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RESEARCH

# Toxin-laced rat carcass baits for stoat elimination

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**Abstract:** Stoats are implicated in the severe decline of certain iconic endemic species in New Zealand. Stoats are notoriously difficult to control, as they are highly cryptic and often neophobic around control techniques such as traps and poison baits in tunnels. Stoats are often killed through secondary poisoning in both aerial and hand-lay operations targeting other mammalian pests. We prototype trialled a novel approach to poisoning of stoats: wild-caught ship rats that had consumed (and subsequently died from) a lethal dose of 1080 cereal baits in a captive facility. Stoats in the treatment area were targeted at food-lured (egg mayonnaise) camera trap sites that had multiple stoat visitations prior to baiting with toxic rat carcasses. Stoats were recorded taking toxic rat carcass baits from 7 out of 15 hand-laid sites. No other species were observed taking toxic rat carcasses during the study. The number of cameras in the treatment area that detected stoats was significantly reduced for 30 days after toxic baiting. There was no significant difference in number of cameras that detected stoats during this period in the non-treatment area. These results suggest that 94% of the stoats in the treatment area were poisoned using toxin-laced rat carcasses within one week of baiting. Toxic rat carcass baits placed at locations of known stoat activity may be a highly successful method of eliminating individual stoats at very low density.

**Keywords:** 1080, camera traps, sodium fluoroacetate, stoats, wildlife management

## Introduction

New Zealand's ambitious goal of becoming predator free by 2050 has put an increased focus on mainland eradication (Russell et al. 2015; Bell et al. 2019); and a suite of tools and techniques will be required to achieve this objective (Murphy et al. 2019). Stoats (*Mustela erminea*) are implicated in the severe decline of many native New Zealand species (King et al. 2021); and they are a target species in the Predator Free 2050 initiative (Russell et al. 2015). Stoats are notoriously cryptic, wide-ranging, and difficult both to trap and to keep out of cleared areas (Smith & Weston 2017). Thus, their eradication from sites so far has been limited to offshore islands where the risk of reinvasion is low and or manageable (Elliott et al. 2010; Edge et al. 2011).

Different vertebrate toxins have been trialled for use on stoats such as Para-aminopropiophenone (PAPP), diphacinone, and sodium fluoroacetate (1080); in meat baits, hen eggs, and mayonnaise (Spurr et al. 1998; Potter et al. 2006; Dilks et al. 2011). Para-aminopropiophenone and 1080 have shown the most success in these trials. Currently, PAPP is the only toxin registered for use on stoats, and delivery methods continue to be tested (Murphy et al. 2018). However, at the time of this study, the authors were not aware of any toxic baits registered for stoats for use outside of a bait station. Stoats are known to be killed after 1080 operations by secondary poisoning through consumption of poisoned pest species: ship rats (*Rattus rattus*), house mouse (*Mus musculus*), and possums (*Trichosurus vulpecula*) (Murphy et al. 1999; Dilks et al. 2020). Overseas, toxin-laced mouse carcasses have been used successfully for the eradication of brown tree snakes (*Boiga irregularis*) (Savarie et al. 2001; Clark et al. 2018).

In the current study, we conducted a preliminary field trial to evaluate toxic (poisoned with 1080) rat carcass baits for eliminating those stoats that reinvaded after a 1080 operation at a site in South Westland, New Zealand.

An aerial 1080 operation conducted the previous year (2019) removed all detected resident stoats from the current field site through secondary poisoning (Nichols et al. 2021). After the first phase of the 2019 complete predator elimination operation, zero stoats were detected for seven months. During the summer season following the operation, stoats reinvaded the research area over the western river boundary. As the management aim for the Perth River Valley research and development site is to become predator free, this preliminary field trial was conducted as a response to the stoat reinvasion. We assumed consumption of poisoned rodents was the primary cause of poisoning of stoats during the 2019 elimination operation. However, there was uncertainty as to whether stoats would be as equally attracted to dead rodents rather than mobile rodents in the process of dying.

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# Methods

## Study area

The Perth River Valley study area (43.2616° S, 170.3590° E) spans approximately 10 000 ha in the wider Whataroa valley in South Westland, New Zealand. Vegetation in the study area consists mostly of indigenous forest, including southern rātā (*Metrosideros umbellata*), rimu (*Dacrydium cupressinum*), and kāmahi (*Weinmannia racemosa*) from 200 m to 1100 m a.s.l. The portion of site used for the treatment area (the western boundary—3500 ha) had the highest rate of stoat activity as detected by cameras. Although the non-treatment area (the eastern boundary—3400 ha) had some cameras detecting stoats, activity was low relative to the treatment area. The treatment and non-treatment areas were largely separated by high mountains that should act as a barrier to movement, with any connection between the areas likely limited along the 2 km separation along the Perth River.

## Toxic rat carcass baits

Wild-caught ship rats ($n = 20$) were acclimatised to captivity at the Johnstone Memorial Laboratory facilities ahead of toxin loading. Ship rats were pre-fed twice with non-toxic 6 g double cinnamon-lured RS5 cereal baits ahead of offering 0.15% 1080 6 g double cinnamon-lured RS5 cereal baits. All rats were offered 20 g of cereal bait (per pre-feed and toxin) alongside a reduced quantity of their normal laboratory diet with water ad libitum. Rats were monitored at regular intervals daily for the duration of the laboratory phase. Five rats did not consume a lethal dose of 1080 and were subsequently euthanised. The 15 lethally dosed rats had consumed a mean of 1.48 g (0.6–4.6 g) of toxic cereal bait.

Regulatory permissions including animal ethics committee approval (Lincoln University AEC 2020-04), Department of Conservation approval, Ministry of Health approval, hazardous substance manufacture (Environmental Protection Agency approval HSC100238), and research approval (Ministry for Primary Industries V009665) were obtained to manufacture and field trial rat carcass baits.

## Lured camera traps

Camera traps are commonly used to measure the results of wildlife management operations (Nugent et al. 2019; Dilks et al. 2020; Nichols et al. 2021). For this trial, we examined 128 camera traps (Browning Dark Ops, Prometheus Group, Birmingham, Alabama) (64 in the treatment area and 48 in the non-treatment area) with c. 500-m spacing between devices on cut tracks, at altitudes ranging from 200−1200 m asl (Fig. 1).

All cameras were mounted on trees (or steel fence posts as required above the treeline) with the base of each camera 45 ± 10 cm from the ground (Nichols et al. 2021). Cameras were set to take a series of three images per trigger, with minimum delay between triggers. Cameras were lured with egg mayonnaise dispensed from automated lure dispensers, known as MotoLures (ZIP 2019; Nichols et al. 2021). MotoLures were mounted on trees (or steel fence posts as required above the treeline) approximately 1.5 m directly in front of the camera's field of view to increase the chance of stoats being detected (Glen et al. 2013). The lured camera sites were continuously in use from the previous year (Nichols et al. 2021); however,

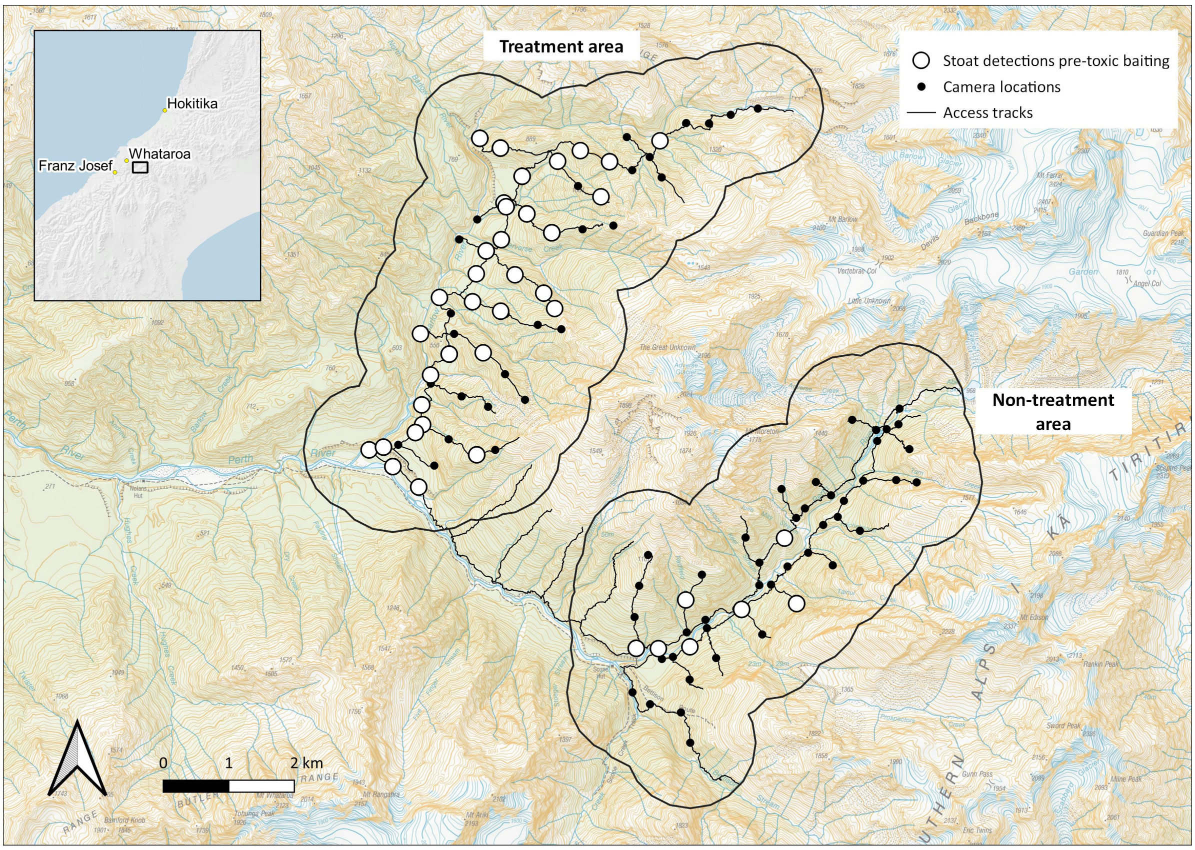


**Figure 1.** Lured camera traps ($n = 112$) in the Perth River Valley research area 2020. Cameras were spaced approximately 500 m apart, at 200–1200 m asl. Stoat detections shown are pre-toxic baiting. The treatment and non-treatment areas are outlined with a 1-km buffer.

surveys for the current study were taken for 30 days before (June–July) and after baiting (July–August).

### Distribution

Stoats were observed at multiple camera trap sites repeatedly visiting to consume the automatically dispensed egg mayonnaise. Toxic baits (dead, toxin-laden rats) were placed strategically at camera traps with recent and repeated (at least two visits within the previous two weeks) stoat detections. A detection is defined here as a '1' or '0' per 24-hr period at a camera. At each of the selected camera sites ($n = 15$), a single toxic dead rat was hand-laid and checked at least once per 10 days for the duration of the field trial. Each toxic bait site was continuously monitored by a camera trap. Any toxic baits not taken by the completion of the field trial (30 days after hand lay) were disposed of by burial at GPS-marked locations within the field trial site.

### Analysis

We used camera traps to observe stoat detections (Rowcliffe et al. 2014) before and after baiting in both the treatment and non-treatment areas of site. Detections were recorded as '1' or '0' per 24-hr period, taken from midnight to midnight.

Two-tailed Fisher's exact tests of the odds ratio (Sokal & Rohlf 1981):

$$\theta = p_1(1 - p_0) / (p_0 (1 - p_1)) \quad (1)$$

were used to test whether there was a difference in the number of cameras detecting stoats before and after baiting. Results with $P < 0.05$ were deemed statistically significant.

Occupancy modelling was not deemed appropriate for this study as sample sizes of detections were very small after baiting.

## Results

Live stoats were recorded on 33 out of 64 cameras in the treatment area, and 7 out of 48 in the non-treatment area before the baiting period (Fig. 1; Table 1). Stoats were observed taking toxic bait (toxic rat carcasses) from 7 out of the 15 toxic bait sites in the treatment area (Fig. 2). One stoat was observed at a toxic bait site a week after toxic bait had already been taken by a stoat. At another toxic bait site, a stoat ignored the toxic bait entirely. Stoats were not detected again at the toxic bait sites that had been taken by stoats. After the toxic baiting period, stoats were recorded on 2 out of 64 cameras in the treatment area (Fig. 2; Table 1), a reduction of 94%; resulting in a Fisher's exact test odds ratio of $P < 0.001$. After the same toxic baiting period, stoats were recorded on 5 out of the 48 cameras in the non-treatment area (Fig. 2; Table 1), a reduction of 29%. However, throughout this trial the number of cameras detecting stoats in the non-treatment was very low relative to the treatment area.

The non-target species recorded on cameras during the survey period included morepork (ruru: *Ninox novaeseelandiae*) and kea (*Nestor notabilis*). No interactions were recorded by non-target species with the toxic baits during this field trial.

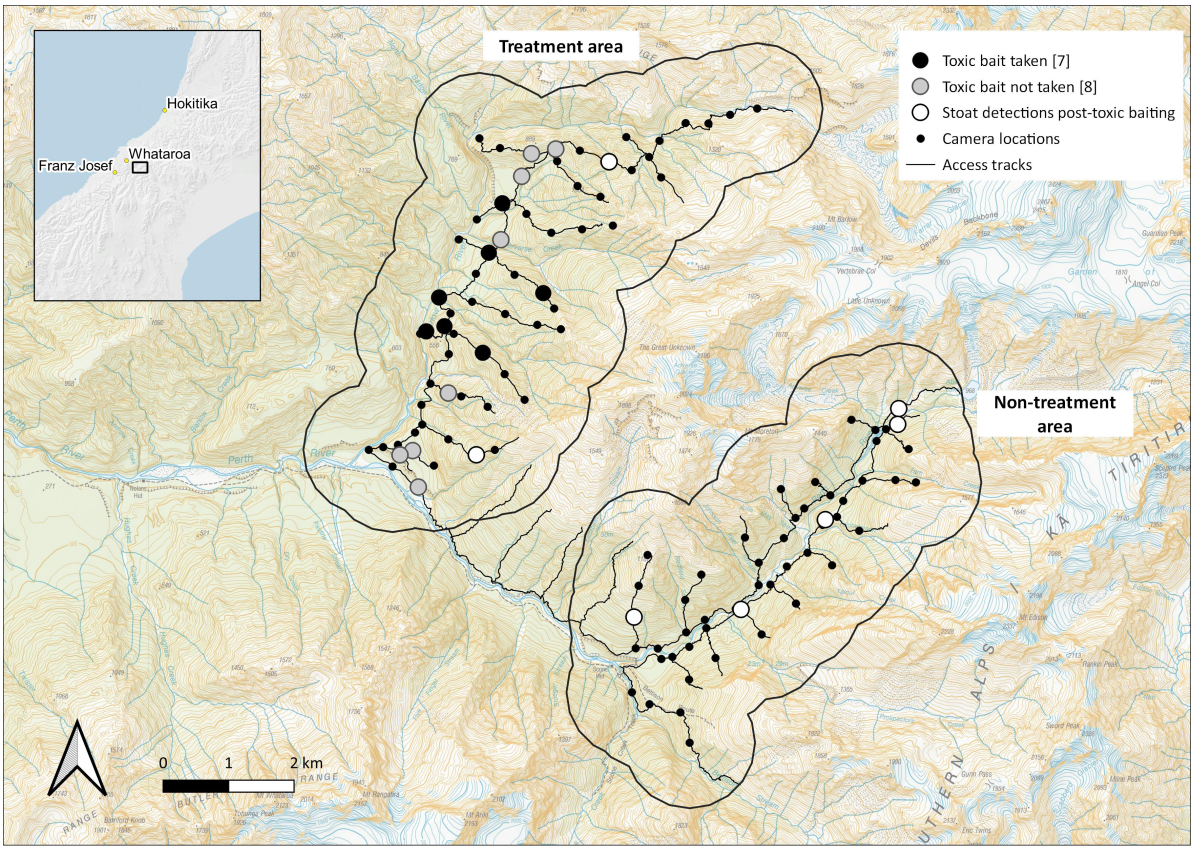


**Figure 2.** Stoat detections shown are post-toxic baiting in both the treatment and non-treatment area. Toxic baits taken ($n = 7$) and not taken ($n = 8$) are shown.

**Table 1.** The number of cameras that detected stoats before and after toxic baiting in the treatment and non-treatment areas within the Perth River Valley research area 2020. Two-tailed Fisher's exact test *P*-values show the results of statistical comparison of detections of stoats before and after toxic baiting. Asterisks denote significant values.

| Site | Pre-baiting period | Post-baiting period | Fisher exact test *P*-value |
|---|---|---|---|
| Treatment | 32 | 2 | < 0.01* |
| Non-treatment | 6 | 5 | 1 |

## Discussion

Stoats are notoriously difficult to detect and control, requiring a range of techniques (Dilks et al. 1996; Murphy et al. 2014; Smith & Weston 2017). Stoats are known to have individual dietary preferences (Murphy & Dowding 1994; Smith et al. 2008), and thus a range of options for toxic baits is also required. This study is the first to target stoats with 1080-poisoned rats.

Prior to hand-lay, stoats were seen repeatedly visiting cameras within the treatment area. We attribute the success of the targeted placement of toxic rat carcass baits partially to the extensive pre-feeding of these sites (albeit with a different food lure). Stoats were regularly seen consuming egg mayonnaise on camera, and at one location, consuming the egg mayonnaise before taking the toxic rat carcass bait. Toxic bait sites were chosen based on high numbers of recent and repeated visits by stoats. All seven toxic rat carcass baits were taken within a week of distribution. Two sites had bait taken the same day they were hand-laid. The lack of camera detections across the treatment area, particularly at the toxic rat carcass bait sites after the baiting period, suggests that a single toxic rat carcass bait was enough to kill a single stoat.

This study was driven by management outcomes (creating and protecting a predator free site) at the Perth Valley research area. As such, the non-treatment site was selected as the experimental control as camera detections suggested there were very few stoats active in this area and hence would not enable us to fully examine the potential of the method. When stoats reinvaded the site after a predator elimination operation in 2020, they appeared to repeatedly visit sites in the Barlow river area (treatment site). In the non-treatment area, the few stoats that were seen on cameras were present, but not repeatedly visiting lured camera sites as often. We acknowledge the much lower numbers of stoat detections in the non-treatment area limits the strength of our experimental control. However, we consider that any process external to our experiment that could have reduced stoat activity so dramatically in the treatment area would have been detectable in the non-treatment area even with the lower levels of stoat activity. Therefore, we feel confident that the reduction in stoat activity in the treatment area was a result of the toxic rat baits.

While stoats are capable swimmers and able to cross rivers readily (Murphy & Dowding 1994; Veale 2013), the fast-flowing river perimeter of the field site is thought to slow reinvasion (Nichols et al. 2021). Thus, we assume that the stoats detected at the two locations within 30 days after baiting were either survivors, or may not have encountered a bait. During the baiting period there was on only one occasion when a stoat detected by a camera did not take bait.

Overall, the results of this field trial suggest using toxic rat carcass baits is a promising technique that has wider implications for the elimination of stoats from islands and mainland sites. We do not foresee this toxic bait being used as a landscape-scale control method. Rather, like the management context in this study, we expect toxic rodents in the future to be used in conjunction with lured detection tools to allow a highly targeted elimination of individual stoats. Within the treatment area we saw a significant drop in stoat activity with as few as 15 toxic rat carcasses per 3500 ha, or 1 toxic rat carcass per c. 2 $km^2$. However, this coverage was possible due to the extensive pre-feeding of camera detection sites allowing us to better understand the distribution of stoats at site.

### Future research

While this preliminary field trial was highly successful in reducing stoat detections, future research may further refine this technique. Advancements may be made in terms of reducing labour involved (i.e. animal husbandry and time to offer rats toxic baits), animal welfare of the rodents used, and efficacy through control of the toxin dosage per carcass bait. This is currently under investigation with wild caught mouse carcass baits, which are injected with 1080 solution after humane euthanasia, rather than through consumption of toxic cereal baits.

## Acknowledgements

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## Author contributions

MN, JD, and AE designed the study. JD manufactured toxic rats. AE led the field trial. MN analysed the results. MN, JD, and AE wrote the manuscript.

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