lengths of time, as in offshore island surveillance programmes. To reduce invertebrate consumption of bait, some bait station manufacturers have incorporated the capacity to use insecticides in their bait stations (Corrigan & Collins 2004b; see also http://get.to/philproof). The removal of bait by rodents could be prevented by securing baits inside bait stations, for example by using bait securing rods as in Philproof bait stations (http://get.to/philproof), and also in Pestoff® tunnel bait stations (http://www.pestoff.co.nz/) (not assessed in our trial). Only a simple modification would be required to secure bait inside the wooden box or wooden tunnel bait stations. It could be argued that it is more important to secure bait in stations used for reduction or eradication of high-density rodent populations than for detection of rodent reinvasion on offshore islands, because in the latter situation there are (generally) no rodents around to remove unsecured baits. In fact, DOC had not been in favour of securing bait inside bait stations used in offshore island surveillance programmes because of concern that rodent consumption of bait might be reduced; however, this concern arose from a ship rat control project using Philproof bait stations, so the lack of bait take might have been erroneously attributed to bait fixing when it was in fact due to bait station design (K. Broome, DOC, Hamilton, pers. comm.). This needs investigating. Fixing of baits is desirable, because if unfixed bait disappears, it may not be certain what took it.

A proportion of the rats entering bait stations, both in this study and in our Norway rat study (Spurr et al. 2006), did not eat bait and thus left no sign that they had entered the stations. If these stations had been on an offshore island, an invading rat might not have been detected. This indicates the need for more attractive bait and/or incorporating other methods of detecting rats, such as footprint tracking pads, lured wax-tags, electronic detectors, or hair-collecting devices into bait station design (Dilks & Towns 2002; Hoare & Hare 2006), or using traps.

The results of our study on ship rats are similar to those for Norway rats (Spurr et al. 2006). Both species avoided bait stations on first exposure, preferred to enter 'tunnel'-type bait stations (plastic pipe or wooden tunnel) or wooden-box-type bait stations ('rat motel') with at least two openings rather than a single opening, and both species spent most time in the wooden-box-type bait station. Both species also ate insufficient bait in one night for a lethal dose had the bait been toxic.

On the basis of our results, yellow plastic pipe, wooden box ('rat motel'), and wooden tunnel bait stations are all suitable for surveillance of ship rats and the first two at least for Norway rats (all were readily entered and had a similar amount of bait eaten from them). However, other bait station types, such as Philproof rodent bait stations and Pestoff® tunnel bait stations, and the responses of kiore and house mice to different bait stations should be tested before any final decision is made on the optimum type to use in multi-species rodent surveillance programmes. Furthermore, DOC should consider funding trials comparing the preferences of the various rodent species for above-ground, on-ground, and below-ground bait stations. This is supported by our observation that most ship rats were recaptured in nest boxes elevated above ground (see methods), and the observation in our previous study that most Norway rats were recaptured underground (Spurr et al. 2006). Research in Hawai'i found more ship rats took bait placed up in trees than placed on the ground (Tobin et al. 1997), although bait stations secured up power poles in Arizona to target ship rats proved unsuccessful (Dave Bergman, US National Wildlife Research Center, Phoenix, Arizona, pers. comm.).

6. Acknowledgements

This investigation was funded by the Department of Conservation (Science Investigation No. 3872) and undertaken with the approval of the Landcare Research Animal Ethics Committee (approval 06/03/01). We thank R. Moffat and K. Washbourne for maintaining rats in captivity and assistance with the pen trials; G. Forrester for statistical analyses; B. Hopkins and J. Russell for comments on the draft manuscript; and C. Bezar for editorial input.

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