

Biosecurity device efficacy testing on ship and Norway rats

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Summary

Project and client

- Pest-free islands are New Zealand's main tool for securing highly threatened endemic species, as for most species we have not developed pest-control methods (or have the resources to apply the intensity of current methods) to recover these species populations on the mainland. This research is driven by the lack of robust data and knowledge around efficacy of devices used for island biosecurity and incursion response on pest-free islands in NZ, and the significant variation of devices and configurations in use across different islands in NZ. These configuration and device choices have not been based on interaction efficacy, but rather than personal preferences/perceptions, or modifications to exclude non-target species. Traps used by the Department of Conservation (DOC) against invasive animals are often modified to reduce the risk of capturing or injuring non-target species. Such alterations may change how target species perceive risk, reducing interaction rates and ultimately trap catches.
- DOC contracted the Bioeconomy Science Institute (BSI) to assess the impact of trap entrance configurations and baffles on capture efficacy for both ship rats and Norway rats.

Objectives

- Test a range of commonly used DOC trap box (hereafter 'box') entrances to compare their influence on capture efficacy for Norway and ship rats.
- Test a range of commonly used box baffles to compare their influence on capture efficacy for Norway and ship rats.
- Test ramped and inset traps in boxes to compare their influence on capture efficacy for Norway and ship rats.
- Investigate whether material type (wood/metal), aperture size (small/large), wire mesh entrance edges (rough/smooth), or rodent characteristics (sex, weight) influence capture efficiency.

Methods

- Twenty wild-caught ship rats and 20 wild-caught Norway rats were individually acclimatised in arenas for 2 nights before being exposed to a different trap modification over 9 nights. After a 2-week break the cohort were then exposed to five different baffles and two ramp inserts over 7 nights.
- Each arena contained a control box with an open entrance and a treatment box with either a baffle, entrance or ramp modification.
- Treatment and control boxes were baited with walnut halves and peanut butter for all trials.
- Rat interactions with the DOC trap modifications were assessed using a combination of bait-take, video recording, and a passive infra-red sensor in the boxes.

Results

Ship rats

- Entrance modifications significantly reduced the odds that ship rats would interact and take bait from DOC traps relative to a control trap (open-ended box). Mesh-based entrance designs and the horizontal rebar treatment showed the largest effects, reducing bait-take odds by roughly 90–93%. Moderate reductions were observed for the plywood entrance hole and stainless-steel front with side-entry designs. The ‘No ends’ treatment did not differ from the control.
- Similarly, baffle modifications substantially reduced the likelihood of trap interaction and bait-take by ship rats relative to an unmodified control trap, although effect sizes and patterns varied among manipulations. The largest effects were observed for the stainless-steel screens, as no ship rats removed the bait with this modification, followed by the galvanised mesh entrance treatments. Upright wooden block and flat wooden block designs also significantly reduced bait take relative to the control.

Norway rats

- Several treatments substantially reduced the likelihood that Norway rats took bait when trap entrances were modified. The largest effects were again observed for all mesh-based entrance designs and the stainless-steel front treatment, which reduced bait-taking odds by approximately 87–98%. Norway rat sex influenced device interactions, with strong evidence that males were considerably more likely to take bait than females.
- Relative to the control there was very strong evidence that all baffle designs dramatically reduced the odds of bait-take by Norway rats. Across treatments, bait-take odds were reduced by approximately 96–99.8%, with the largest effects again observed for the stainless-steel screen and galvanised mesh entrance treatments.

Species comparisons

- In general, baffle modifications produced larger reductions in interactions and bait-take for both rat species compared to the entrance modifications. Norway rat interactions with DOC traps were influenced by entrance material (wood/metal), aperture (large/small), and mesh entrance structure (rough/smooth). Norway rats exhibited higher interaction and bait-take for larger aperture sizes, which is consistent with their larger body size. We did not find statistical support for rough being preferable to smooth entrances, although the trend indicated that smooth may offer incremental gains in capture probability.
- Norway rats were more sensitive to entrance aperture and baffle treatments than ship rats, showing marked reductions in interaction with metal-modified entrances, whereas ship rats showed more variable responses and generally higher bait-take. Collectively, our results indicate that prioritising non-metal, larger, smoother entrances will improve trap efficacy. While larger sample sizes would be required to confirm these trends, even incremental gains may be important when targeting rodent incursions to islands.

Conclusions

- Our results demonstrate that both entrance and baffle modifications can strongly influence rat interactions with traps and subsequent bait-taking, with effects generally more pronounced for baffles than entrances.
- While ship rats and Norway rats responded similarly in terms of overall deterrence, species-specific differences emerged: Norway rats were particularly sensitive to baffle treatments for interaction probability. Male ship rats and female Norway rats appeared to be the most difficult to trap based on entrance modifications, with mesh treatments resulting in the lowest bait uptake for both groups. Sex effects were inconsistent between species,

highlighting that behavioural differences may interact with device type. Importantly, substantial individual-level variation in bait-take indicates that some rats consistently avoid traps despite modifications, suggesting that even effective devices may not capture all rats.

- Male and female rats differed in some responses depending on species and device type: male Norway rats were less likely to interact, but the ones that did interact were sometimes more likely to take bait, whereas male ship rats were less likely to take, bait but showed little difference in interaction. Male ship rats and female Norway rats appeared to be the most difficult to trap based on entrance modifications, with mesh treatments resulting in the lowest bait uptake for both groups. Traps with baffles had lower bait take in comparison to traps with entrance modifications. Although males generally engaged less than females, both species and both sexes had the lowest bait take from the stainless steel and galvanised mesh baffle treatments.
- Based on these results, we suggest increasing the use of wooden entrances (e.g. plywood hole) for both ship and Norway rats. Pairing this with a ramp should increase the capture rate compared to a standard trap set. Incremental gains in trapping performance may be achieved by prioritising non-metal, larger, smoother entrances, particularly for Norway rats.

Recommendations

- Baffles and entrance modifications are typically deployed simultaneously to reduce risks to non-target species. A captive trial could be undertaken to compare rodent bait uptake from the best-performing combinations of ramps, entrances, and baffles. A DOC 200 trap should be included to align with standard field deployment, and the effectiveness of the optimal design in reducing impacts to non-target species should be explicitly considered. This proposed study would identify the combinations with the highest interaction rates and ensure there are no compounding effects between the top-performing entrances and baffles when deployed together in field operations.
- Compare rodent interaction rates with trap boxes raised above ground level by different means (e.g. ramps) against boxes set at ground level. On islands, DOC boxes are often elevated to reduce non-target bycatch. However, it is currently unclear how elevated trap boxes influence device interaction when a rodent invades an island, although interaction rates are likely to decrease, particularly for less arboreal species (e.g. Norway rats).
- Determine whether the location of the trap entrance influences interaction probability for rodents. For example, on some islands the entrance is positioned at the top of the box rather than at ground level, which is expected to reduce device interactions.
- Compare rodent interaction rates when the metal treadle of the DOC 200 is covered with wood or cork laminate as an additional element of the optimal design for standard devices. There is growing evidence that metal may reduce interaction rates, with rodents removing less bait from metal (e.g. stainless steel) inserts and, in some cases, refusing to consume feed pellets when they are provided in metal bowls.
- Conduct a field trial comparing boxes fitted with the most common entrance and baffle types versus the optimal design to maximise rodent interactions identified in the captive trial, and quantify whether ramps and wooden blocks further increase rodent capture rates. Because baffles and modified entrances help reduce non-target risks, any improvements in trapping performance must be balanced against additional risks to non-target species.

1 Introduction

Rodents are among the world's most widespread and damaging invasive species (Doherty et al. 2016). Wildlife managers in New Zealand attempt to mitigate this damage using traps and baits, but a subset of pests often survive after failing to engage with control tools. A recent study has shown that the responses of stoats (*Mustela erminea*) to traps and bait stations not only depend on their individual characteristics (e.g. sex, weight, personality), but also on the characteristics of the control device (Johnstone et al. 2024). In a comparable study testing ship rat (*Rattus rattus*) responses to a range of control devices, ship rats were significantly more likely to interact with an 'open-architecture' DOC trap compared with an 'enclosed' box or a 'head-in' bait station (Garvey et al. unpublished). These studies suggest that, when targeting pests with control devices, failure to account for individual variability and device characteristics may undermine the effectiveness of wildlife management programmes.

While standard DOC series traps achieve the highest stoat and rodent interaction rates compared with enclosed boxes and head-in bait stations (Johnstone et al. 2025; Johnstone et al. unpublished), DOC traps are often modified to reduce the risk of capturing or injuring non-target species (Taylor & Thomas 1993; Campbell et al. 2015). Such alterations may change how target species perceive risk, reducing interaction rates and ultimately trap catches. For example, inserting wire mesh or wooden ramps involves a trade-off between maintaining ease of access for target species and excluding non-target species.

As a result, there is a need to better understand why existing management methods often fall short of expected capture efficacy. Pest-free islands are New Zealand's primary tool for securing highly threatened endemic species, because effective pest-control methods to recover endangered species populations on the mainland are not yet effective at the scale required (Russell et al. 2015). Trapping networks across islands and the surrounding mainland are often the first line of defence against invading pests and provide an opportunity to both detect their arrival on an island and kill individual invaders. When a rodent encounters a trap, it is therefore vital that the trap architecture does not deter the animal from being caught.

Previous field trials in New Zealand have demonstrated that trap box architecture can strongly influence capture outcomes for invasive mammals, particularly stoats and rats. Comparative studies at Rotoiti and elsewhere have shown that more open, 'run-through' trap designs often achieve equal or higher capture rates than enclosed, baited DOC trap boxes. This suggests that visual openness, reduced confinement, and ease of movement may reduce trap avoidance behaviour (Brown & Ward 2016; Waite et al. 2020).

These trials also highlighted important trade-offs, including increased non-target risk, and revealed that small design differences in entrances, baffles, ramps, and materials can substantially alter outcomes. However, because these studies were based on field capture data they could not isolate which specific design elements drove changes in trap performance, nor explain the behavioural mechanisms underlying avoidance or engagement. As a result, key aspects of current trap design and incursion-response guidance remain largely based on inference, practitioner experience, or precautionary modification rather than direct behavioural evidence.

Our research is motivated by the lack of robust data on the efficacy of devices used for island biosecurity and incursion responses on pest-free islands in New Zealand, as well as the significant variation in devices and configurations used across different islands. Trap design influences trap efficacy, but the trap with the highest efficiency at trapping pests may not be the best at excluding non-target species (Weihong et al. 1999). Many configuration and device choices have not been

based on interaction efficacy, but on individual preferences, perceptions, or modifications intended to exclude non-target species.

To better understand how trap housing and design affect capture rates, ship rats and Norway rats (*R. norvegicus*) were exposed to different configurations of trap entrances and baffles to assess their impact on capture efficacy. Our aim was to identify the most effective trap configurations for capturing rats that invade islands, using designs that have been reconfigured to reduce non-target harm.

2 Objectives

- Test a range of commonly used trap entrances to compare their influence on capture efficacy for Norway and ship rats.
- Test a range of commonly used box baffles to compare their influence on capture efficacy for Norway and ship rats.
- Test ramped and inset traps in boxes to compare their influence on capture efficacy for Norway and ship rats.
- Investigate whether material type (wood/metal), aperture size (small/large), wire mesh entrance edges (rough/smooth), and rodent characteristics (sex, weight) influence capture efficiency.

3 Methods

3.1 Trial design

Adult ship rats ($n = 20$) and Norway rats ($n = 20$) of mixed sex were caught from the Selwyn region. We selected only adult rats for the study, so the effect of age class was not tested. Rats were acclimatised for at least 2 weeks in individual housing and maintained on a diet of rodent pellets (Prolab RMH LabDiet) and fruit, with *ad libitum* access to water.

Groups of 10 rats were placed individually in arenas (2.16 m length × 0.94 m width × 0.6 m height) for 3 nights to acclimatise to open trap boxes before being exposed to nine different trap entrance modifications over 9 nights (Tables 1 and 2; Appendix 1). A Latin square design was developed to randomise the presentation of treatments to avoid any order effects (Table 3). Rats were offered 20 g of standard lab pellets each night, along with free access to water. Pellets were placed in a metal feeding bowl for the first ship rat cohort, but were placed on the arena floor next to the bowl for subsequent trials. This was due to the reluctance of rats in the first cohort to eat from the metal bowls. Rats were provided with two refuges: a standard nest box and a second nest box made from a plastic bait station with bedding material.

Each arena contained two open DOC trap boxes (255 mm height × 257 mm width × 790 mm length). One of these was a control trap box, open at both ends and without any inserts, while the other was the treatment trap box, which had a different modification (entrance/ramp/baffle) each night (Tables 1 and 2; Appendix 1). DOC 200 kill traps were not included in the entrance treatments or the control trap box.

The position of the treatment and control boxes was alternated each day to reduce any positional bias. Both boxes were oriented lengthways in the rectangular arenas and were located centrally between the more frequently used nest box and the feed pellets and water. Each trap box was baited with a piece of walnut and peanut butter, which was placed in the centre of the box and replaced daily. Each trap box contained a passive infra-red (PIR) sensor in the centre. Additional PIR sensors at each entrance were added during subsequent replicates.

After a 2-week break, during which time the second group of 10 rats were run through the trial, the first group of rats was returned to the arenas and exposed to five different baffle combinations and two ramp configurations (Table 2 and Appendix 1). This consisted of 3 nights' acclimatisation and 7 trial nights. This study was first trialled with ship rats and then repeated with Norway rats.

For the second phase of the trial during which we tested baffles, DOC 200 kill traps were placed in the treatment trap boxes and set but locked open. When a rat passed over the trap plate it depressed, and the sear (trap trigger) disengaged, but the trap could not close on the rat. The control trap boxes had no inserts or DOC trap. The treatment and control boxes were baited with a walnut piece and peanut butter stuck on the wall of the box over the trap plate. The bait placement, which differs from standard practice, was due to having one trap in a tunnel with two entrances.

For the first group of ship rats the trap was locked open using the metal clip supplied with the traps. Rodents triggered the trap on the first night, but seldom thereafter. Subsequent testing showed that the sear moved and the trap produced a loud noise when triggered. To minimise disturbance in subsequent rounds of testing, we included additional restraints to decrease the amount of trap movement when triggered by rodents.

Table 1. Details of the control, entrance, ramp, and baffle treatments used in the study

Configuration label	Trap present	Entrance modification	Internal baffle/ramp	Purpose in study
Control – open box	No	Open at both entrances	None	Baseline measure of unrestricted box use and bait take
Control – trap only	Yes (DOC 200, locked open)	Open at both entrances	None	Baseline for baffle and ramp comparisons where a trap was present
No entrances	No	Wooden box identical to control, no entrance restriction	None	Structural control to test whether box material alone affected behaviour
Entrance treatments	No	Modified entrance only (e.g. plywood hole, rebar, mesh, stainless steel)	None	Isolate the effect of entrance restriction, material, and aperture
Baffle treatments	Yes (DOC 200, locked open)	Open entrance	Internal baffle and/or ramp	Isolate the effect of internal obstruction on interaction and bait access
Ramp treatments	Yes (DOC 200, locked open)	Open entrance	Ramp only, or ramp + baffle	Assess whether ramps facilitate engagement relative to baffles

Trap configurations differed between entrance and baffle trials to ensure treatment effects were assessed relative to the most appropriate baseline (i.e. absence of a trap for entrance trials, and presence of a trap for baffle trials).

We used ‘bait removal’ as a surrogate to confirm that the rat would have triggered the trap, but determining when the trap was triggered was based on a combination of video recordings (Tapo camera) and PIR sensors. Rat interactions with the different entrances and baffles were recorded via video and the metrics described below were analysed for each rat.

In addition to investigating each entrance treatment independently, we also investigated whether rodent bait removal from DOC boxes with wire mesh entrances was influenced by the aperture size, or whether the mesh entrance edges were rough or smoothed. This was done by grouping device designs into:

- wood entrance (plywood entrance hole) versus metal (all mesh entrances, horizontal rebar, and stainless-steel entrances)
- small entrance (small rough mesh, small smooth mesh) versus large (large rough mesh, large smooth mesh)
- rough entrance (small rough mesh, large rough mesh) versus smooth (small smooth mesh, large smooth mesh).

Table 2. Device modification category and iterations to be tested

Modification category	Device	Variables	No. of iterations to test
Effect of trap entrances on efficacy	Wooden box	<ol style="list-style-type: none"> 1. Rough-sawn H4 timber box, no entrances (base) 2. Wooden front, plywood round entrance hole 5 cm 3. Horizontal rebar (hardened half-inch steel rod positioned across the entrance) 4. Galvanised mesh (2 cm) on entrances – entrance smoothed and hole size 6 cm 5. Galvanised mesh (2 cm) on entrances with unsmoothed edges and entrance hole size 6 cm 6. Galvanised mesh (2 cm) on entrances – entrance smoothed and hole size 8 cm 7. Galvanised mesh (2 cm) on entrances with unsmoothed edges and entrance hole size 8 cm 8. Stainless steel front entrance 9. Stainless-steel grill entrances and side entrance on box 	9
Effect of baffles, ramps and inset traps on efficacy	DOC 200 in wooden box	<ol style="list-style-type: none"> 1. No baffle 2. Wooden baffle 3. Galvanised mesh (2 cm) entrance baffle 4. Wooden corridor 5. Stainless-steel screen baffle 6. Ramp (ramped to treadle) 7. Ramp and trap partially concealed (ramped to treadle, and trap partially concealed by upright wooden block) 	5

Table 3. A Latin square design used to create the randomised presentation order for trap entrances.

Rat ID	Night 1	Night 2	Night 3	Night 4	Night 5	Night 6	Night 7	Night 8	Night 9
1	5	1	8	7	2	9	3	6	4
2	2	4	5	6	1	3	9	7	8
3	8	9	5	2	4	1	6	3	7
4	4	9	1	3	8	2	5	6	7
5	9	8	2	1	7	4	3	5	6
6	4	5	2	3	6	1	7	9	8
7	3	1	5	2	9	7	8	4	6
8	3	4	8	5	2	7	6	1	9
9	9	6	1	4	2	8	3	7	5
10	6	1	8	4	7	2	5	9	3

Note: Numbers 1–9 in the body of the table represent entrance types that influence the effects of device efficiency as listed in Table 2 above .

3.2 Analysis

The detection data from the PIR sensor were extracted using R and assigned to each rat. This was combined with bait consumption records and video observations. Each video was initially watched until the rodent first interacted (defined below) with the trap. Where the sensor data, bait-take, and/or video observations did not line up, additional video analysis was undertaken to confirm when the rat first entered the trap box.

To test whether entrance-design treatments alter rat behaviour, we fitted mixed-effects models for three responses: (1) the probability of interacting with the trap (p_{Int}), (2) the time taken to interact (t_{Int}), and (3) the probability of taking the bait ($p_{BaitTake}$). We defined a *trap interaction* as when a rat put its head inside the DOC trap box. We defined the measure *time taken to interact* as the interval (minutes) between when a rat first emerges from its nest box until it interacts with the trap box. Rodents that failed to interact were excluded from this measure. *Probability of bait-take* was a binary measure (1/0) based on whether the bait was present or absent after a trial night.

The response variables p_{Int} and $p_{BaitTake}$ were modelled using penalised generalised linear mixed-effects models (GLMMs) with binomial errors and logit link functions, while t_{Int} was modelled using a linear mixed-effects model (LMM) after log-transforming to improve normality. Penalisation was implemented via weakly informative normal priors on the fixed effects to prevent extreme coefficient estimates caused by treatment groups with very high or very low response rates (i.e. complete or quasi-complete separation) (Clark et al. 2023).

Treatment, sex, and mean-centred body mass ($weight_c$, calculated by subtracting the mean body mass of each sex from each individual's body mass to separate weight effects from sex differences) were included as fixed effects in all models, and a random intercept for ID accounted for repeated measures of individuals. Models were fitted using maximum likelihood (Laplace approximation for GLMMs).

Model results are reported as odds ratios in the appendices and summarised in the Results section. We also report probabilities of bait-take and interaction, and raw times to interaction, as well as highlighting any significant treatment differences, evaluated using estimated marginal means with Dunnett-type contrasts against the reference design ('No baffles' or 'No ends') for the

latency to interaction, and using binomial generalised linear models with a logit link followed by Tukey-adjusted pairwise comparisons of estimated marginal means for the probabilities of bait-take and interaction.

4 Results

4.1 Ship rats – entrances

We tested ship rats ($n = 20$) to determine whether modifying DOC trap entrances influenced three behavioural responses: interaction probability, time to first interaction, and bait-take.

Relative to the 'No ends' treatment, there was moderate evidence that some entrance modifications reduced the likelihood of trap interaction (Figure 1a). Large, rough mesh and a horizontal rebar showed clear reductions in interaction probability relative to the 'No ends' treatment (large rough mesh: OR = 0.179, 95% CI = 0.035–0.906, $P = 0.038$; horizontal rebar: OR = 0.117, 95% CI = 0.023–0.591, $P = 0.009$, see Table A2.3), corresponding to odds reductions of approximately 80–90%.

Small, rough mesh showed weaker evidence for a reduction, while other treatments showed little evidence for an effect. In contrast, the control devices (without any trap inside) had substantially higher interaction probability than the 'No entrances' device. There was little evidence that sex or body mass influenced interaction probability, and individual-level variability in interaction propensity was high.

Among rats that did interact with the trap, there was evidence that some of the entrance modifications increased the time taken to approach the entrance (Figure 1b, Table A2.3). The largest effect was observed for the stainless-steel side treatment, which was associated with approximately a three-fold increase in time to approach relative to the control (estimate = 3.20, 95% CI = 1.389–7.370, $P = 0.006$). Stainless-steel front and small smooth mesh also increased the time to approach, each associated with approximately a two- to three-fold increase in latency (stainless-steel front: estimate = 2.695, 95% CI = 1.139–6.378, $P = 0.024$; small, smooth mesh: estimate = 2.311, 95% CI = 1.068–4.997, $P = 0.033$).

The plywood entrance hole and the small, rough mesh showed marginal evidence for a delay, while other treatments showed little evidence for an effect. There was evidence that heavier rats interacted slightly sooner (estimate = 1.008, 95% CI = 1.001–1.015, $P = 0.034$), and weak evidence that males took longer to interact.

There was evidence that several entrance modifications reduced the probability of bait take (Figure 1c). Mesh-based designs and the horizontal rebar treatment showed the largest effects, reducing bait-take odds by roughly 75–85% (e.g. large, rough mesh: OR = 0.161, 95% CI = 0.039–0.672, $P = 0.012$; horizontal rebar: OR = 0.164, 95% CI = 0.039–0.682, $P = 0.013$, see Table A2.3). Small, smooth mesh and large, rough mesh showed similar but slightly weaker reductions.

There was little evidence that the plywood entrance hole, stainless-steel front, or stainless-steel side treatments altered bait-take relative to the 'No ends' treatment. In contrast, the control devices with no trap inside had higher bait-take odds than the 'No entrances' treatment. There was strong evidence that males were less likely to take bait than females (OR = 0.152, 95% CI = 0.038–0.612, $P = 0.008$), but little evidence for an effect of body mass. The random intercept for individual ID indicated substantial among-individual variation in bait-taking behaviour.

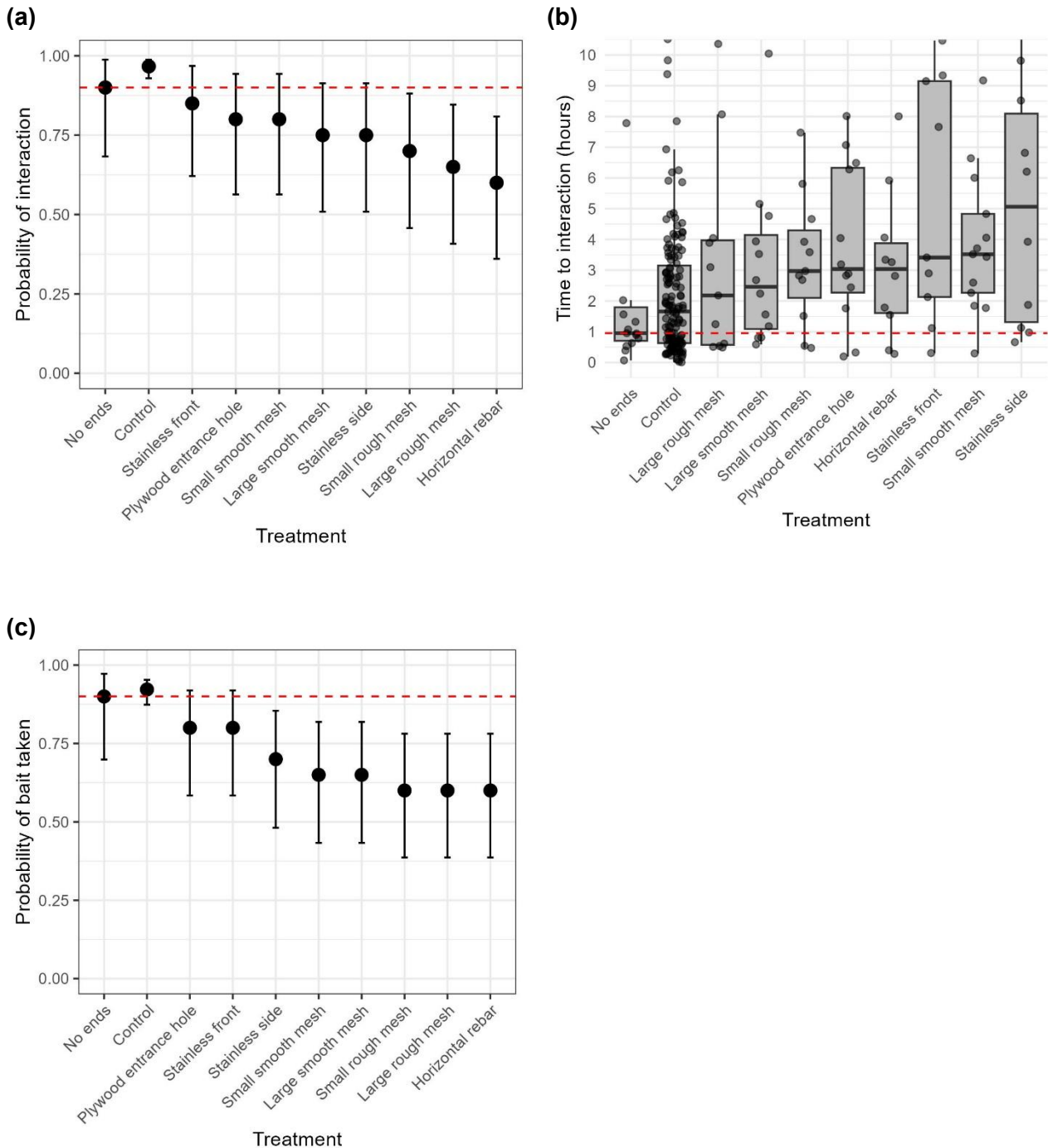


Figure 1. Ship rat responses to modified entrance devices.

(a): Conditional probability that a device registered an interaction event, given that the rat approached it, across treatments. Points show treatment-level summaries with 95% binomial confidence intervals. The dashed red line indicates the median probability of bait taken for the reference treatment ('No ends'). Red asterisks indicate treatments significantly different from the reference treatment.

(b): Delay between the first interaction and the subsequent trigger event across treatments. Boxplots show treatment-level distributions, with jittered points representing individual observations. The dashed red line marks the median delay time for the control treatment. Red asterisks indicate treatments significantly different from the reference treatment.

(c): Conditional probability that bait was taken, given that the rat interacted with the device, across treatments. Points show treatment-level summaries with 95% binomial confidence intervals. The dashed red line indicates the median probability of bait taken for the reference treatment ('No ends'). Red asterisks indicate treatments significantly different from the reference treatment.

4.2 Ship rats – baffles

Interaction probability was much higher in the empty control than in the 'No baffles' devices (Figure 2a; Table A2.4). None of the individual baffle treatments showed statistically significant effects, although the stainless-steel screen showed some evidence of a reduction, with high uncertainty.

Among rats that did interact with the trap there was little evidence that baffle design substantially altered the time taken to approach the entrance (Figure 2b; Table A2.4). Effect sizes for latency were highly variable and uncertain across all treatments, with confidence intervals spanning a wide range. In contrast, there was strong evidence that heavier rats took longer to interact (estimate = 1.028, 95% CI = 1.012–1.044, $P = 0.001$), while there was little evidence for an effect of sex.

Relative to the empty control there was very strong evidence that bait take was substantially higher in the absence of baffles, but when compared to the 'No baffles' treatment there was limited evidence that baffle designs reduced the odds of bait-take (Figure 2c; Table A2.4). The only treatment showing strong evidence for a reduction in bait removal was the stainless-steel screen, which decreased bait-taking odds by approximately 96% (OR = 0.040, 95% CI = 0.004–0.360, $P = 0.004$). Other baffle designs, including galvanised mesh, wooden blocks, and ramp-based treatments, showed little evidence of an effect relative to the 'No baffles' treatment, with wide confidence intervals overlapping 1.

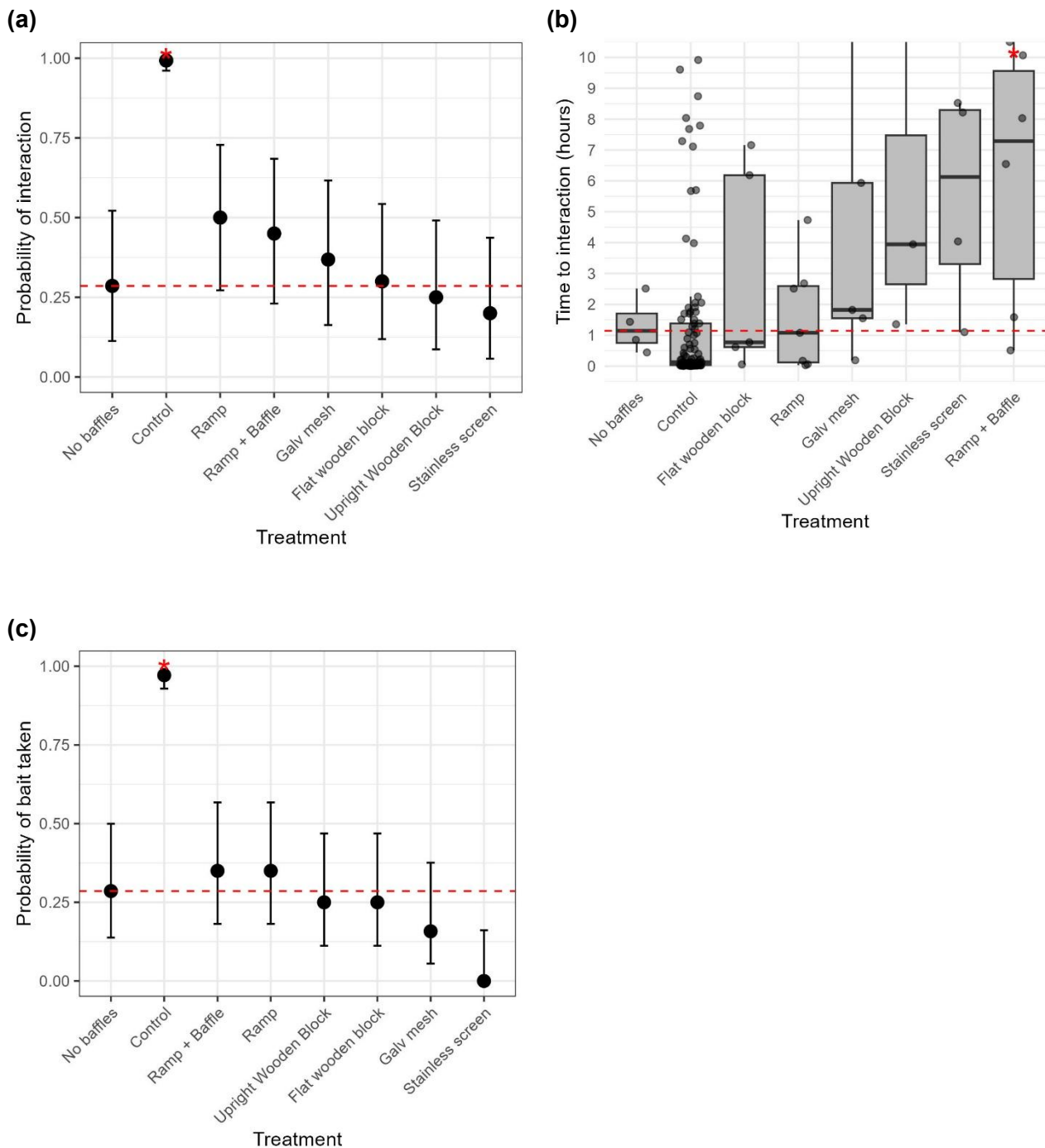


Figure 2. Ship rat responses to modified baffles devices.

(a): Conditional probability that a device registered an interaction event, given that the rat approached it, across treatments. Points show treatment-level summaries with 95% binomial confidence intervals. The dashed red line indicates the median probability of bait taken for the reference treatment ('No baffles'). Red asterisks indicate treatments significantly different from the reference treatment.

(b): Delay between the first interaction and the subsequent trigger event across treatments. Boxplots show treatment-level distributions, with jittered points representing individual observations. The dashed red line marks the median delay time for the control treatment. Red asterisks indicate treatments significantly different from the reference treatment.

(c): Conditional probability that bait was taken, given that the rat interacted with the device, across treatments. Points show treatment-level summaries with 95% binomial confidence intervals. The dashed red line indicates the median probability of bait taken for the reference treatment ('No baffles'). Red asterisks indicate treatments significantly different from the reference treatment.

4.3 Norway rats – entrances

Most entrance treatments altered the likelihood that Norway rats interacted with the trap relative to the 'No ends' treatment (Figure 3a; Table A2.5). There was some evidence that all mesh-based designs and the stainless-steel front treatment substantially reduced interaction probability, with interaction odds reduced by approximately 90–98% (e.g. small, rough mesh: OR = 0.015, 95% CI = 0.001–0.189, $P = 0.001$; stainless-steel front: OR = 0.038, 95% CI = 0.003–0.458, $P = 0.010$). There was also moderate, non-statistically significant evidence that stainless-steel sides and horizontal rebars reduce interaction probability. Males were substantially less likely to interact than females (OR = 0.071, 95% CI = 0.012–0.417, $P = 0.003$), and there was evidence that heavier rats were slightly less likely to interact. Individual-level variability in interaction propensity was high.

Among Norway rats that did interact with the trap, there was strong evidence that several entrance modifications increased the time taken to approach the entrance (Figure 3b; Table A2.5). The largest delays were observed for the stainless-steel front treatment, which increased latency to interaction by approximately 17-fold relative to the 'No ends' treatment (stainless-steel front: estimate = 16.888, 95% CI = 3.124–91.297, $P = 0.001$). Stainless-steel side also showed a large increase in latency (estimate = 11.544, 95% CI = 2.793–47.704, $P = 0.001$). Small, smooth mesh, large, rough mesh, and large, smooth mesh showed moderate increases in latency (approximately five- to six-fold), while other treatments showed little evidence for an effect. There was weak evidence that males took longer to interact, while body mass showed no clear effect on latency.

Relative to the 'No ends' treatment there was strong evidence that several entrance treatments reduced the likelihood that Norway rats took the bait (Figure 3c; Table A2.5). Mesh-based designs showed the largest effects, particularly small, rough mesh, which reduced bait-take odds by approximately 96% (OR = 0.040, 95% CI = 0.008–0.188, $P < 0.001$). Small, smooth mesh, large, rough mesh, and stainless-steel front also showed strong reductions (ORs ≈ 0.11 – 0.16 , all $P \leq 0.013$), while large, smooth mesh showed weaker evidence for an effect. In contrast, the empty control devices had higher bait-take odds than the 'No ends' devices. There was little evidence that the plywood entrance hole, stainless-steel side, or horizontal rebar treatments altered bait take, and strong evidence that males were more likely to take bait than females (OR = 12.748, 95% CI = 2.373–68.485, $P = 0.003$), while body mass showed little evidence of an effect. The random intercept for individual ID indicated substantial among-individual variation in bait-taking behaviour.

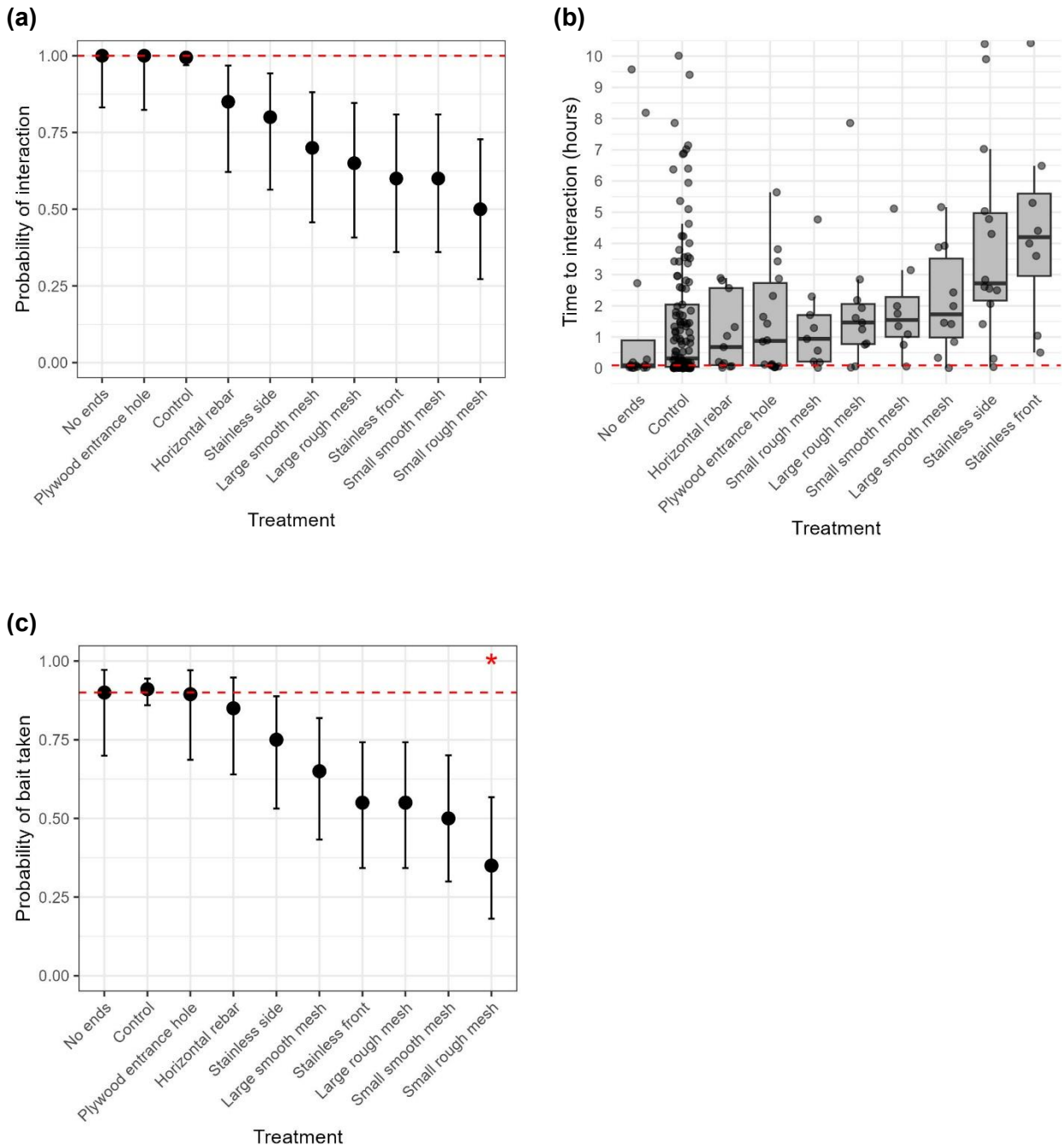


Figure 3. Norway rat responses to modified entrance devices.

(a): Conditional probability that a device registered an interaction event, given that the rat approached it, across treatments. Points show treatment-level summaries with 95% binomial confidence intervals. The dashed red line indicates the median probability of bait taken for the reference treatment ('No ends'). Red asterisks indicate treatments significantly different from the reference treatment.

(b): Delay between the first interaction and the subsequent trigger event across treatments. Boxplots show treatment-level distributions, with jittered points representing individual observations. The dashed red line marks the median delay time for the control treatment. Red asterisks indicate treatments significantly different from the reference treatment.

(c): Conditional probability that bait was taken, given that the rat interacted with the device, across treatments. Points show treatment-level summaries with 95% binomial confidence intervals. The dashed red line indicates the median probability of bait taken for the reference treatment ('No ends'). Red asterisks indicate treatments significantly different from the reference treatment.

4.4 Norway rats – baffles

Relative to the 'No baffles' devices, there was strong evidence that some baffle devices reduced the likelihood that Norway rats interacted with the trap (Figure 4a; Table A2.6). Stainless-steel screen and galvanised mesh showed clear reductions in interaction probability (stainless-steel screen: OR = 0.133, 95% CI = 0.027–0.657, $P = 0.013$; galvanised mesh: OR = 0.205, 95% CI = 0.046–0.922, $P = 0.039$), corresponding to reductions of approximately 80–90%. Other treatments showed little evidence for an effect. In contrast, the control treatment had substantially higher interaction probability than the 'No baffles' treatment. There was little evidence that sex or body mass influenced interaction probability. Individual-level variability in interaction propensity was moderate to high.

Among rats that did interact with the trap, there was little evidence that baffle design substantially altered the time taken to approach the entrance (Figure 4b; Table A2.6). Effect sizes for latency were small and highly uncertain across all treatments, including upright wooden block and ramp designs, indicating that baffles primarily influenced whether rats interacted with the trap rather than how quickly they did so once engagement occurred. There was little evidence for consistent effects of sex or body mass on interaction latency.

There was moderate evidence that some baffle treatments reduced the likelihood that Norway rats took the bait (Figure 4c; Table A2.6). The largest effects were observed for stainless-steel screen and galvanised mesh, which reduced bait-taking odds by approximately 80–90% (OR = 0.108, 95% CI = 0.019–0.606, $P = 0.011$; galv. mesh: OR = 0.186, 95% CI = 0.040–0.860, $P = 0.031$). In contrast, the control treatment had substantially higher bait-taking odds, and there was weak evidence that the ramps and flat wooden blocks increased bait take, but no clear evidence for an effect of the other treatments. There was marginal evidence that males were more likely to take bait than females (OR = 2.928, 95% CI = 0.986–8.697, $P = 0.053$), while body mass showed little evidence of an effect. Substantial among-individual variation in bait-taking behaviour was again evident.

The traps were triggered 43 times out of a possible 140 trial nights, with 25 of those triggers on the first 2 nights. All the rats triggered the trap at least once, and 15 out of 20 rats triggered it two or more times. Control baits were eaten 85% of the time compared to 31% for the treatment baits. The differences in bait take between the different baffle types probably indicates the relative ease of removing the bait without triggering the trap.

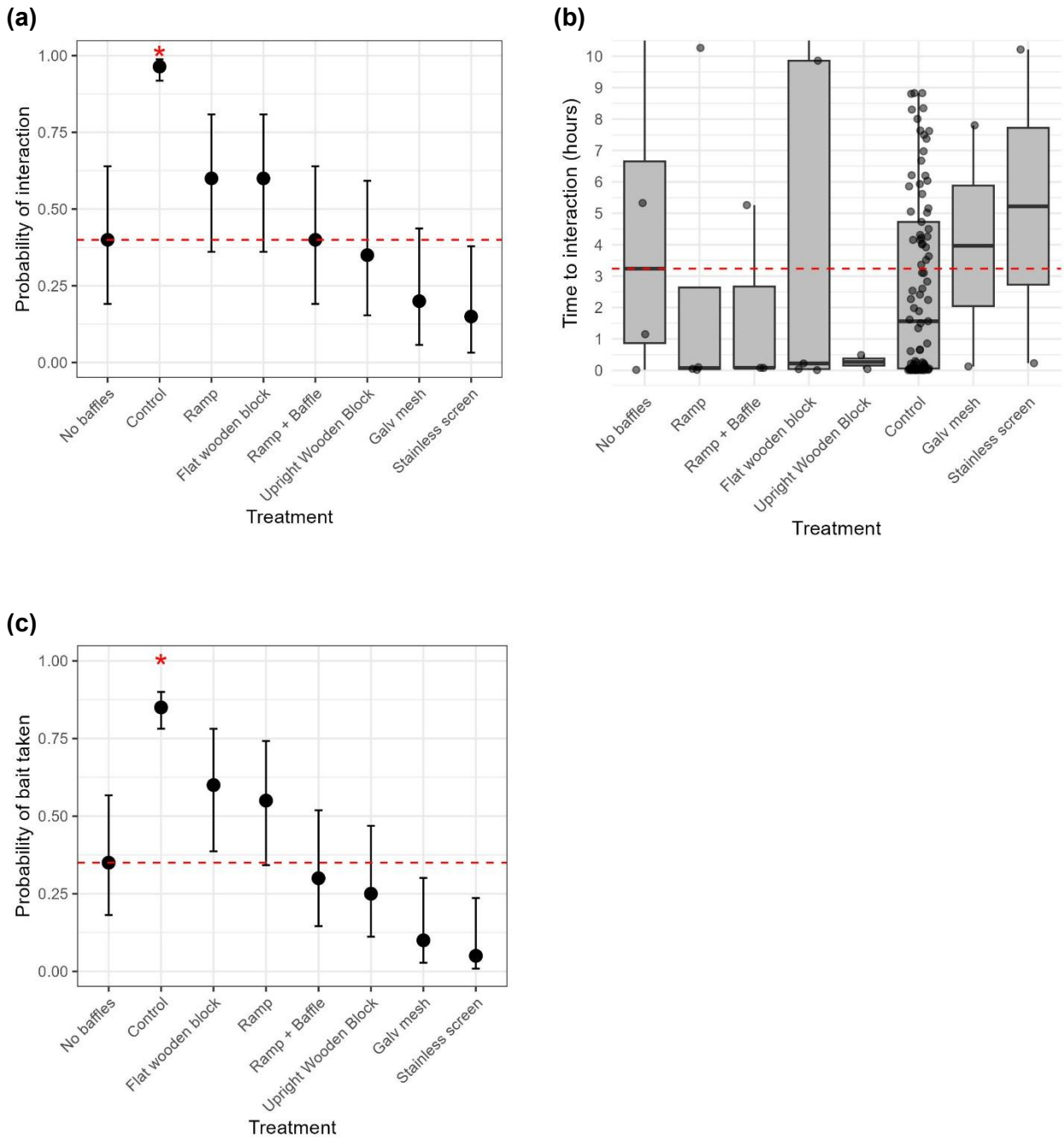


Figure 4. Norway rat responses to modified baffles devices.

(a): Conditional probability that a device registered an interaction event, given that the rat approached it, across treatments. Points show treatment-level summaries with 95% binomial confidence intervals. The dashed red line indicates the median probability of bait taken for the reference treatment ('No baffles'). Red asterisks indicate treatments significantly different from the reference treatment.

(b): Delay between the first interaction and the subsequent trigger event across treatments. Boxplots show treatment-level distributions, with jittered points representing individual observations. The dashed red line marks the median delay time for the control treatment. Red asterisks indicate treatments significantly different from the reference treatment.

(c): Conditional probability that bait was taken, given that the rat interacted with the device, across treatments. Points show treatment-level summaries with 95% binomial confidence intervals. The dashed red line indicates the median probability of bait taken for the reference treatment ('No baffles'). Red asterisks indicate treatments significantly different from the reference treatment.

4.5 Materials, apertures, and sex

We grouped device designs into wood entrance (plywood entrance hole) versus metal (all mesh entrances, horizontal rebar, and stainless-steel entrances), small entrance (small, rough mesh, small, smooth mesh) versus large (large, rough mesh, large, smooth mesh), and rough entrance (small, rough mesh, large, rough mesh) versus smooth (small, smooth mesh, large, smooth mesh) to investigate the influence of these groupings on rodent bait take. For ship rats there was no significant effect of aperture size, rough versus smooth, or wood versus metal (Figure 5). For Norway rats there was modest evidence of a negative effect of small, rough mesh entrances vs. large, smooth ones on the probability of bait take. Norway rats were significantly more likely to take bait from traps with a wooden entrance compared to metal (Figure 5).

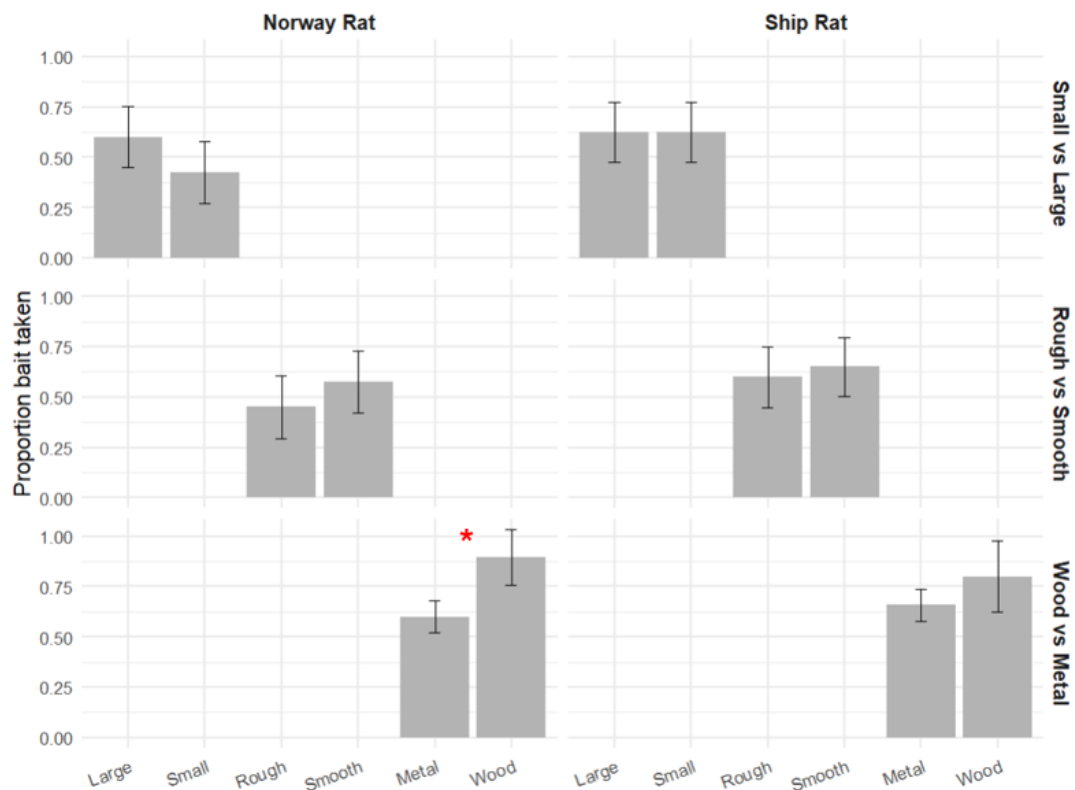
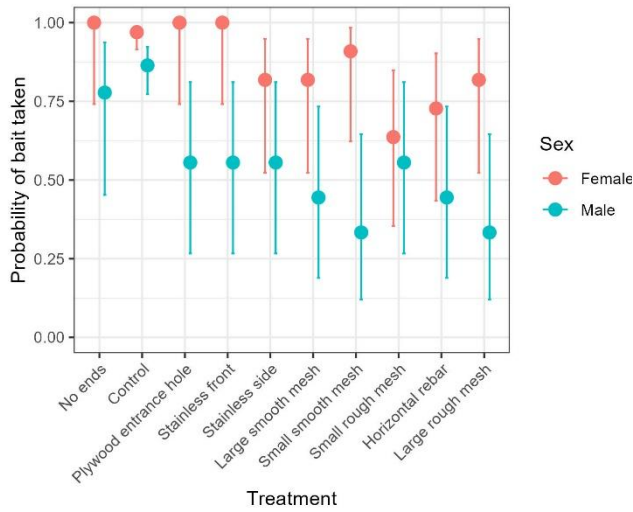


Figure 5. Proportion of trials in which bait was taken across entrance-modified device subgroups for Norway rats and ship rats.

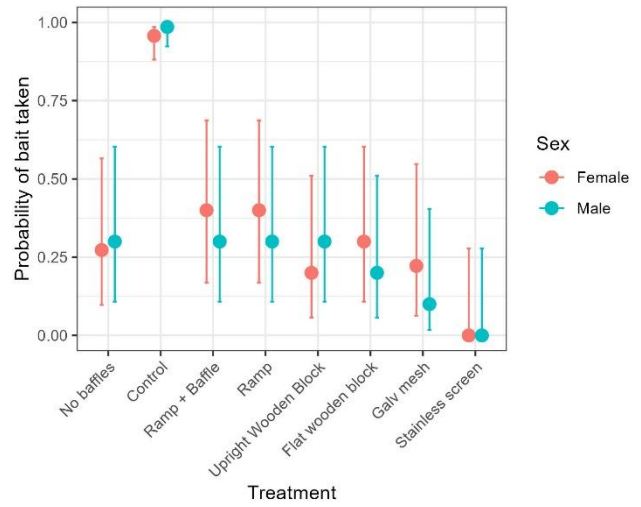
Notes: Bars show the estimated proportion of bait taken for each subgroup, with error bars indicating 95% binomial confidence intervals. Rows correspond to paired entrance device comparisons (small vs. large mesh entrance, rough vs. smooth mesh entrance, and wood vs. metal material), and columns correspond to species.

Sex effects were inconsistent between species, highlighting that behavioural differences may interact with device type. Female ship rats were more likely to remove bait from modified traps than males (Figure 6 a,b). The opposite effect was observed for Norway rats, where males were more likely to take bait than females (Figure 6 c,d).

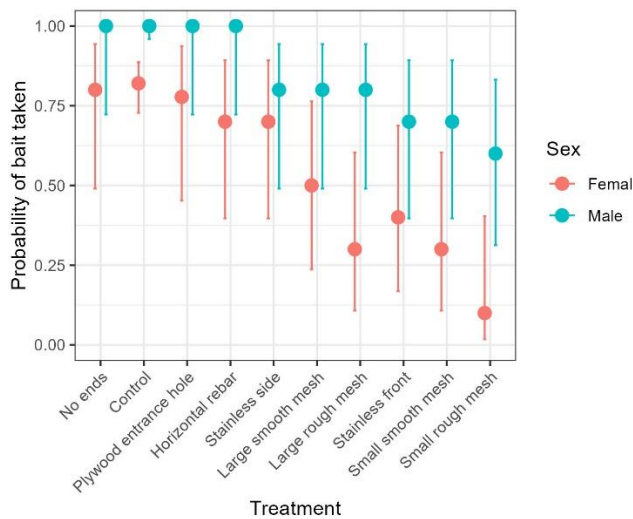
(a) Ship rats – entrances



(b) Ship rats – baffles



(c) Norway rats – entrances



(d) Norway rats – baffles

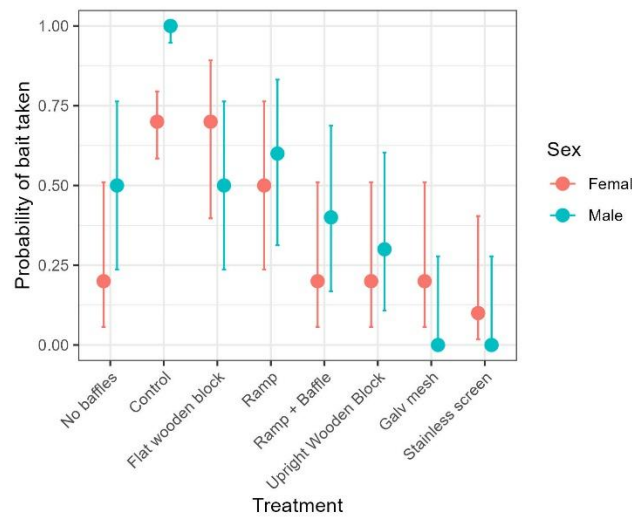


Figure 6. Mean probability that bait was taken at each treatment, for both species of rats exposed to each device type.

Notes: Red data correspond to female rats, blue data correspond to male rats. Points represent treatment means, ordered by decreasing probability, and vertical lines represent the 95% binomial confidence intervals.

5 Conclusions

Overall, both ship rats and Norway rats were moderately influenced by modifications to trap entrances and baffles. Across species many treatments showed little evidence of an effect relative to the 'No ends' and 'No baffles' treatments, although some designs produced strong deterrent responses, and effect sizes and patterns varied between species and manipulations. In general, only certain baffle modifications (particularly metal designs) produced large reductions in interaction and bait-taking, rather than a consistent effect across all treatments.

Male and female rats differed in some responses depending on species and device type: male Norway rats were less likely to interact, but the ones that did interact were sometimes more likely to take bait, whereas male ship rats were less likely to take bait but showed little difference in interaction. Male ship rats and female Norway rats appeared to be the most difficult to trap based on entrance modifications, with mesh treatments resulting in the lowest bait uptake for both groups. Traps with baffles had lower bait take in comparison to traps with entrance modifications. Although males generally engaged less than females, both species and both sexes had the lowest bait take from the stainless steel and galvanised mesh baffle treatments.

Body mass had little consistent influence on behaviour across species, and substantial individual-level variation in bait-taking was observed for both species. These results are consistent with recent work on ship rats and stoats, which showed that individual personality traits associated with neophobia/neophilia and boldness/shyness strongly influence interactions with a range of pest control devices (Johnstone et al. 2024; Johnstone et al. unpublished).

Our results demonstrate that modifying trap housing/architecture to exclude non-target species can strongly influence rodent interaction rates. Norway rats were particularly averse to metal entrances. Ship rats were hesitant to approach or enter some trap designs, such as stainless screen.

Although sex differences were anticipated, the trend that female ship rats had higher bait take than males was unexpected, as females are typically more risk averse than males. In comparative research, female stoats were less likely to interact with devices (Johnstone et al. 2024), while raccoon trapping is strongly skewed towards males (Gehrt & Fritzell 1996), a pattern consistent with Norway rats in this study. Although ship rats showed a male capture bias in this study, as males were less likely to take bait from baffles and entrances, a device interaction study with a larger sample size (44 ship rats) found no capture bias based on sex (Johnstone et al. in prep). This suggests that the non-significant trend in this study of male ship rats being more risk averse probably reflects individual variability within the samples rather than a true capture bias.

Rats, particularly Norway rats, were less likely to enter traps when they were modified with metal baffles and entrances compared to wooden modifications. Stainless-steel screens consistently produced the lowest interaction rates and bait take, while modifications with wire mesh entrance also significantly reduced bait take. In fact, only one of the forty rats tested took the bait when the stainless-steel screen baffles were introduced. In contrast the wooden ramp and block treatments resulted in the highest bait take for Norway rats, and ramps were also associated with the highest bait take for ship rats, although differences were non-significant. This preference for wood is consistent with recent findings showing that ship rats were approximately four times more likely to remove bait from wooden bait stations compared to identical devices constructed from metal (Grant et al. unpubl.). While the mechanisms underlying these material preferences remain unclear, differences in thermal conductivity, visual and tactile properties, and scent retention may contribute to the results.

A general trend was observed whereby larger entrances were associated with higher interaction rates and bait take, particularly for Norway rats, whose larger body size makes them more reluctant to enter the smaller apertures. However, several mesh designs were found to reduce interaction and bait take relative to the default 'No ends' design. Similar patterns were observed when comparing rough and smooth entrances of equivalent size: larger Norway rats showed reduced interaction rates with rough entrances.

Across entrance treatments, several odds ratios deviated substantially from 1, particularly for mesh and rebar designs, indicating strong deterrent effects. However, even modest increases in capture probability may be important in the context of island surveillance, pest incursions, and eradication projects that are targeting the last individuals. For ship rats there was little evidence that wooden or other entrance modifications increased capture probability relative to the 'No ends' treatment, while several mesh and rebar designs reduced bait take and interaction. For Norway rats, mesh entrances generally reduced capture probability, and there was no consistent evidence that larger or smoother entrances improved interaction or bait take relative to alternative designs.

One potential weakness in the experimental design was that we did not include an unset DOC 200 trap in the entrance treatments but included unset traps in the baffle treatment. However, this allowed us to deduce the influence of the trap alone on rodent bait take when compared to the corresponding control box (no trap). This is reflected in the substantially higher interaction and bait-taking probabilities observed in the control relative to the 'No baffles' treatment, indicating that comparisons with an empty tunnel may overstate deterrent effects of baffles: ship rats removed 98% of control baits compared to 24% of treatment baits for the 'No baffles' treatment. Also, baffle devices presented to one of our two ship rats groups were not fixed securely and shifted slightly when stepped on, which may have increased neophobic responses or hesitation and contributed to longer apparent latencies or reduced interaction probabilities, independent of treatment effects.

When the 'No baffles' treatment, which is the standard trap presentation in the field, is compared to the other treatments, several baffle treatments had higher interaction and bait takes. However, most baffle treatments showed either reduced or uncertain effects relative to the 'No baffles' treatment, with strong reductions primarily associated with metal designs such as stainless-steel screen and galvanised mesh. Ship rats had higher probabilities of bait take, interaction or time to interaction with ramps, ramps and baffles, and flat wooden baffles. Norway rats similarly favoured ramps and flat wooden blocks. In future box design research should include traps in the control boxes if the treatment box contains one

Our results demonstrate that both entrance and baffle modifications can strongly influence rat interactions with traps and subsequent bait-taking, with effects generally more pronounced for baffles than entrances. However, these effects were treatment-specific, with strong deterrent responses largely driven by particular designs (e.g. mesh entrances and metal baffles) rather than a consistent pattern across all modifications.

Norway rats appeared relatively sensitive to certain entrance treatments (notably metal designs), whereas ship rats showed limited evidence for consistent latency responses to baffles. Norway rats were particularly sensitive to baffle treatments for interaction probability, whereas ship rats showed large delays in time taken to interact with baffles.

Sex effects were inconsistent between species, highlighting that behavioural differences may interact with device type. Importantly, substantial individual-level variation in bait-taking indicates that some rats consistently avoid traps despite modifications, suggesting that even effective devices may not capture every rat in a population.

Based on these results we suggest increasing the use of wooden entrance designs for both ship and Norway rats. Pairing this with a ramp should increase the capture rate compared to a standard trap set. Although there was weak statistical support, odds ratios suggest that prioritising non-metal, larger, and smooth entrances can improve capture rates, particularly for Norway rats.

Our study tested the influence of baffle and entry treatments on rodent interaction rates. However, the primary function of these modifications is to reduce the risk to non-target species. If future research identifies the optimal combination of ramps, baffles, and entrances for rodents, an important consideration will be how effective this configuration is at reducing non-target captures.

Overall our results provide empirical context for operational trap-design guidance used in island biosecurity, incursion responses, and targeting individuals of Norway and ship rats. Previous recommendations for more open entrances, minimal internal obstruction, and the use of ramps in run-through trap boxes were largely informed by field performance and practitioner experience (e.g. Brown et al. 2021; Brown & Ward 2016; Waite et al. 2020). For example, run-through devices with ramps and larger mesh apertures caught significantly more rats than standard DOC devices (Brown & Ward 2016; Waite et al. 2020).

Our findings support several of these principles, particularly the importance of reducing visual and physical restriction at the entrance and avoiding metal screens or fine mesh entrance that may reduce trapping efficacy. At the same time, the magnitude of the deterrent effects observed for baffles and metal components highlights the inherent trade-off between non-target exclusion and target species efficacy. While baffles and screens may be justified in some mainland or non-target-sensitive contexts, their use in island incursion scenarios – where rapid detection and capture is critical – may substantially reduce the probability of intercepting invading rodents. These trade-offs emphasise the need for context-specific trap configurations rather than a single best-practice design.

6 Recommendations

- Baffles and entrances are typically deployed simultaneously to reduce risks to non-target species. A captive trial could be undertaken to compare rodent bait uptake from the best-performing combinations of ramps, entrances, and baffles. A DOC 200 trap should be included to align with standard field deployment, and the effectiveness of the optimal design in reducing impacts to non-target species should be explicitly considered. This proposed study would identify the combinations with the highest interaction rates and ensure there are no compounding effects between the top-performing entrances and baffles when deployed together in field operations.
- Compare rodent interaction rates with trap boxes raised above ground level by different means (e.g. ramps) against boxes set at ground level. On islands, DOC boxes are often elevated to reduce non-target bycatch. However, it is currently unclear how elevated trap boxes influence device interaction when a rodent invades an island, although interaction rates are likely to decrease, particularly for less arboreal species (e.g. Norway rats).
- Determine whether the location of the trap entrance influences interaction probability for rodents. For example, on some islands the entrance is positioned at the top of the box rather than at ground level, which is expected to reduce device interactions.
- Compare rodent interaction rates when the metal treadle of the DOC 200 is covered with wood or cork laminate as an additional element of the optimal design for standard devices. There is growing evidence that metal may reduce interaction rates, with rodents removing less bait from metal (e.g. stainless steel) inserts and, in some cases, refusing to consume feed pellets when they are provided in metal bowls.
- Conduct a field trial comparing boxes fitted with the most common entrance and baffle types versus the optimal design to maximise rodent interactions identified in the captive trial, and quantify whether ramps and wooden blocks further increase rodent capture rates. Because baffles and modified entrances help reduce non-target risks, any improvements in trapping performance must be balanced against any additional risks to non-target species.

7 Acknowledgements

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Appendix 1 – Arena layouts, box entrances, and baffle set-ups



Area type 1 ($n = 6$)



Arena type 2 ($n = 4$)

Figure A1.1. Arena layouts.

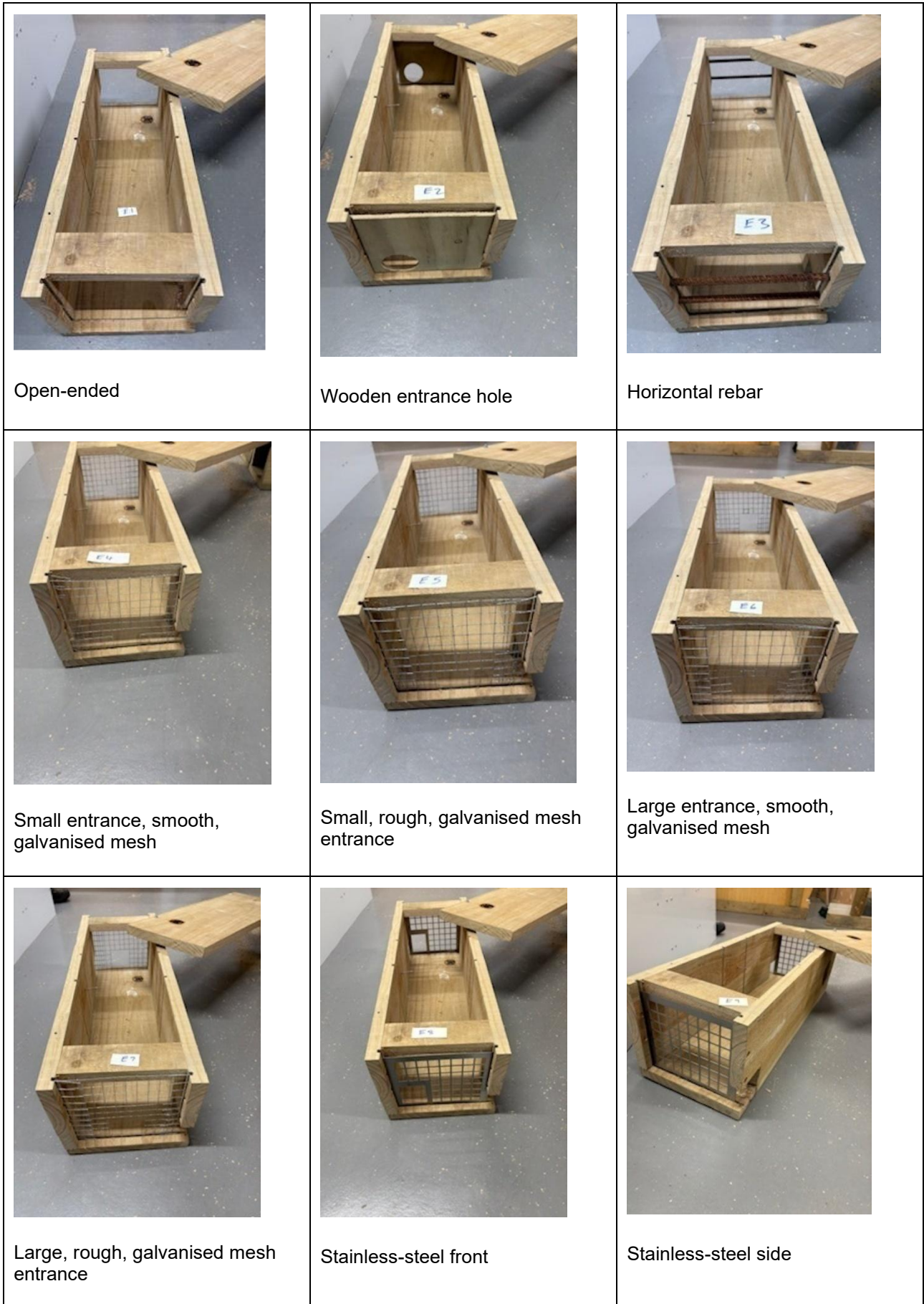


Figure A1.2. Entrance modifications.








 <p>No Baffles</p>	 <p>Flat wooden block</p>	 <p>Upright wooden block</p>
 <p>Galvanised mesh entrance</p>	 <p>Stainless-steel screen</p>	 <p>Ramp</p>
 <p>Ramp and baffles</p>		

Figure A1.3. Baffles.

Appendix 2 – Additional data

Table A2.1. Raw counts of interactions and bait-take, by entrance treatment, for ship rats and Norway rats

Treatment	SHIP RATS				NORWAY RATS			
	Interaction		Bait taken		Interaction		Bait taken	
	TRUE	FALSE	TRUE	FALSE	TRUE	FALSE	TRUE	FALSE
Control	174	6	166	14	178	163	163	16
No ends	18	2	18	2	20	18	18	2
Plywood entrance	16	4	16	4	19	17	17	2
Small rough mesh	14	6	12	8	10	7	7	13
Small smooth mesh	16	4	13	7	12	10	10	10
Large rough mesh	13	7	12	8	13	11	11	9
Large smooth mesh	15	5	13	7	14	13	13	7
Stainless front	17	3	16	4	12	11	11	9
Stainless side	15	5	14	6	16	15	15	5
Horizontal rebar	12	8	12	8	17	17	17	3

Notes: The table shows the number of individuals that interacted with the trap (Interaction: TRUE/FALSE) and the number that took bait (Bait taken: TRUE/FALSE) for each trap entrance design. Data are presented separately for ship rats and Norway rats. 'Control' represents an empty box, 'No ends' represents a box that is identical to the control box, while other treatments correspond to experimental modifications to the trap entrance. These raw counts provide a straightforward view of the behavioural responses to each treatment before accounting for covariates or random effects in mixed-effects models.

Table A4.2. Raw counts of interactions and bait-take, by baffle treatment, for ship rats and Norway rats

Treatment	SHIP RATS				NORWAY RATS			
	Interaction		Bait taken		Interaction		Bait taken	
	TRUE	FALSE	TRUE	FALSE	TRUE	FALSE	TRUE	FALSE
Control	139	1	136	4	135	5	119	21
No baffles	6	15	6	15	8	12	7	13
Flat wooden block	6	14	5	15	12	8	12	8
Galv mesh	7	12	3	16	4	16	2	18
Ramp	10	10	7	13	12	8	11	9
Ramp + Baffle	9	11	7	13	8	12	6	14
Stainless screen	4	16	0	20	3	17	1	19
Upright wooden block	5	15	5	15	7	13	5	15

Notes: The table shows the number of individuals that interacted with the trap (Interaction: TRUE/FALSE) and the number that took bait (Bait taken: TRUE/FALSE) for each trap baffle design. Data are presented separately for ship rats and Norway rats. 'Control' represents an empty box, 'No baffles' represents a box with a trap in its centre but no other modifications, while other treatments correspond to experimental baffle devices. These raw counts provide a straightforward view of the behavioural responses to each treatment before accounting for covariates or random effects in mixed-effects models.

Note on model fit results presented below

Although penalised GLMMs were used to mitigate issues associated with separation, some models fitted using standard maximum likelihood (e.g. via *glmer*) showed minor convergence warnings. This reflects the presence of extreme response probabilities in certain treatment groups, which can lead to flat likelihood surfaces and instability in parameter estimation. However, the magnitude and direction of effect estimates were consistent with those obtained from penalised models, suggesting that the biological interpretation of results is robust. Given the small deviation from convergence thresholds, these warnings are unlikely to materially affect inference, but they are acknowledged as a limitation associated with modelling near-separated data.

Table A2.3. Effects of trap entrance design, sex, and body mass on ship rat behaviour

SHIP RATS	pBaitTake				plnt				Time to interaction (s)			
	Odds Ratio	SE	95% CI	p-value	Odds Ratio	SE	95% CI	p-value	Estimate	SE	95% CI	p-value
No ends (Intercept)	1	1-1	NA	NA	1	1-1	NA	NA	3919.11	1130.37	2220.315 – 6917.6	NA
Control	3.653	2.225	1.107 – 12.052	0.033	49.509	49.13	7.079 – 346.239	<0.001	1.06	0.297	0.611 – 1.839	0.836
Plywood entrance hole	0.656	0.518	0.140 – 3.080	0.593	0.809	0.724	0.140 – 4.673	0.812	2.142	0.857	0.974 – 4.709	0.058
Small rough mesh	0.164	0.12	0.039 – 0.685	0.013	0.281	0.236	0.054 – 1.455	0.13	1.834	0.754	0.816 – 4.124	0.142
Small smooth mesh	0.226	0.166	0.053 – 0.953	0.043	0.809	0.724	0.140 – 4.673	0.812	2.311	0.905	1.068 – 4.997	0.033
Large rough mesh	0.161	0.117	0.039 – 0.672	0.012	0.179	0.148	0.035 – 0.906	0.038	1.718	0.707	0.764 – 3.863	0.19
Large smooth mesh	0.226	0.166	0.053 – 0.952	0.043	0.461	0.397	0.086 – 2.488	0.368	1.927	0.772	0.875 – 4.243	0.103
Stainless front	0.62	0.487	0.133 – 2.887	0.542	1.546	1.47	0.240 – 9.962	0.647	2.695	1.179	1.139 – 6.378	0.024
Stainless side	0.302	0.225	0.070 – 1.300	0.108	0.461	0.396	0.085 – 2.484	0.367	3.2	1.355	1.389 – 7.370	0.006
Horizontal rebar	0.164	0.119	0.039 – 0.682	0.013	0.117	0.097	0.023 – 0.591	0.009	1.894	0.801	0.823 – 4.358	0.133
Sex [Male]	0.152	0.108	0.038 – 0.612	0.008	0.362	0.481	0.027 – 4.898	0.445	1.468	0.294	0.989 – 2.178	0.057
weight c	0.974	0.015	0.945 – 1.004	0.092	0.987	0.033	0.924 – 1.055	0.707	1.008	0.004	1.001 – 1.015	0.034
Random Effects												
σ^2	3.29				3.29				1.06			
τ_{00}	2.00 _{ID}				10.99 _{ID}				0.10 _{ID}			
ICC	0.38				0.77				0.09			
N	20 _{ID}				20 _{ID}				20 _{ID}			
Observations	360				360				250			
Marginal R ² / Conditional R ²	0.369 / 0.608				0.299 / 0.839				0.146 / 0.221			

Notes: Results from mixed-effects models examining three responses: probability of taking bait (pBaitTake), probability of interacting with the trap (plnt), and time to first interaction (time to interaction, back-transformed to seconds). pBaitTake and plnt were analysed using penalised, generalised, linear mixed-effects models (binomial errors, logit link), while time to interaction was analysed using a linear mixed-effects model on log-transformed latency. Estimates are presented as odds ratios (OR) for pBaitTake and plnt, and as back-transformed time estimates (seconds) for time to interaction, with standard errors (SE), 95% confidence intervals (CI), and P-values. Random intercepts for individual ID accounted for repeated measures. Sex-specific, mean-centred body mass (weight_c) was included as a covariate. Odds ratios <1 indicate reduced probability relative to the 'No ends' treatment, while values >1 indicate increased probability.

Table A2.4. Effects of trap baffle design, sex, and body mass on ship rat behaviour

SHIP RATS	pBaitTake				plnt				Time to interaction (s)			
	Odds Ratio	SE	95% CI	p-value	Odds Ratio	SE	95% CI	p-value	Estimate	SE	95% CI	p-value
No baffles (Intercept)	1	1-1	NA	NA	1	1-1	NA	NA	4957.537	4424.4	846.979 – 29017.	NA
Control	170.091	122.193	41.608 – 695.315	<0.001	267.32	211.681	56.624 – 1262.021	<0.001	0.111	0.095	0.021 – 0.602	0.011
Flat wooden block	0.628	0.458	0.151 – 2.621	0.523	0.706	0.487	0.182 – 2.730	0.613	1.561	1.731	0.174 – 14.030	0.689
Galv mesh	0.303	0.241	0.064 – 1.438	0.133	0.989	0.676	0.259 – 3.772	0.988	3.105	3.444	0.345 – 27.913	0.309
Ramp	1.166	0.809	0.300 – 4.538	0.824	2.165	1.43	0.593 – 7.904	0.242	0.414	0.426	0.054 – 3.181	0.393
Ramp + Baffle	1.224	0.847	0.316 – 4.748	0.77	1.676	1.109	0.458 – 6.130	0.435	1.906	2.056	0.225 – 16.136	0.551
Stainless screen	0.04	0.045	0.004 – 0.360	0.004	0.357	0.264	0.084 – 1.521	0.164	2.488	2.951	0.237 – 26.060	0.444
Upright wooden block	0.621	0.45	0.150 – 2.567	0.51	0.503	0.358	0.124 – 2.032	0.335	4.778	6.099	0.382 – 59.821	0.223
Sex [Male]	0.913	0.682	0.211 – 3.946	0.903	0.695	0.464	0.188 – 2.572	0.586	2.061	0.988	0.798 – 5.323	0.134
weight c	0.979	0.014	0.953 – 1.007	0.142	0.975	0.012	0.951 – 0.999	0.038	1.028	0.008	1.012 – 1.044	0.001
Random Effects												
σ^2	3.29				3.29				2.64			
τ_{00}	2.43 _{ID}				1.68 _{ID}				0.63 _{ID}			
ICC	0.43				0.34				0.19			
N	20 _{ID}				20 _{ID}				20 _{ID}			
Observations	280				280				132			
Marginal R ² / Conditional R ²	0.626 / 0.785				0.642 / 0.763				0.378 / 0.498			

Notes: Results from mixed-effects models examining three responses: probability of taking bait (pBaitTake), probability of interacting with the trap (plnt), and time to first interaction (time to interaction, back-transformed to seconds). pBaitTake and plnt were analysed using penalised, generalised, linear mixed-effects models (binomial errors, logit link), while time to interaction was analysed using a linear mixed-effects model on log-transformed latency. Estimates are presented as odds ratios (OR) for pBaitTake and plnt, and as back-transformed time estimates (seconds) for time to interaction, with standard errors (SE), 95% confidence intervals (CI), and P-values. Random intercepts for individual ID accounted for repeated measures. Sex-specific, mean-centred body mass (weight_c) was included as a covariate. Odds ratios <1 indicate reduced probability relative to the 'No baffles' treatment, while values >1 indicate increased probability.

Table A2.5. Effects of trap entrance design, sex, and body mass on Norway rat behaviour

NORWAY RATS	pBaitTake				plnt				Time to interaction (s)			
	Odds Ratio	SE	95% CI	p-value	Odds Ratio	SE	95% CI	p-value	Estimate	SE	95% CI	p-value
Predictors												
No ends (Intercept)	1	1-1	NA	NA	1	1-1	NA	NA	474.81	256.414	163.820 – 1376.17	NA
Control	3.821	2.19	1.242 – 11.753	0.019	29.002	63.106	0.408 – 2063.344	0.122	1.801	0.944	0.641 – 5.059	0.263
Plywood entrance hole	2.086	1.849	0.367 – 11.849	0.407	1.116	1.939	0.037 – 33.633	0.95	2.546	1.717	0.674 – 9.617	0.167
Small rough mesh	0.04	0.031	0.008 – 0.188	<0.001	0.015	0.02	0.001 – 0.189	0.001	2.72	2.244	0.535 – 13.821	0.226
Small smooth mesh	0.114	0.085	0.027 – 0.492	0.004	0.081	0.103	0.007 – 0.994	0.049	5.877	5.036	1.086 – 31.798	0.04
Large rough mesh	0.161	0.119	0.038 – 0.684	0.013	0.04	0.051	0.003 – 0.483	0.011	5.127	3.958	1.120 – 23.469	0.035
Large smooth mesh	0.325	0.241	0.076 – 1.388	0.129	0.068	0.087	0.006 – 0.833	0.035	5.724	4.551	1.195 – 27.417	0.029
Stainless front	0.161	0.119	0.038 – 0.684	0.013	0.038	0.048	0.003 – 0.458	0.01	16.888	14.463	3.124 – 91.297	0.001
Stainless side	0.677	0.516	0.152 – 3.019	0.609	0.121	0.156	0.010 – 1.527	0.103	11.544	8.312	2.793 – 47.704	0.001
Horizontal rebar	1.618	1.33	0.323 – 8.103	0.558	0.156	0.204	0.012 – 2.025	0.156	2.723	2.002	0.639 – 11.597	0.174
Sex [Male]	12.748	10.935	2.373 – 68.485	0.003	0.071	0.064	0.012 – 0.417	0.003	2.067	0.783	0.979 – 4.362	0.057
weight c	1.003	0.006	0.991 – 1.015	0.646	0.985	0.006	0.973 – 0.997	0.014	0.998	0.003	0.993 – 1.003	0.464
Random Effects												
σ^2	3.29				3.29				3.83			
τ_{00}	3.33 _{ID}				3.03 _{ID}				0.35 _{ID}			
ICC	0.5				0.48				0.08			
N	20 _{ID}				20 _{ID}				20 _{ID}			
Observations	358				358				240			
Marginal R ² / Conditional R ²	0.371 / 0.687				0.649 / 0.817				0.137 / 0.209			

Notes: Results from mixed-effects models examining three responses: probability of taking bait (pBaitTake), probability of interacting with the trap (plnt), and time to first interaction (time to interaction, back-transformed to seconds). pBaitTake and plnt were analysed using penalised, generalised, linear mixed-effects models (binomial errors, logit link), while time to interaction was analysed using a linear mixed-effects model on log-transformed latency. Estimates are presented as odds ratios (OR) for pBaitTake and plnt, and as back-transformed time estimates (seconds) for time to interaction, with standard errors (SE), 95% confidence intervals (CI), and P-values. Random intercepts for individual ID accounted for repeated measures. Sex-specific mean-centred body mass (weight_c) was included as a covariate. Odds ratios <1 indicate reduced probability relative to the 'No ends' treatment, while values >1 indicate increased probability.

Table A2.6. Effects of trap baffle design, sex, and body mass on Norway rat behaviour

NORWAY RATS	pBaitTake				plnt				Time to interaction (s)			
	Odds Ratio	SE	95% CI	p-value	Odds Ratio	SE	95% CI	p-value	Estimate	SE	95% CI	p-value
<i>Predictors</i>												
No baffles (Intercept)	1	1-1	NA	NA	1	1-1	NA	NA	2305.854	2731.8	220.230 – 24142.	NA
Control	17.111	8.853	6.207 – 47.170	<0.001	131.965	101.115	29.393 – 592.476	<0.001	0.712	0.821	0.072 – 7.002	0.769
Flat wooden block	3.085	1.965	0.885 – 10.752	0.077	2.517	1.722	0.659 – 9.619	0.177	0.508	0.753	0.027 – 9.593	0.649
Galv mesh	0.186	0.145	0.040 – 0.860	0.031	0.205	0.157	0.046 – 0.922	0.039	0.894	1.726	0.019 – 41.094	0.954
Ramp	2.424	1.531	0.703 – 8.360	0.161	2.497	1.708	0.654 – 9.540	0.181	0.164	0.257	0.007 – 3.681	0.252
Ramp + Baffle	0.713	0.464	0.199 – 2.553	0.603	0.79	0.541	0.207 – 3.021	0.73	0.388	0.662	0.013 – 11.407	0.58
Stainless screen	0.108	0.095	0.019 – 0.606	0.011	0.133	0.108	0.027 – 0.657	0.013	1.388	2.681	0.030 – 63.807	0.865
Upright wooden block	0.541	0.361	0.146 – 1.998	0.357	0.582	0.404	0.149 – 2.270	0.436	0.128	0.248	0.003 – 5.897	0.29
Sex [Male]	2.928	1.626	0.986 – 8.697	0.053	2.786	2.179	0.601 – 12.907	0.19	1.707	1.061	0.498 – 5.855	0.392
weight c	1.005	0.004	0.996 – 1.013	0.275	1.012	0.007	0.999 – 1.025	0.061	1.006	0.004	0.998 – 1.015	0.164
Random Effects												
σ^2	3.29				3.29				4.85			
τ_{00}	1.10 _{ID}				2.82 _{ID}				0.72 _{ID}			
ICC	0.25				0.46				0.13			
N	20 _{ID}				20 _{ID}				16 _{ID}			
Observations	280				280				119			
Marginal R ² / Conditional R ²	0.457 / 0.593				0.579 / 0.773				0.055 / 0.177			

Notes: Results from mixed-effects models examining three responses: probability of taking bait (pBaitTake), probability of interacting with the trap (plnt), and time to first interaction (time to interaction, back-transformed to seconds). pBaitTake and plnt were analysed using penalised, generalised, linear mixed-effects models (binomial errors, logit link), while time to interaction was analysed using a linear mixed-effects model on log-transformed latency. Estimates are presented as odds ratios (OR) for pBaitTake and plnt, and as back-transformed time estimates (seconds) for time to interaction, with standard errors (SE), 95% confidence intervals (CI), and P-values. Random intercepts for individual ID accounted for repeated measures. Sex-specific, mean-centred body mass (weight_c) was included as a covariate. Odds ratios <1 indicate reduced probability relative to the 'No baffles' treatment, while values >1 indicate increased probability.

Appendix 3 – Rat information

SPECIES	GROUP	RAT ID	SEX	WEIGHT (G)
SHIP RAT	1	1	Male	182.7
SHIP RAT	1	2	Male	200.2
SHIP RAT	1	3	Male	185.3
SHIP RAT	1	4	Male	208.9
SHIP RAT	1	5	Male	216.9
SHIP RAT	1	6	Female	123.5
SHIP RAT	1	7	Female	159.9
SHIP RAT	1	8	Female	163.9
SHIP RAT	1	9	Female	97.6
SHIP RAT	1	10	Female	116.3
SHIP RAT	2	11	Male	147
SHIP RAT	2	12	Male	201.7
SHIP RAT	2	13	Male	170.8
SHIP RAT	2	14	Male	176.5
SHIP RAT	2	15	Female	197.5
SHIP RAT	2	16	Female	175.1
SHIP RAT	2	17	Female	116.2
SHIP RAT	2	18	Female	133.5
SHIP RAT	2	19	Female	174.3
SHIP RAT	2	20	Female	166.5
NORWAY RAT	1	1	Male	314
NORWAY RAT	1	2	Male	374
NORWAY RAT	1	3	Male	343
NORWAY RAT	1	4	Male	289
NORWAY RAT	1	5	Male	234
NORWAY RAT	1	6	Female	405
NORWAY RAT	1	7	Female	186
NORWAY RAT	1	8	Female	166
NORWAY RAT	1	9	Female	360
NORWAY RAT	1	10	Female	281
NORWAY RAT	2	11	Male	392
NORWAY RAT	2	12	Male	338
NORWAY RAT	2	13	Male	476
NORWAY RAT	2	14	Male	357
NORWAY RAT	2	15	Male	343
NORWAY RAT	2	16	Female	275
NORWAY RAT	2	17	Female	410
NORWAY RAT	2	18	Female	391
NORWAY RAT	2	19	Female	331
NORWAY RAT	2	20	Female	224