Diphacinone bait for ground control of rats on mainland conservation land

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Cover: A Philproof possum bait station and a rodent tracking tunnel at Boundary Stream Mainland Island, 1997. *Photo: Alan J. Saunders, DOC Image Collection.*

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ABSTRACT

The objective of this project was to test the field efficacy of the first-generation anticoagulant rodenticide diphacinone (at a concentration of 0.05 g/kg) in Sentinel™ blocks and Pestoff® 50D pellet baits using currently accepted best practice rat (ship rat *Rattus rattus*, and Norway rat *R. norvegicus*) control techniques at Mapara, Whirinaki, Trounson, Moehau and Boundary Stream, New Zealand. The Sentinel™ blocks effectively controlled rats to below target indices of abundance at Mapara and Whirinaki after two baiting rounds. The inclusion of Feratox® capsules in the Sentinel™ blocks not only offset the problem of possum (*Trichosurus vulpecula*) interference with the baits, but also reduced possum abundance at the Whirinaki site. The Pestoff® 50D pellet baiting operation at Trounson successfully controlled rats to below target indices, and at Boundary Stream continued to suppress rats to non-detectable levels. However, at Moehau, the Pestoff® 50D pellet baiting operation failed to reduce rat abundance, possibly because of interference by possums. Based upon the results from the trials at Mapara and Whirinaki, we have recommended that Feral R&D pursue registration for diphacinone to be used in the Sentinel™ blocks; however, more field trials are needed before any such recommendation can be made for the Pestoff® 50D pellets.

Keywords: diphacinone, rodent control, rat, *Rattus rattus*, *R. norvegicus*, bait, possum, *Trichosurus vulpecula*

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1. Introduction

Up until the late 1990s, the second-generation anticoagulant rodenticide brodifacoum was the poison most commonly used by Department of Conservation (DOC) staff for controlling rats (ship rats *Rattus rattus*, and Norway rats *R. norvegicus*) on the New Zealand mainland. However, brodifacoum is a cumulative toxin that persists in the tissue of sub-lethally poisoned animals, including non-target native wildlife; furthermore, it poses a risk to human health through consumption of contaminated game meat (Eason 1999). In an attempt to reduce these risks, a DOC policy came into force in October 2000, which placed restrictions on the use of brodifacoum (and other second-generation anticoagulants) on the New Zealand mainland conservation estate (DOC 2000). Since then, warfarin and pindone, which are both less persistent first-generation anticoagulant rodenticides, have been trialled at several sites on the New Zealand mainland. However, results have been variable (Gillies 2002), possibly because they are less toxic to rats than the second-generation formulations (Eason & Wickstrom 2001). The first-generation anticoagulant diphacinone is used outside New Zealand, especially in Hawaii (Dunlevy & Campbell 2000; Nelson et al. 2002), because it is effective against rats, but does not pose a significant risk to native avian predators through secondary poisoning (Lindsey & Mosher 1994). Diphacinone is more toxic to rats than warfarin or pindone (Eason & Wickstrom 2001), but is less persistent in animal tissues than brodifacoum (Fisher et al. 2003). Thus, diphacinone has the potential to be a useful option for controlling rats on the New Zealand mainland, or at least as an additional tool for supplementing other control options (e.g. trapping and acute poisons such as 1080—sodium monofluoroacetate).

Diphacinone is currently only registered and commercially available in New Zealand for rodent control (at a concentration of 0.05 g/kg) in the 'Ditrac® all weather rodent block' (Animal Compounds and Veterinary Medicines (ACVM) no. V4538). The objective of this project was to determine whether diphacinone[1] applied using currently accepted best-practice rat control techniques, could reduce rat abundance indices to target levels of 5% or less of tracking tunnels (King & Edgar 1977) tracked by rats.

[1] At a concentration of 0.05 g/kg, in two alternative bait matrices: the Feral R&D Ltd Sentinel™ block, and ACP Ltd Pestoff® 50D pellet baits.

2. Methods

We tested two types of diphacinone rodent baits during this trial: the Sentinel™ block (Feral R&D Ltd, Auckland, New Zealand), and the Pestoff® 50D pellet (Animal Control Products Ltd, Wanganui, New Zealand). The Sentinel™ rodent block was chosen as it is popular with many pest managers because Feratox® (potassium cyanide) capsules can be incorporated into the block to reduce possum (*Trichosurus vulpecula*) interference with the rat bait. We also decided to test the Pestoff® cereal-pellet baits because these (containing other toxins) have been successfully used by DOC staff for rodent control on the New Zealand mainland. However, neither of these bait matrices are registered to contain diphacinone for rodent control, so the trials needed to be carried out following the ACVM group guidelines for efficacy studies for product registration (NZFSA 2002). The trials were carried out as a series of five stand-alone case studies, and were completed between October 2003 and January 2005.

2.1 STUDY SITES

The trial sites were not chosen at random; they were selected based on responses to a general request for study areas that was made on the DOC internal email system. The request required that these trial sites should be places where the local staff were planning to carry out rodent control using anticoagulants to DOC best-practice standards, to monitor the results using tracking tunnels, and were prepared to test one of the two trial diphacinone baits as an alternative to what they had originally been intending to use. Furthermore, we required study sites where possum abundance was low, especially for the diphacinone Pestoff® 50D trials.

We selected five trial sites that met our basic criteria and at which there were local staff with experience in using anticoagulants to control rodents. We tested the diphacinone Sentinel™ blocks at Mapara and Whirinaki, and the diphacinone Pestoff® 50D pellet baits at Trounson, Moehau and Boundary Stream. Since the trials were carried as a series of stand-alone case studies, a matched non-treatment site was required for each trial site in order to meet the ACVM group guidelines (NZFSA 2002).

2.1.1 Mapara

Mapara Scenic Reserve is situated c. 27 km south-east of Te Kuiti in the central North Island (Fig. 1). The area of the reserve under management comprises 1427 ha of mostly lowland tawa (*Beilschmiedia tawa*)–podocarp (*Podocarpus totara*)–broadleaf (Poole & Adams 1994) forest on rolling hill country (elevation 260–611 m a.s.l.). The non-treatment comparison site for this trial was Waipapa-east in Pureora Forest Park, located c. 30 km east of Mapara.

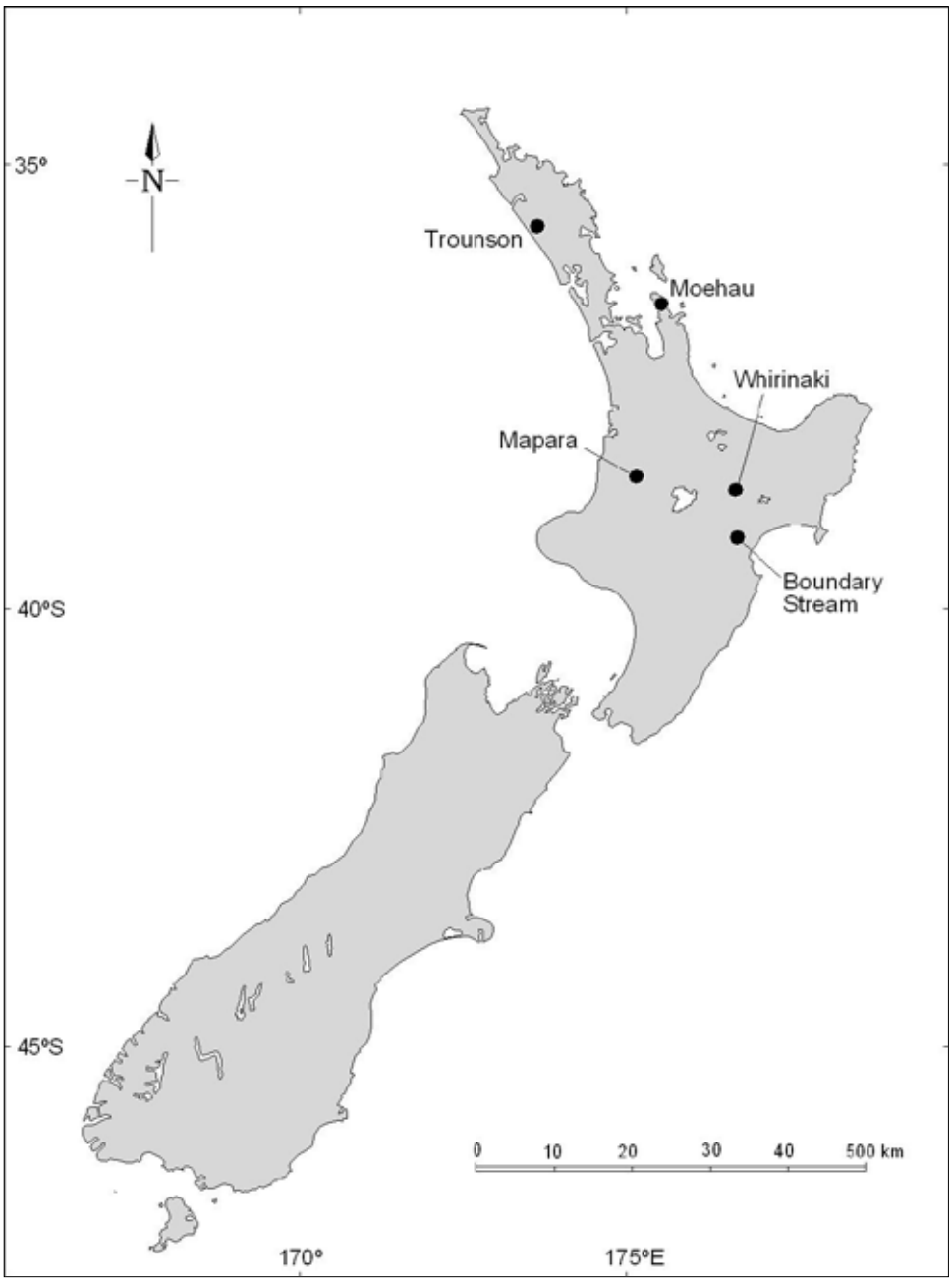


Figure 1. Map of New Zealand showing the locations of the sites where the diphacinone trials took place.

2.1.2 Whirinaki

Whirinaki Forest Park is situated c. 50 km east of Taupo in the eastern-central North Island (Fig. 1). The Sentinel™ trial was carried out over 220 ha of mixed tawa (*Beilschmiedia tawa*)–podocarp (*Podocarpus totara*)–broadleaf (Poole & Adams 1994) forest (elevation 400–576 m a.s.l.) within the 54 921 ha Forest Park. The non-treatment comparison site for this trial was in an adjacent 300-ha block.

2.1.3 Trounson

Trounson Kauri Park is located c. 36 km north of Dargaville on the west coast of the North Island (Fig. 1). The management area comprises 445 ha of mixed kauri (*Agathis australis*)–podocarp (*Podocarpus totara*)–broadleaf (Poole &

Adams 1994) forest (elevation 150–300 m a.s.l.), mostly surrounded by grazed pastureland except for the north-eastern edge, which is adjacent to a pine forest (*Pinus radiata*). The non-treatment comparison site for this trial was Katui Scenic Reserve, 6.5 km west of Trounson.

2.1.4 Moehau

The Moehau Ecological Area is situated at the northern end of the Coromandel peninsula, c. 70 km north of Thames on the east coast of the North Island (Fig. 1). The Pestoff® 50D trial was carried out over 350 ha of mixed regenerating kauri (*Agathis australis*)–podocarp (*Podocarpus totara*)–broadleaf (Poole & Adams 1994) forest and coastal pohutukawa (*Metrosideros excelsa*) forest in the Stony Bay area on the eastern side of the Moehau range (elevation 0–500 m a.s.l.). The non-treatment comparison sites for this trial were Doctor's Bay, which is 1.5 km from the Moehau management area, and Papa Aroha, which is c. 2 km away.

2.1.5 Boundary Stream

The Boundary Stream Scenic Reserve is situated c. 60 km north-west of Napier on the east coast of the North Island (Fig. 1). The management area consists of 800 ha of mixed tawa (*Beilschmiedia tawa*)–podocarp (*Podocarpus totara*)–broadleaf (Poole & Adams 1994) and beech (*Nothofagus* sp.) forest (elevation 300–1000 m a.s.l.), surrounded by grazed pastureland. The non-treatment comparison sites for this trial were Thomas Bush (Opouahi Scenic Reserve), which is situated 1 km south of Boundary Stream, and Cashes Bush, which is situated c. 5 km south-west of Boundary Stream.

2.2 SENTINEL BLOCK TRIALS

The Sentinel™ was designed to be a 'stand alone', disposable poison bait station, which could be attached to a tree or post and would not require recovery at the end of the operation. Each Sentinel™ block consisted of a c. 40 mm diameter cylinder of Ferafeed Plus® hard bait, which was dyed green and laced with diphacinone at a concentration of 0.05 g/kg. The individual Ferafeed Plus® baits were enclosed within blue waxed cardboard tubes, which were open at both ends and had a cardboard tongue extending off one side, enabling the Sentinel™ to be attached to a tree or post without damaging the bait (Fig. 2). The Sentinel™ blocks came in two sizes: the full-size 300 g block (which could contain two Feratox® capsules if required), and the half-size 150 g block; both types were used in each trial. The Sentinel™ blocks were purchased from Feral R&D, who marketed these under the 'Pest Gone rodent bait' label (ACVM no. P3392). The Ferafeed Plus® hard bait formulation is not the same as the 'Pest Gone rodent bait' and is not shown on

Figure 2. A half-size Feral R&D Ltd diphacinone Sentinel™ block. Length of cardboard tube is 100 mm. *Photo courtesy of D. MacMorran (Connovation Ltd, Auckland, New Zealand).*

the product label, but Feral R&D notified us in writing that they had permission from the ACVM group to carry out palatability and efficacy studies in the field that did not require animal ethics committee approval.

2.2.1 Baiting technique

At both sites, the diphacinone Sentinel™ blocks were attached (at c. 350 mm above the ground) to tree trunks every c. 50 m along bait-station lines, which were spaced c. 125–200 m apart throughout the treatment areas. The first round of baiting used full-size diphacinone 300 g blocks, each containing Feratox® capsules. Follow-up (and subsequent) baiting to replace eaten baits, and to treat areas or lines missed on the first round, used either half-size or full-size blocks without Feratox® capsules (Table 1).

TABLE 1. DETAILS OF THE BAITING METHODOLOGY EMPLOYED AT EACH OF THE STUDY SITES.

SITE	AREA (ha)	BAIT TYPE TRIALLED*	BAIT STATION/BLOCK LAYOUT† (m)	MONTH–YEAR POISON BAITS LAID	NUMBER OR BLOCKS OR BAIT STATIONS USED × AMOUNT OF BAIT USED (g)
Mapara	1427	Sentinel™ blocks	50 × c. 150–200	Oct–2003 Nov–2003	1746 × 300 g blocks‡ Follow-up: any baits from the Oct. round that were more than 50% eaten were replaced with 150 g blocks (n = 2287)
Whirinaki	220	Sentinel™ blocks	50 × 125 50 × 125 (+ 1 roadside line on eastern boundary)	Sept–2003 Oct–2003 Nov–2003	338 × 300 g blocks‡ 378 × 300 g blocks Follow-up: any baits from the Oct. round that were more than 50% eaten were replaced with 150 g blocks (n = 173)
Trounson§	445	Pestoff® 50D pellets in Philproof feeder stations	50 × 100	Apr–2004 Jun–2004 Aug–2004	c. 900 × 200 g c. 900 × 200 g c. 900 × 200 g
Moehau (Stock track plus Shag Bay)	365 (165 + 200)	Pestoff® 50D pellets in Philproof feeder stations	75 × 75	Feb–2004 Feb–2004 May–2004 May–2004 Jun–2004 Jun–2004	787 × 250 g 787 × 200 g (follow up) 376 × 300 g (Stock track only) 376 × 200 g (Stock track follow up) 411 × 300 g (Shag Bay only) 411 × 200 g (Shag Bay follow up)
Boundary Stream §	800	Pestoff® 50D pellets in Philproof feeder stations	150 × 150 (internal lines) Stations also set every 100 m around edge of reserve (perimeter line)	Dec–2003 Feb–2004 Apr–2004 May–2004	567 × 250 g 567 × 250 g (top up as required) 567 × 250 g (top up as required) 350 × 250 g (internal lines only, top up as required)

* Diphacinone 0.05 g/kg.

† Spacing along line (m) × distance between lines (m).

‡ Each Sentinel™ also contained two Feratox® (potassium cyanide) capsules to target any possums (*Trichosurus vulpecula*) that might have interfered with the baits.

§ Possums controlled at these sites using Feratox® as part of ongoing pest control work not related to this trial.

2.3 PESTOFF 50D BAIT TRIALS

The Pestoff® 50D pellets (Fig. 3) are smaller than the Sentinel™ block and are designed to be used in permanent bait stations; any uneaten baits left at the end of the operation are removed. The individual Pestoff® 50D cereal-based pellets were cylindrical (c. 20 mm in diameter), weighed 6 g, were dyed green and were laced with diphacinone at a concentration of 0.05 g/kg. The three trial sites (Trounson, Moehau and Boundary Stream) were selected because they all had existing networks of possum and rodent bait stations in place. Animal ethics approval to undertake the diphacinone Pestoff® 50D bait trials was granted by the DOC animal ethics committee (AEC 95), and the work was carried out under ACVM research approval number A009267.

Figure 3. ACP Ltd Pestoff® baits. *Photo: P. Tyree. Crown Copyright: Department of Conservation* Te Papa Atawhai *(2001).*

2.3.1 Baiting technique

At all three sites, 200–300 g of diphacinone Pestoff® 50D pellets were placed in Philproof feeder bait stations (Philproof Pest Control Products, New Zealand), which were attached (with the bases c. 150 mm above the ground) to trees (Fig. 4). Depending on the site, these bait stations were placed at 50 m, 75 m, or 150 m intervals along lines that were spaced between 75 m, 100 m, or 150 m apart across each treatment area (see Table 1).

Figure 4. Philproof Pest Control Products bait station at Trounson Kauri Park.

2.4 RODENT AND POSSUM MONITORING

At each treatment site and the relevant non-treatment sites, ink footprint tracking tunnel surveys were conducted prior to and throughout each poison operation to monitor the effect of the diphacinone baits or blocks on rodent relative abundance. Individual tunnels were baited with peanut butter and spaced every 50 m along randomly orientated lines; however, the number of tunnels and lines used varied between sites (Table 2). Each survey was conducted over one fine night and the results were expressed as the mean percentage of tunnels that contained rat tracks (Gillies & Williams 2003). The tracking tunnel data were analysed using non-parametric techniques incorporated in the SPSS® 12.0.1 for Windows software. Probability values were calculated using the Exact Tests function because the data were small and contained many tied values. The initial reduction in rat abundance (% kill) at the treatment site was corrected to reflect any changes in abundance at the matched non-treatment site over the same time period; we calculated this for the first baiting rounds at Mapara, Whirinaki, and Trounson. The corrected % kill was estimated by the following equation:

$$\text{Corrected \% kill} = ((\text{Expected Post}_t - \text{Post}_t)/\text{Expected Post}_t) \times 100)$$

Where the Expected $\text{Post}_t = \text{Pre}_t \times (\text{Post}_{nt}/\text{Pre}_{nt})$ (subscripts $_t$ and $_{nt}$ indicate treatment and non-treatment respectively).

One of our main concerns with this trial was that possums would interfere with the diphacinone baits or blocks. Therefore, trapping surveys following standardised

TABLE 2. DETAILS OF RODENT (*Rattus rattus* AND *R. norvegicus*) AND POSSUM (*Trichosurus vulpecula*) RESULT MONITORING METHODOLOGY EMPLOYED AT EACH OF THE STUDY SITES.

SITE	PEST	NUMBER OF SURVEY LINES	NUMBER OF DEVICES PER LINE*	MONTH–YEAR OF POSSUM SURVEYS
Mapara (treatment)	Rats	2	50 tracking tunnels	–
	Possums	10	10 Victor No. 1 unpadded leg-hold traps	Sept–2003
Waipapa–east (non-treatment)	Rats	4	25 tracking tunnels	–
Whirinaki (treatment)	Rats	5	10 tracking tunnels	–
	Possums	5	10 Victor No. 1 unpadded leg-hold traps	Aug–2003 & Feb–2004
Whirinaki (non-treatment)	Rats	5	10 tracking tunnels	–
Trounson (treatment)	Rats	1	100 tracking tunnels	–
	Possums	5	20 Victor No. 1.5 unpadded leg-hold traps	Nov–2004
Katui (non-treatment)	Rats	1	100 tracking tunnels	–
Moehau (Stock track and Shag Bay†) (treatment)	Rats	6†	10 tracking tunnels	–
	Possums	3	20 Victor No. 1 unpadded leg-hold traps	Jan–2004
Doctors Bay (non-treatment)	Rats	4	10 tracking tunnels	–
Papa Aroha (non-treatment)	Rats	6	10 tracking tunnels	–
Boundary Stream (treatment)	Rats	8	10 tracking tunnels	–
	Possums	13	10 Victor No. 1 unpadded leg-hold traps	June–2003
Cashes Bush† and Thomas Bush† (non-treatment)	Rats	6†	10 tracking tunnels	–

* 50 m spacing between devices for tracking tunnels, 20 m for possum traps.

† Three at each site.

protocols (NPCA 2002) were carried out to measure possum relative abundance at each treatment site. Depending on the site, these surveys consisted of 3–13 randomly located trap lines, each of which had 10 or 20 Victor No. 1 or No. 1.5 unpadded leg-hold traps (Woodstream Corporation, USA), which were spaced at 20 m intervals (Table 2), lured with flour and icing sugar, and opened for three consecutive fine nights. These trap-catch data were corrected for sprung traps and converted to an index of abundance, expressed as the mean (± SEM) number of possums caught per 100 corrected trap nights (CTN) (NPCA 2002).

3. Results

3.1 SENTINEL BLOCK TRIALS

The diphacinone Sentinel™ block baiting trials at Mapara and Whirinaki successfully reduced rat abundance to below the target levels of less than 5% of tunnels tracked by rats. At Mapara, tracking indices of rat abundance were reduced significantly (Friedman test, $\chi^2 = 7.54$, df = 2, Exact $P = 0.037$); the initial baiting operation reduced rat abundance by 92.2% (corrected kill), whilst rat abundance at the non-treatment comparison site in Waipapa-east increased over the same period (Fig. 5). The second round of baiting at Mapara in November 2003 further reduced rat abundance, so that rats were not detected in the February survey 2 months later. Possum abundance was very low at Mapara; 17 days before the start of the trial, 0.33 ± 0.003 possums were trapped per 100 CTN.

At Whirinaki, rat tracking indices of relative abundance were similar at the treatment and non-treatment sites prior to the first round of baiting (Mann-Whitney $U = 6$, Exact $P = 0.214$). However, at the treatment site they decreased significantly during the study (Friedman test, $\chi^2 = 12.75$, df = 3, Exact $P = 0.004$). Rat abundance was reduced by 90.1% (corrected kill) just over 3 weeks after the first round of baiting at the treatment site, but remained high in the adjacent

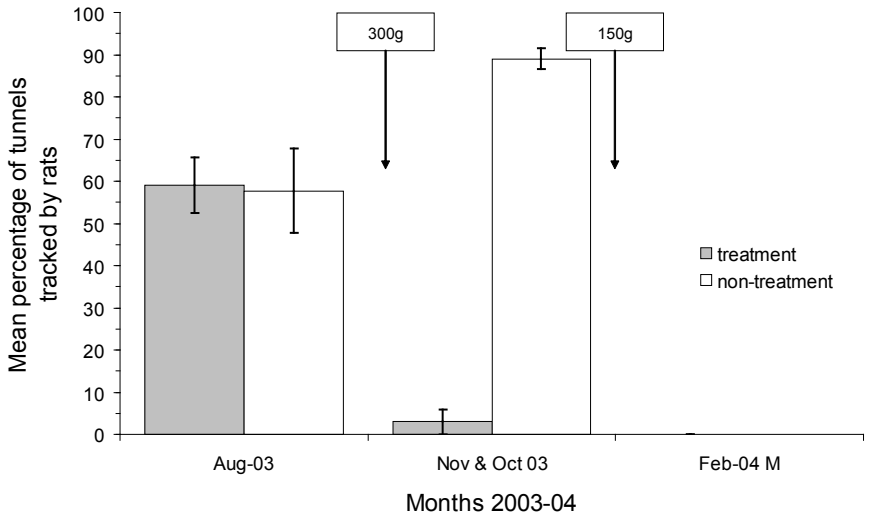


Figure 5. Mean (± SEM) percentages of tracking tunnels that contained rat (*Rattus rattus* and *R. norvegicus*) tracks at Mapara (treatment) and Waipapa-east (non-treatment). Note: M = tracking survey carried out at Mapara only. Labelled arrows show size of diphacinone Sentinel™ blocks used and indicate the approximate timing of each baiting round.

non-treatment comparison block (Fig. 6). No rats were detected in the treatment block during the January survey, c. 1.5 months after the final 'top-up' baiting round conducted in November. Rat abundance also declined at the adjacent non-treatment comparison site following the second round of baiting. Even though rats were detected at low abundance (2% of tunnels tracked) in the treatment area in February, they were still below the target level, and significantly lower than in the non-treatment comparison block for the entire post-baiting period (Mann-Whitney $U = 25.5$, Exact $P < 0.001$). Possums were present at moderate abundance (11.33 ± 0.029 possums per 100 CTN) in the treatment block at Whirinaki 38 days prior to the diphacinone trial. However, by 160 days after the start of the trial, in February 2004, they had declined to lower levels (2.67 ± 0.007 possums per 100 CTN).

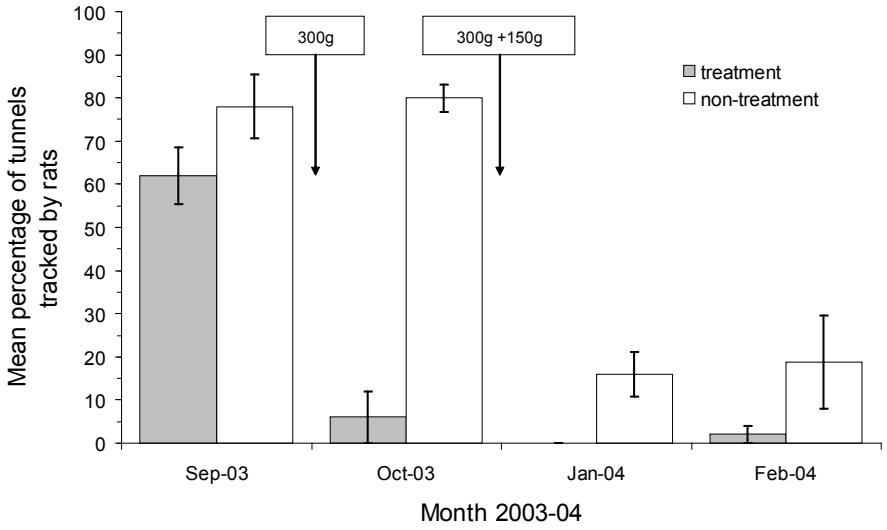


Figure 6. Mean (± SEM) percentages of tracking tunnels that contained rat (*Rattus rattus* and *R. norvegicus*) tracks in the treatment and non-treatment trial areas at Whirinaki. Labelled arrows show size of diphacinone Sentinel™ blocks used and indicate the approximate timing of each baiting round.

3.2 PESTOFF 50D BAIT TRIALS

The Pestoff® 50D baiting operation at Trounson reduced rat abundance by 92% (corrected kill) to below the target level of less than 5% of tunnels tracked by rats, and continued to suppress them to below the target levels until the baits were removed in January, 22 weeks after the baits were last replenished in the stations (Fig. 7). Throughout the baiting operation, the rat tracking rates at Trounson were significantly lower than in the non-treatment site at Katui (Mann-Whitney $U = 0$, Exact $P < 0.001$). Possum abundance was very low at Trounson; the trap survey carried out c. 6 months after the trial started returned an index of only 1 ± 0.007 possums per 100 CTN.

At Moehau, the Pestoff® 50D baiting failed to reduce rat abundance (Fig. 8), even though pest-control staff reported that the baits were consumed from most of the bait stations within 3–4 days and in some cases overnight (EM, pers. obs.). Possums were present at moderate abundance (12.22 ± 0.015 possums per 100 CTN) in the treatment block 15 days prior to the start of the operation.

At Boundary Stream, rats were not detected in tracking tunnels before or during the trial but they were present at the non-treatment comparison sites (Fig. 9). No possums were caught in the trapping survey conducted 5.5 months before the trial started at Boundary Stream.

Figure 7. The percentages of tracking tunnels that contained rat (*Rattus rattus* and *R. norvegicus*) tracks at Trounson Kauri Park (treatment) and Katui (non-treatment). Labelled arrows show the amount of diphacinone Pestoff® 50D bait used in each bait station and indicate the approximate timing of each baiting round.

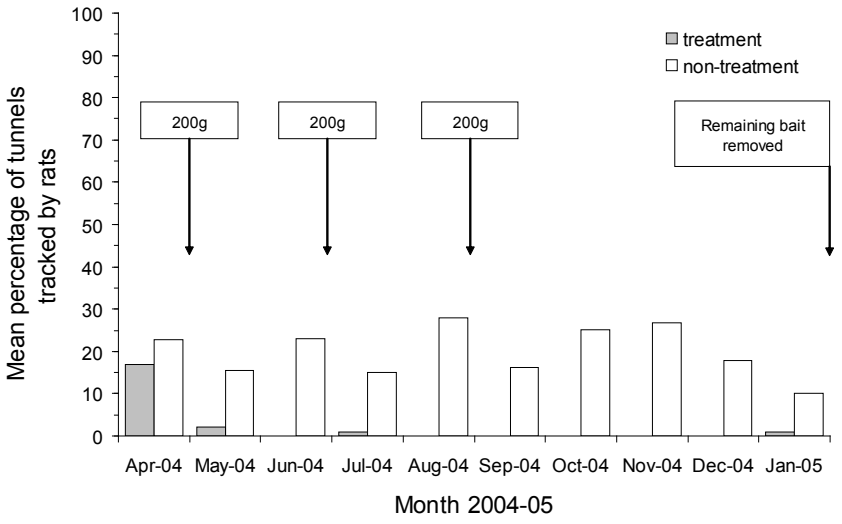
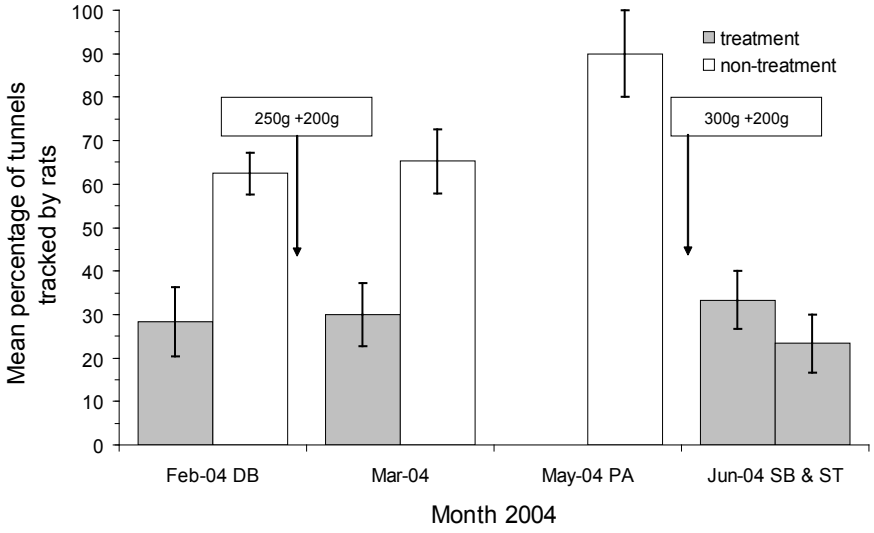
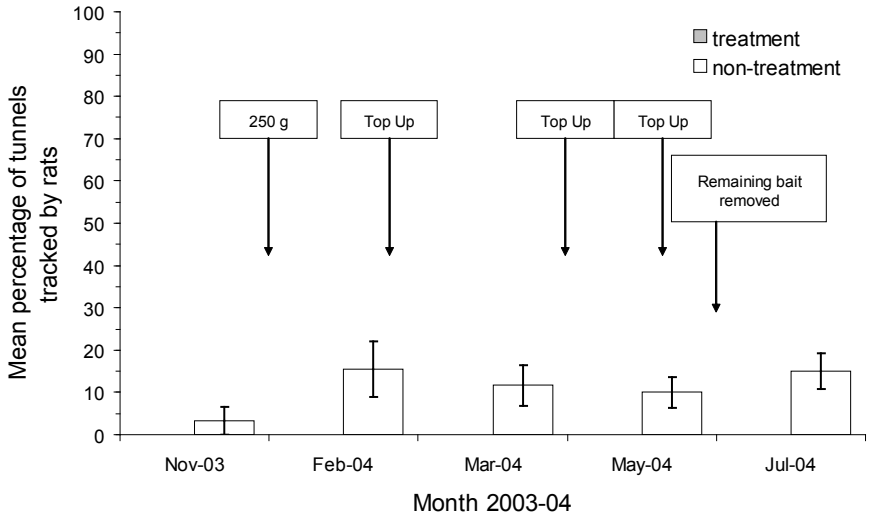


Figure 8. Mean (± SEM) percentages of tracking tunnels that contained rat (*Rattus rattus* and *R. norvegicus*) tracks at Moehau (treatment), and at Doctors Bay and Papa Aroha (non-treatment sites). Labelled arrows show the amount of diphacinone Pestoff® 50D bait used in each bait station and indicate the approximate timing of each baiting round.



DB = Doctors Bay, which was used as the non-treatment site for the February 2004 survey.
PA = tracking survey carried out at Papa Aroha only.
SB = Shag Bay and ST = Stock Track, the results from the June 2004 surveys at the treatment site are presented separately for these two management blocks.

Figure 9. Mean (± SEM) percentages of tracking tunnels that contained rat (*Rattus rattus* and *R. norvegicus*) tracks at Boundary Stream (treatment), and at Thomas Bush and Cashes Bush combined (non-treatment sites). Labelled arrows show the amount of diphacinone Pestoff® 50D bait used in each bait station and indicate the approximate timing of each baiting round.



4. Discussion

The diphacinone Sentinel™ blocks successfully reduced rat abundances to below the target levels (5%) at both Mapara and Whirinaki. At Whirinaki, rat numbers were not reduced to below 5% until the follow-up round of baiting; this was probably due to bait interference by possums, which were present in moderate numbers at this site before the trial began. The large reduction in possum abundance during this trial is likely to have been caused by the Sentinel™ blocks (or at least the Feratox® cyanide capsules within them), although a non-treatment comparison would be required to establish this. The reduction in possum interference ensured that sufficient diphacinone bait was available to reduce the rats below the target levels after the second baiting round. Unfortunately, the results were somewhat confounded by the reduction in rat abundance at the non-treatment site following the second round of baiting. We suspect that this was because of the proximity of the non-treatment site to the treatment site. Ideally, in a trial of this nature, the treatment site should be biologically independent of the non-treatment site; however, in this case the two sites were adjacent. Range lengths of between 100 m and 700 m have been reported for ship rats in forests (Innes 2005), so it is quite possible that rats could have moved between the two sites over the course of the study.

At Mapara, possum interference was unlikely to have been a serious problem given the very low number caught in the pre-control trap survey; therefore, rats probably had little competition for baits, so were reduced to the target levels after the initial baiting round. At both Mapara and Whirinaki, rat numbers were suppressed below target levels for the duration of the trials, at least until February 2004. Suppressing rat abundances to these levels over the late spring/early summer would have provided sufficient protection for those native bird species that are vulnerable to ship rat predation over that period (Innes et al. 1999, 2004; Powlesland et al. 1999).

Our results for the Pestoff® 50D bait trials were not as conclusive as those from the Sentinel™ block trials; although the Trounson operation was a success, the Boundary Stream operation was inconclusive, and the Moehau operation was unsuccessful. At Trounson, diphacinone in Pestoff® 50D baits not only successfully reduced rat abundances, but continued to suppress them for c. 4.5 months after the last bait fill, which was considerably longer than expected. Competition with possums for access to the baits was not an issue at this site because they had been controlled to low numbers there since 1996 (Gillies et al. 2003) and were still being targeted using Feratox® in separate bait stations during the course of our trial (Leach 2005). Ideally, the possum trapping survey at Trounson should have been carried out prior to the start of our trial rather than 6 months after the baits were first put in the stations. The trapping survey was scheduled as a part of the ongoing pest control work at Trounson, so we decided that there was little to be gained by paying for an additional survey, since we knew possums were being specifically targeted and unlikely to be present in high abundances.

The impact of the Pestoff® 50D baiting operation on the rat population at Boundary Stream was not as easy to interpret. At Trounson, the project staff stopped any rat control work 4 months prior to the start of the trial (Leach 2005),

which allowed rat numbers to increase so that we could target them with the diphacinone Pestoff® 50D baits. However, Boundary Stream is a DOC 'mainland island', where staff are tasked with controlling pest mammals to very low levels to allow the reintroduction of native species that were formerly present (Ward-Smith et al. 2004). At the time of our trial, five pairs of North Island kokako (*Callaeas cinerea wilsoni*) were destined to be released into Boundary Stream and were beginning to show signs of breeding behaviour. Since nesting kokako are particularly vulnerable to predation by ship rats (Innes et al. 1996), we were reluctant to stop the existing rat-control operation at Boundary Stream until we were ready to start the diphacinone trial. Consequently, rat abundance was at a non-detectable level at the start of our trial, which made it impossible to determine the impact of diphacinone Pestoff® 50D baits on the rat population.

Although we could not detect rats in the tracking tunnels prior to the trial at Boundary Stream, the diphacinone Pestoff® 50D operation in effect replaced the existing control operation and continued to suppress rats to non-detectable levels whilst the baits were in the stations. During the course of the baiting operation, rats were caught in the perimeter and buffer mustelid traps surrounding the treatment area (TWS, pers. obs.), and there appeared to be a slight increase in abundance at the nearby non-treatment sites between November 2003 and February 2004. Consequently, it is likely that the rat population at Boundary Stream would have recovered at least to detectable levels had the diphacinone Pestoff® 50D baits been ineffective. No possums were detected in the trap survey in Boundary Stream 5 months before we started this trial, and they were also targeted with Feratox® during the trial; consequently, possums were unlikely to have been competing for access to the baits during the operation.

The diphacinone Pestoff® 50D baiting operation at Moehau failed to produce any measurable decline in rat abundance, even though several dead rats were noticed in the treatment area and the baits were eaten very quickly (EM, pers. obs.). One of the biggest challenges with this series of management trials was that the timing of the treatments and monitoring at each site was constrained by local staffing levels, work priorities, and task scheduling. For the most part these constraints were not a problem, but they did affect the Moehau trial, especially because some of the problems did not become apparent until after the study began. Firstly, the scheduled timing for the pre-control rodent monitoring at the non-treatment site (Papa Aroha) turned out to be unsuitable for our purposes because it was collected 3 months prior to the treatment site data. Therefore, we used the rodent monitoring data from Doctor's Bay as it was collected at a similar time to the 'pre-control' data from the treatment site. This was certainly far from ideal and it meant that the most we could conclude from the non-treatment data was that rats were present at high abundances before and during the trial period in Coromandel forests where no rat control was taking place.

Secondly, the rate at which baits were removed from the stations at Moehau was much faster than anticipated and all the bait earmarked for a baiting round in April was used in February. Given that the February operation failed to reduce rats to the target levels, we decided to wait until the next planned baiting round scheduled for autumn/winter (May/June) to attempt to reduce rat numbers again rather than order a new batch of bait, which would have required changes to the ACVM research approval. Having seen how quickly the baits were removed from the stations in the February treatment, the local staff decided to treat the

management area in the May/June baiting round as two smaller, but more easily serviced, blocks (Stock track and Shag bay); these were to be treated one after the other (including bait replenishment) rather than simultaneously. How this might have affected the overall results is unclear, so we presented the data for the two separate operations rather than combined.

Despite the logistic and scheduling problems faced at Moehau, there are some possible biological reasons for the operation failing to reduce rats to the target levels. Diphacinone is most effective against rats when they can freely consume multiple doses for 10 days or more without running out of bait (Fisher & Broome 2004). Unfortunately, at Moehau the baits were eaten within 3–4 days of each bait fill, and although the stations were immediately replenished, we believe that a lot of rats probably failed to ingest a lethal dose of poison. Given that rat abundance was very high in the Coromandel non-treatment sites, it is possible that there were simply too many rats in the Moehau treatment area to be effectively controlled with the limited amount of diphacinone Pestoff® 50D baits used in this trial. However, we suspect that possums were responsible for consuming the majority of the baits and thereby reducing the amount available to rats at Moehau. Project staff found one dead possum, and noticed signs of possums having fed at some of the bait stations during the course of the baiting operation (EM, pers. obs.). The trapping-survey results indicated that possums were moderately abundant at Moehau just prior to the start of the trial and probably remained so throughout both the February and May baiting rounds. Unlike at Trounson and Boundary Stream, possums were not specifically targeted by other control methods during the Moehau trial because they were thought to be present only in very low numbers (EM, pers. comm.). The possum trapping survey revealed that this was, in fact, not the case, but by the time those data were made available the trial was already completed. As far as we are aware, there are no published LD_{50} levels (the estimated lethal dose of a toxin that will kill 50% of a test population) for diphacinone on possums, but they usually eat excessive amounts of anticoagulant-laced baits before they die (Eason et al. 2000), so even if they were present in relatively low numbers, they could have considerably reduced the amount of baits available to rats.

5. Conclusions and recommendations

The diphacinone Sentinel™ blocks successfully controlled rats to the target levels at both Mapara and Whirinaki. We believe that the results of our trials adequately demonstrate the efficacy of the product in the field and that Feral R&D Ltd should utilise these data to support an application for registration of the diphacinone Sentinel™ block for rat control. The diphacinone Pestoff® 50D baiting operation was successful at Trounson and possibly also at Boundary Stream, although we could not determine the impact on the rat population at the latter site. However, the operation was not successful at Moehau, probably due to possum interference. Consequently, there is currently not sufficient

field efficacy data to support an application for registration of diphacinone Pestoff® 50D baits for rat control. Nevertheless, the results from the Trounson and Boundary Stream trials were very encouraging and indicated that the bait will suppress rat populations when possums are controlled to low abundances. Therefore, we recommend that at least one more field trial of the diphacinone Pestoff® 50D baits be conducted at a site where rats are abundant and possums are controlled to low levels or absent.

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