Bait station preferences of Norway rats

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ABSTRACT

Department of Conservation (DOC) surveillance programmes to detect rodent invasion 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 Norway rats (*Rattus norvegicus*) to four currently used bait station types: yellow plastic pipe, black plastic box, white plastic bottle, and wooden motel. The bait stations contained non-toxic bait similar to the toxic bait used in surveillance programmes. More than 80% of the rats entered the wooden motel, yellow plastic pipe, and black plastic box bait stations, but fewer than 50% entered the white plastic bottle bait stations. Significantly more rats ate bait from the wooden motel and yellow plastic pipe bait stations than from the other two types tested. The average amount of bait eaten by the rats that ate bait 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 the wooden motel or yellow plastic pipe bait stations rather than the black plastic box or white plastic bottle bait stations for surveillance for Norway rats. However, the responses of ship rats (*R. rattus*) and kiore (*R. exulans*) to these same four bait station types should be tested before any final decision is made on the best bait station type to use in multi-species rodent surveillance programmes. Furthermore, the responses of the various rodent species to other bait station types, and the responses of Norway rats to under-ground versus above-ground bait stations, should also be investigated. A systematic study of bait station design would be useful.

Keywords: bait stations, Norway rats, *Rattus norvegicus*, rodents, preferences, surveillance.

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1. Introduction

Offshore islands that are pest-free are regarded as sanctuaries for New Zealand's vulnerable native animal species. To use these sanctuaries effectively, the Department of Conservation (DOC) must provide effective protection from pest reinvasion. There is also a need for available and effective pest management tools in the event that an invasion is detected or suspected.

The protection of offshore island ecosystems is one of the priorities in the DOC Statement of Intent 2003–2006, and protection from rodent reinvasion is the top priority for these islands. The main method for detecting rodent reinvasion is the use of bait stations, checked periodically for bait interference. A research project is currently underway to improve the effectiveness of such surveillance programmes. Part one (DOC Science Investigation No. 3738) is investigating which bait is best to put in the bait stations. Part two (this project) investigates the bait station itself—what designs have the highest probability of use?

At present, the type of bait station used in any individual surveillance programme is based on personal human choice rather than on rigorous assessment of rodent preference. In this investigation we compare four types of bait stations currently used by DOC. We tested Norway rat (*Rattus norvegicus*) preferences for these bait stations first because this species is most likely to be the invading species, may be neophobic to bait stations (e.g. Moors et al. 1992; Inglis et al. 1996), and may respond differently to different bait station designs (Moors 1985; Kaukeinen 1987).

2. Objective

To identify the best of the available bait stations to use for Norway rat surveillance in an island protection situation, by determining the initial behavioural responses of wild-caught Norway rats to four bait station types currently used by DOC.

3. Methods

Twenty-four Norway rats (9 males, 15 females) were caught on Canterbury pig and poultry farms 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 (DOC Animal Facility Quality Manual SOP 3.2). The rats were acclimatised for a minimum of 18 days prior to testing, until their body weights stabilised or at

least did not decrease. Most rats were acclimatised for 30 days (as in SOP 1.3). During acclimatisation, they had free access to rat and mouse pellets (Weston Animal Nutrition, Rangiora) scattered around the pen 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, and then weekly. The average weight of rats when first tested was 169 g.

Rat preferences were tested for four different bait station types currently used by DOC (see Fig. 1):

- Yellow plastic Novacoil drain pipe (1 m long × 100 mm internal diameter), similar to that used on Hawea and Breaksea islands (Thomas & Taylor 1988; Taylor & Thomas 1989, 1993), regarded as the 'gold' standard but currently not used much by any DOC conservancy. Bait was placed in the centre of the pipe, through a lid in the top, but was not secured in place because there was no securing device.
- Black plastic box-shaped rodent bait station (Protecta®, Bell Laboratories, Madison, WI, USA), a commercially available bait station (320 mm long × 230 mm wide × 80 mm high, with two 57-mm-diameter entrances, one at each end), currently used by Southland and Bay of Plenty conservancies. This bait station normally has bait-securing rods for baits with hollow centres, to prevent rats removing the bait, but the rods were missing from

Figure 1. Bait station types as set up for testing Norway rat preference (left to right, top then bottom): yellow plastic pipe, black plastic box, white plastic bottle, and wooden motel.

two of the three bait stations supplied to us. Consequently, bait could be secured in only one bait station.

- White plastic bottle (300 mm long × 150 mm wide × 150 mm high, laid on its side, with a 43-mm-square entrance in the lid), similar to that used on the Noises Islands (Moors 1985), and currently used by Northland Conservancy. Bait was secured inside the bait station on a piece of wire.
- Wooden rat motel (570 mm square × 180 mm high, with four 55-mm diameter entrances, one on each side), currently used by Nelson and Southland conservancies. Bait was placed in the centre of the bait station but not secured in place because there was no securing device.

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 3 days elapsed before the same bait station was used again. Each bait station type was tested separately, at approximately the same location in an outdoor observation pen (10 × 5 × 2 m), and set up as they would be on an offshore island. The bait stations were baited with fresh non-toxic Pestoff® Rodent Bait Block (normally containing 20 ppm brodifacoum) similar to the type of toxic bait used in island rodent surveillance programmes. The bait had a hole through the middle for securing it inside bait stations equipped with a securing device.

To mimic the situation of an invading rat exploring a new area—rather than a new bait station 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 early May to early July 2005. Each time, the rats were presented with a different bait station type, in random order, in a crossover design. 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, so 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. 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. 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).

The rats all dug underground burrows in the observation pens overnight, so to facilitate recapture we placed artificial nest boxes in these burows. The rats were recaptured next morning at approximately 0900 hours, often in the underground artificial nest boxes, and returned to the indoor temperature-controlled room.

The observation pens had overhead 300-watt 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 (survival being survival of the behaviour, not the animal) and the generalised linear models (GLM) procedure in the statistical package 'R' (version 2.1.1, 2005, http://www.R-project.org). On 24 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 indicate 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 (i.e. the behaviour was not observed) and 1 = uncensored (i.e. 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 will be beyond the maximum value measured. Without censoring, the mean time to first entry was greatly underestimated. Even with censoring, it will still be underestimated because Norway rats are nocturnal and most likely wouldn't 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 box within minutes of being placed in the observation pens, and explored their surroundings increasingly over time. All dug burrows in the ground overnight. Some returned to their original nest box the next morning but most remained in their underground burrow or underground nest box (see Methods), and were dug up for recapture.

4.1 TIME TO FIRST APPROACH A BAIT STATION

The time taken by rats to first approach a bait station, since first leaving the nest box, was significantly affected by bait station type ($F_{3, 69} = 5.508$, $P < 0.001$) (Fig. 2). Rats took significantly longer to approach the white plastic bottle and yellow plastic pipe bait stations than the Protecta® black plastic box and wooden motel bait stations. Previous exposure to a bait station did not significantly affect the time taken to first approach other bait station types ($F_{4, 65} = 1.454$, $P = 0.213$).

4.2 TIME TO FIRST ENTER A BAIT STATION

The time taken by rats to first enter a bait station since first leaving the nest box (or the estimated time to first entry for the 24 occasions that rats had not entered before recording stopped) was significantly affected by bait station type ($F_{3, 66} = 10.784$, $P < 0.001$). Rats took longer to enter the white plastic bottle bait stations than the other bait station types tested (Fig. 3). They also took longer to enter bait stations (average of all types) on first exposure (i.e. with no previous exposure) than after previous exposure to bait stations of any type ($F_{4, 62} = 6.630$, $P < 0.001$) (Fig. 4).

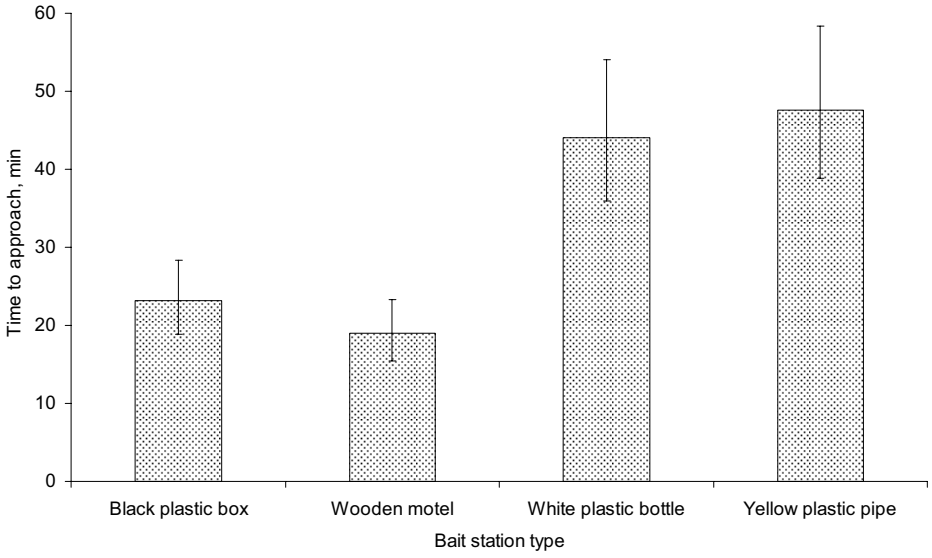


Figure 2. Time to first approach a bait station (mean ± SE).

Figure 3. Time to first enter a bait station (mean ± SE).

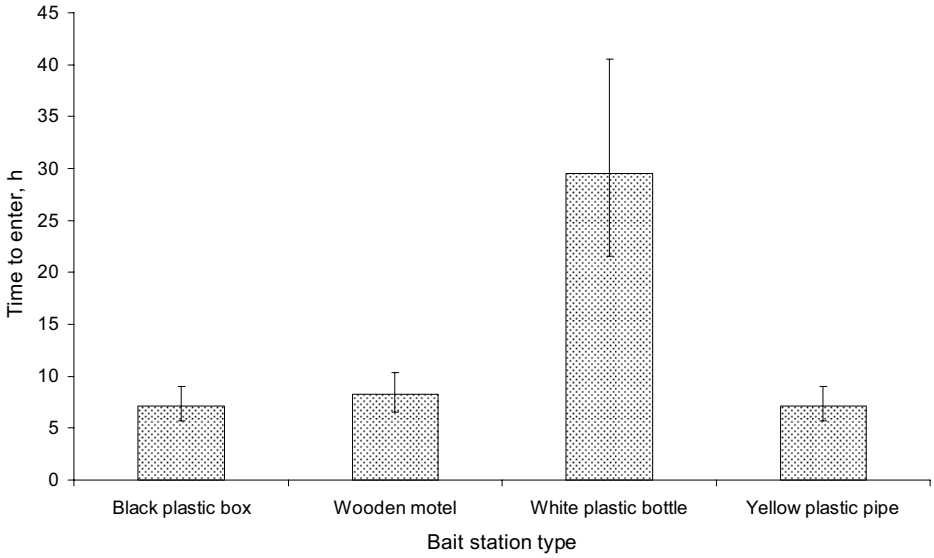
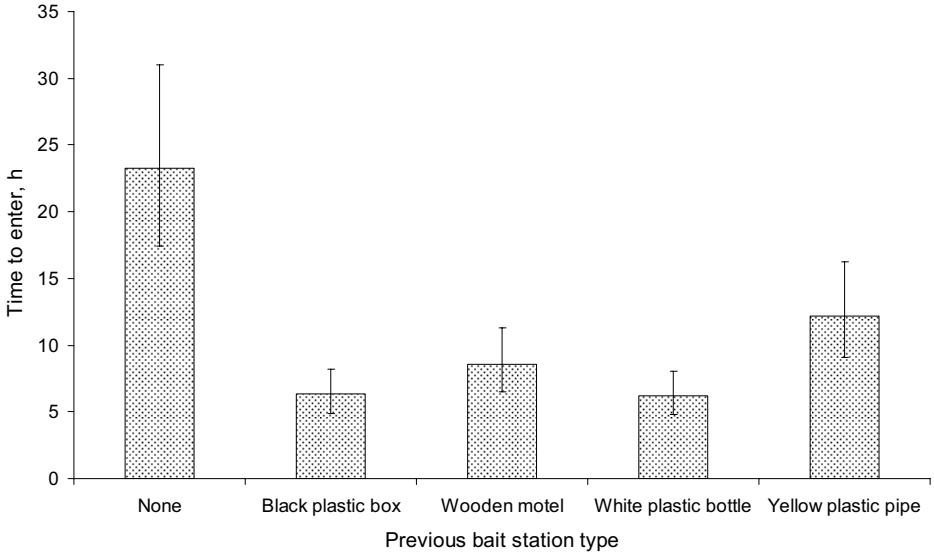


Figure 4. Time to first enter a bait station (average of all types) in relation to bait station type exposed to in previous trials (mean ± SE).



4.3 PROPORTION OF RATS ENTERING BAIT STATIONS

The proportion of rats that entered a bait station was significantly affected by bait station type ($\chi^2_3 = 19.852$, $P < 0.001$) and by previous exposure to other bait stations ($\chi^2_4 = 17.802$, $P < 0.001$). Proportionately fewer rats entered the white plastic bottle bait stations (Fig. 5), and fewer entered bait stations (average of all types) on first exposure than after previous exposure to bait stations (Fig. 6). One rat did not enter any of the bait stations over the four nights of testing.

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 ($F_{3, 41} = 13.844$, $P < 0.001$) but not by previous exposure to other bait stations ($F_{4, 37} = 1.580$, $P = 0.200$). Rats stayed

Figure 5. Proportion of rats entering a bait station (mean ± SE).

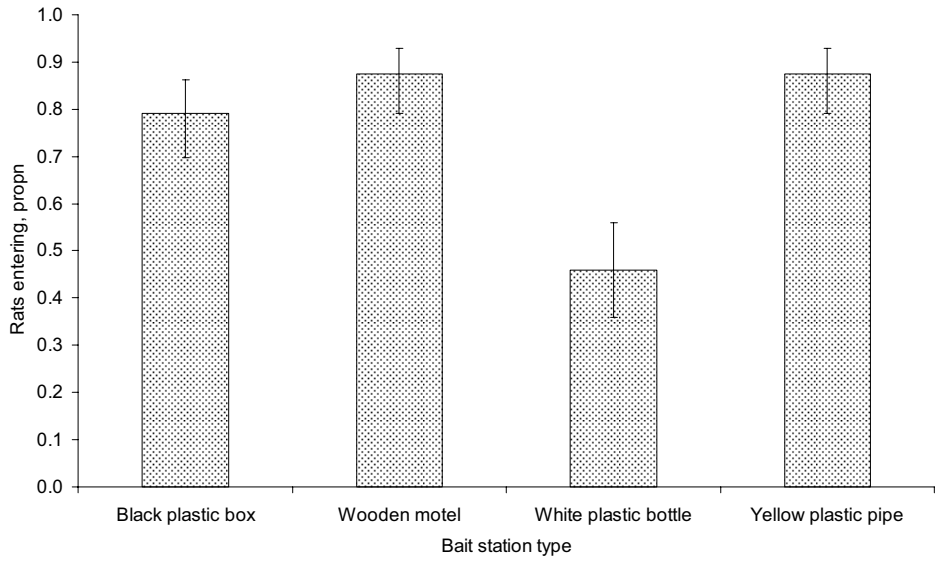
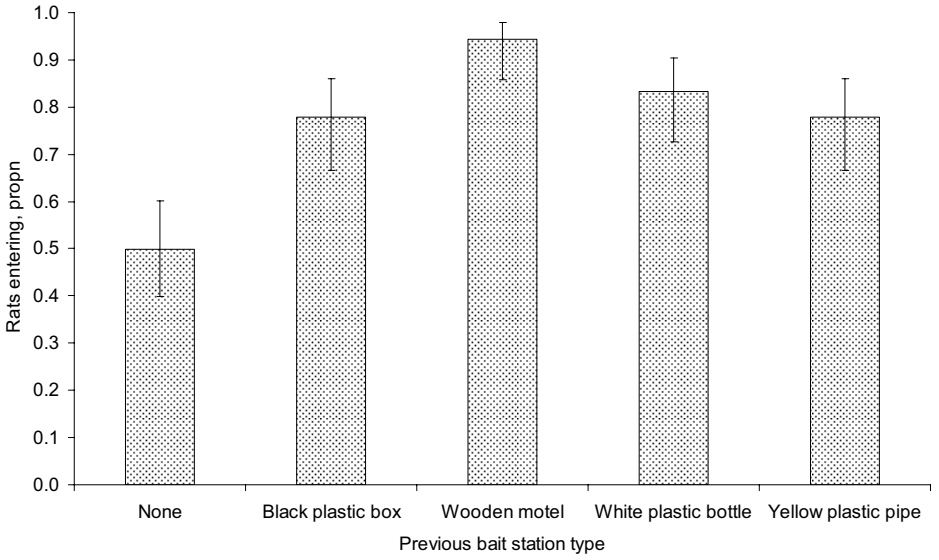


Figure 6. Proportion of rats entering a bait station (average of all types) in relation to bait station type exposed to in previous trials (mean ± SE).



significantly longer in the wooden motel bait stations than in any of the other bait station types tested (Fig. 7).

4.5 NUMBER OF ENTRIES

The number of times that rats entered a bait station ranged from 0 to 26 per night, and was significantly affected by bait station type ($F_{3, 62}$ = 57.759, P < 0.001) and previous exposure to bait stations ($F_{4, 58}$ = 16.415, P < 0.001). Rats entered white plastic bottle bait stations significantly fewer times than the other bait station types tested (Fig. 8). They also entered bait stations (average of all types) significantly less often on first exposure than after previous exposure to bait stations of any type (Fig. 9).

Figure 7. Duration of first entry into a bait station (mean ± SE).

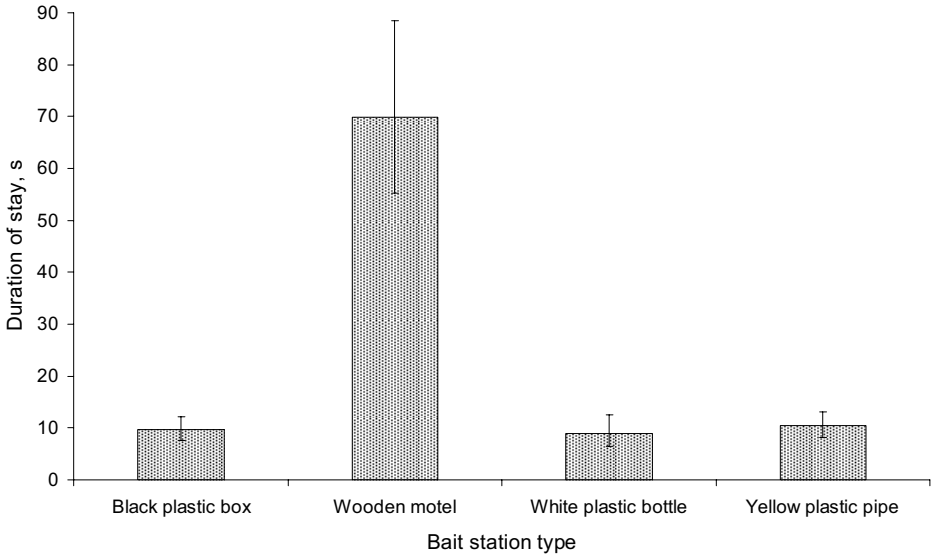


Figure 8. Number of entries into a bait station (mean ± SE).

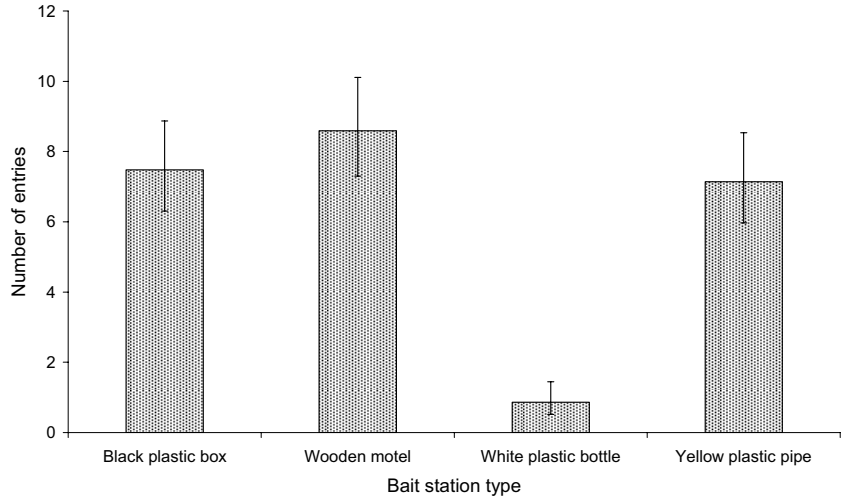
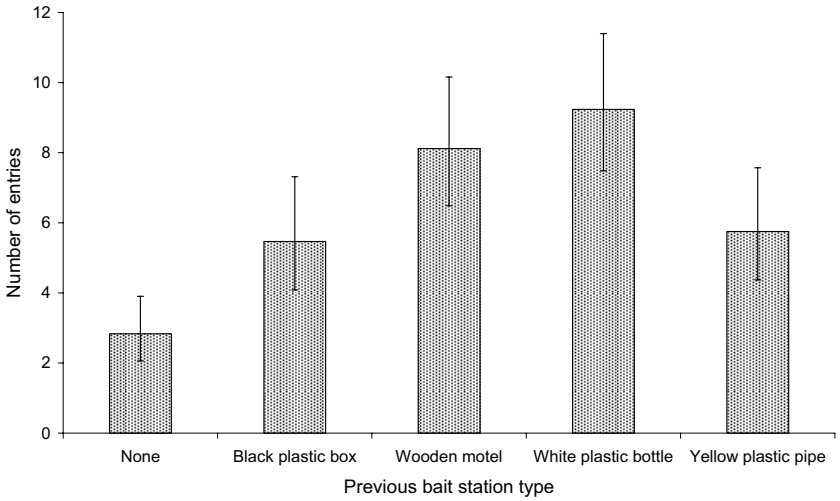


Figure 9. Number of entries into a bait station (average of all types) in relation to bait station type exposed to in previous trials (mean ± SE).



4.6 DURATION OF ALL ENTRIES

The average duration of all entries into a bait station was significantly affected by bait station type ($F_{3, 39} = 24.948$, $P < 0.001$) but not by previous exposure to other bait stations ($F_{4, 35} = 1.870$, $P = 0.138$). Rats remained in the wooden motel bait stations significantly longer than in the other bait station types tested (Fig. 10).

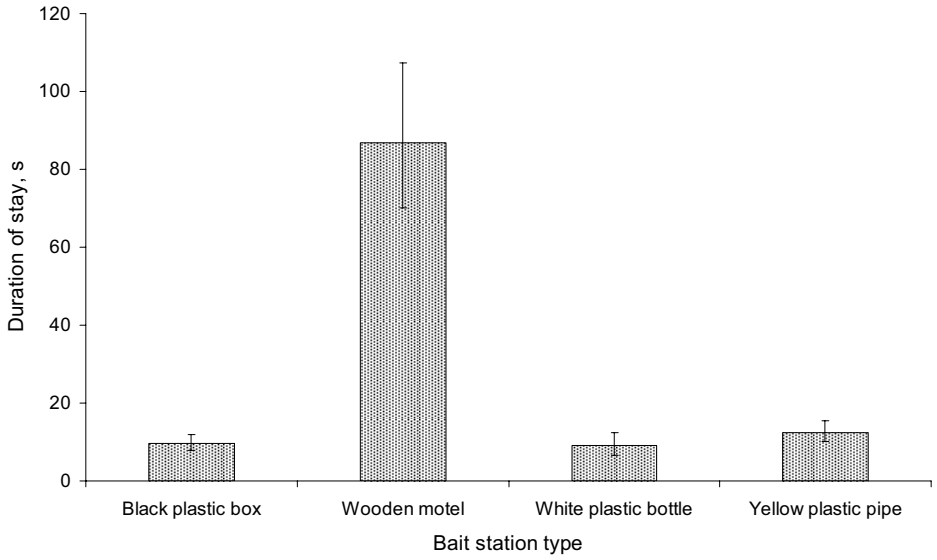


Figure 10. Average duration of all entries into a bait station (mean ± SE).

4.7 PROPORTION EATING BAIT

The proportion of those rats entering bait stations that ate bait was significantly affected by bait station type ($\chi^2_3 = 9.754$, $P = 0.021$) (Fig. 11). A higher proportion of rats that entered bait stations ate bait from the wooden motel and yellow plastic bait stations than from the other two bait station types tested. However, the proportion of rats entering bait stations that ate bait was not affected by previous exposure to bait stations ($\chi^2_4 = 3.731$, $P = 0.444$).

4.8 AMOUNT OF BAIT EATEN

The amount of bait eaten by rats that entered a bait station and ate bait was not significantly affected by bait station type ($F_{3, 13} = 0.762$, $P = 0.543$) (Fig. 12) or by previous exposure to other bait stations ($F_{4, 9} = 0.495$, $P = 0.741$). On average, rats that ate bait ate 1.33 g per night (range < 1–21 g, $n = 39$). They ate more than 5 g of bait during only seven test-nights. On 13 test-nights, rats removed baits from wooden motel, yellow plastic pipe, and black plastic box bait stations without bait-securing rods, and carried them to the nest box or to an underground burrow. No baits were removed from white plastic bait stations but, as noted above, all baits were secured in this bait station type. Three of the baits removed from bait stations to underground burrows could not be recovered for weighing.

Figure 11. Proportion of rats entering a bait station that ate bait (mean ± SE).

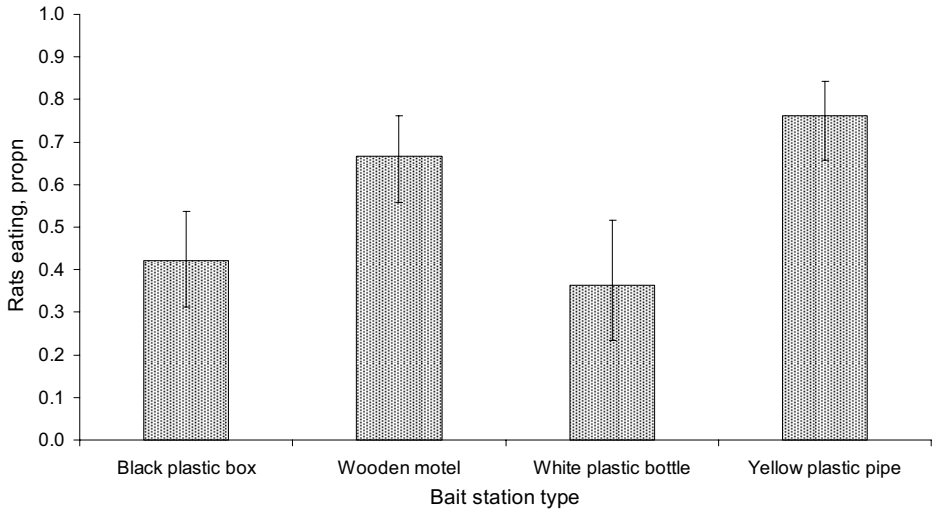
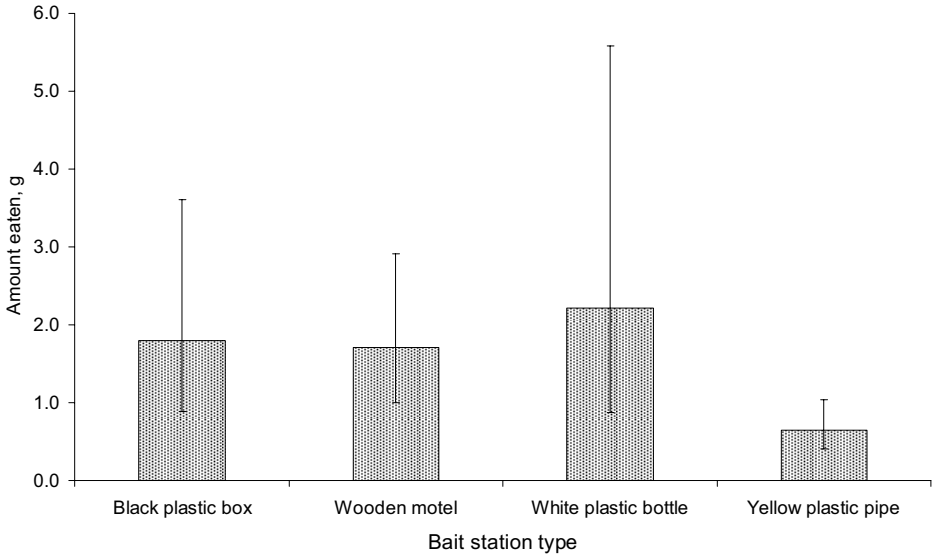


Figure 12. Amount of bait eaten by rats that entered a bait station and ate bait (mean ± SE).



5. Discussion

White plastic bottle 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, and equal lowest proportion of rats eating bait. This bait station type was the only one of the four tested that had only one entrance; it also had the smallest hole. Previous research also found that Norway rats were reluctant to enter the white plastic bottle bait stations, although kiore (*R. exulans*) entered them readily (McFadden 1984; Moors 1985).

Wooden motel bait stations had the longest duration of entry by rats, and equal (with yellow plastic pipe) highest proportion of rats eating bait. As noted above, significantly more rats ate bait from the yellow plastic pipe and wooden motel bait stations than from the other bait station types tested. However, there was no significant difference between these two bait station types in the number of repeat entries or amount of bait eaten. Yellow plastic pipe bait stations are

known to be readily entered by both Norway rats (Thomas & Taylor 1988; Taylor & Thomas 1989, 1993) and ship rats (*R. rattus*) (Taylor 1984).

The critical parameters are the proportion of rats entering bait stations and eating bait, the number of repeat visits, and the amount of bait eaten. As noted above, significantly more rats ate bait from the wooden motel and yellow plastic pipe bait stations than from the other two bait station types tested (Fig. 11). The average amount of bait eaten per rat per night by those rats that ate bait (1.33 g) was not enough for a lethal dose, whether the bait had contained the 20 ppm brodifacoum it normally does, or 50 ppm brodifacoum as some bait types do. Based on an acute LD_{50} (lethal dose to 50% of the population) of 0.27 mg brodifacoum per kg body weight for Norway rats (Godfrey 1985), a large (400 g) rat would need to eat 5.4 g of bait containing 20 ppm brodifacoum, or 2.2 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 4 nights' feeding on 20 ppm bait or 2 nights' feeding on 50 ppm bait. A 200-g rat would need to eat only half these amounts. 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 is important that they are able to 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.

Rats that did not enter bait stations (and therefore did not eat baits) may have been preoccupied with digging their own burrows. However, this should be the same for all bait stations, and should not affect comparisons between the bait station types. 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. As a consequence of neophobia, some rats may never enter bait stations. Previous exposure to bait stations did not affect the proportion of rats eating bait once they entered a bait station, nor the amount of bait eaten.

Bait station design has been investigated several times overseas. For example, Kaukeinen (1987) evaluated eight bait station designs and found that wild Norway rats 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 while feeding in the bait stations. This is important not just to encourage rats to eat sufficient bait but also to ensure that the bait is eaten inside the bait station, and not removed, thereby minimising the risk to non-target species (Clapperton 2004).

As noted in the results, rats removed bait from three of the four types of bait stations tested in our trial. This could pose a risk for non-target species, especially if the bait contained 50 ppm brodifacoum. Only a simple modification would be required to secure bait inside the wooden motel bait stations. However, it would be more difficult, though not impossible, to secure bait inside the yellow plastic pipe bait stations. The Protecta® black plastic rodent bait stations normally have bait-securing rods for baits with hollow centres (see http://www.belllabs/ and http://www.nopests.co.nz/). Other bait

station types also have bait-securing devices. For example, New Zealand's own Philproof rodent bait stations have spikes for securing baits with hollow centres (http://rimu.orcon.net.nz/philproof/), and Pestoff® tunnel bait stations have baffles to help contain the bait (http://www.pestoff.co.nz/). To our knowledge, rodent preferences for these different bait station types have not been determined. The extensive burrowing habits of Norway rats prompts us to suggest that under-ground bait stations may be more effective than above-ground ones for this species.

On the basis of these results, DOC should use the wooden motel or yellow plastic pipe bait stations rather than the black plastic box or white plastic bottle bait stations for surveillance of Norway rats. However, the responses of ship rats and kiore to these same four bait station types should be tested before any final decision is made on the optimum type to use in multi-species rodent surveillance programmes. DOC should also consider funding trials comparing the preferences of the various rodent species for other bait station types, and under-ground versus above-ground bait stations, especially for Norway rat surveillance. A systematic study of bait station design, including number and size of holes, material, colour, height, and volume, would be useful.

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