Palatability and efficacy of Pestoff 20R bait on mice from Mokoia Island, Rotorua

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Mark Cleghorn and Richard Griffiths

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Mark Cleghorn and Richard Griffiths

Department of Conservation, P.O. Box 281, Rotorua

A B S T R A C T

Following an unsuccessful eradication attempt on mice (*Mus musculus*) on Mokoia Island, the palatability of the bait used and mouse tolerance to anticoagulants were raised as possible reasons for the operation's failure. To alleviate these concerns before another eradication attempt, a two-choice trial was carried out on 21 mice from Mokoia to compare the palatability of Pestoff 20R to a standard diet. A no-choice trial was also run to assess bait efficacy. A high degree of variability was recorded between individual mice, but in general, mice found Pestoff 20R significantly less palatable than the standard diet. No evidence for tolerance to brodifacoum could be found. The absence of information on dietary preferences and reasons that several mouse eradication attempts have failed are discussed and recommendations are made for the need to test the palatability of a range of bait types in a natural situation. Research on the impact of social interactions on the success of eradication attempts is also recommended.

Keywords: pest control, mouse, rodent bait, laboratory trials, Mokoia Island, Rotorua, New Zealand

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1. Introduction

Following a ground-based eradication of rats (*Rattus norvegicus*) on Mokoia Island in 1989, it was discovered that mice (*Mus musculus*) still existed on the island. This led to an attempt in 1996 to eradicate mice and rid Mokoia of all introduced mammals. The operation took place in September 1996 using aerially sown Wanganui No.7 cereal pellets containing brodifacoum. Bait was sown at a rate of approximately 10 kg/ha by helicopter guided by a differential global positioning system.

Initial indicators suggested that mice had been eradicated, as their tracking index fell to zero. However, in December 1996 a mouse sighting was made, and by 1997 mice were once again distributed right across the island (K. Owen, unpubl. report 1997).

Several possibilities for the operation's failure have been proposed. It is possible that some mice were not exposed to bait. Coverage of the island with bait may not have been one hundred percent due to gaps in flight lines flown by the helicopter, spreader bucket malfunction, or inadequate coverage of bait spread by hand at the front of the island. Areas of dense blackberry on the eastern side of the island made spreading bait by hand difficult in some areas.

Another possible scenario is that all mice were exposed to bait, but some failed to consume it or ingest a fatal dose. The bait used in the 1996 mouse eradication attempt contained Bitrex® and cinnamon lure. Bitrex is designed to make bait unpalatable to humans, but may also have made the bait less palatable to mice (Kaukeinen & Buckle 1992). Cinnamon is commonly added to possum baits, but it is not known whether it increases or decreases palatability of bait to mice.

Few quarantine measures were in place at the completion of the 1996 mouse eradication attempt and it is possible that mice may have been subsequently reintroduced. However, the short time interval between the operation and the reappearance of mice and the fact that mice reappeared at more than one point on the island, suggests that mice survived the operation rather than reinvaded.

The last possibility and the least likely is that all mice were exposed to bait and consumed it but did not die. Tolerance to first-generation anticoagulants has been recorded in some rodent populations in Europe but generally as a result of long-term exposure (Boyle 1960; Rowe & Redfern 1965). Mice on Mokoia have been exposed to two different anticoagulants on separate occasions, once during the rat eradication and once during the mouse eradication attempt so have not been exposed to these toxins for an extended period.

In 2001 another attempt at eradicating mice was proposed. To reduce the chance of leaving gaps in bait distribution during the proposed operation it was planned to implement higher standards in the helicopter operation and carry out two separate applications rather than one. All bait spreading would be done by helicopter to further minimise the risks of gaps occurring.

The Mokoia Island Pest Quarantine and Contingency Plan (R.W. Griffiths unpubl. report 2000) is fully operational, except for construction of a rodent-proof room due to be completed in 2001. Access to the island is restricted to

permitted operators, and quarantine facilities are in place both on the mainland and on Mokoia. The likelihood of mice being reintroduced is therefore greatly reduced.

To eliminate the other two factors that might have contributed to the failure of the 1996 operation, it was proposed to carry out a trial into the efficacy and palatability of Pestoff® 20R, the rodenticide intended for the proposed operation. Pestoff 20R does not contain Bitrex or cinnamon and has been used successfully for a large number of island rodent eradication programmes both in New Zealand and overseas. Most of these operations have targeted rats, but mice were successfully eradicated from Enderby Island using the same bait and toxin (N. Torr pers. comm.).

Pestoff 20R, manufactured by Animal Control Products Limited (ACP), is currently the only toxic bait registered for aerial distribution on offshore islands It would have been desirable to have a range of options for the Mokoia operation, but this would have necessitated registration of other bait types or obtaining experimental use permits. Both these options were unavailable due to financial and time constraints.

Few island eradication programmes for rodents have been principally aimed at mice, the Enderby Island eradication was initially intended for rabbits (*Oryctolagus cuniculis cuniculis*), and the majority of other campaigns have focused on exterminating rat species *(Rattus rattus, R. norvegicus and R. exulans*). Consequently little research has been carried out on the most effective bait types and toxins for mice.

Dubock & Kaukeinen (1978) demonstrated that, of all the anticoagulants available at the time, brodifacoum was the most potent for both rat and mice control, but no references in the literature could be found comparing more recently developed toxins such as flocoumafen. Apart from a bait preference trial carried out by Todd & Miskelly (unpubl. report 1989) on Mana Island, no other references could be found regarding bait preference in mice. These authors compared Talon® wax blocks with kibbled wheat, kibbled maize, poultry pellets and Mapua pellets and found Talon to be the most preferred bait.

Consequently, it was decided to run an experiment along the same lines as Ross et al. (2000) that tested bait preference in Norway rats. They used a standard two-choice test to compare four rodenticides produced by ACP with Ditrac® All-Weather Blox.

It was considered that any additional information on the efficacy of rodenticides such as Pestoff 20R would be valuable. The work would also help set the period of time necessary between aerial applications of bait proposed for the eradication of mice from Mokoia Island. Currently, there is a potential risk that some mice will not be exposed to bait for long enough to ingest a fatal dose. It would also serve to answer any questions about toxin tolerance that might be present in the Mokoia mouse population.

1.1 OBJECTIVES

- Test the relative palatability and efficacy of Pestoff 20R on mice from Mokoia Island.
- Determine time to death after lethal dose ingestion for mice from Mokoia Island.

2. Methods

2.1 BAIT USED IN THE TRIAL

Pestoff 20R cereal pellet baits (2 g, 12 mm dia.) in the form to be used in the eradication program were supplied in both toxic and non-toxic forms from ACP. The toxic pellets were dyed green and contained brodifacoum at a concentration of 20 mg/kg.

2.2 ANIMAL HUSBANDRY

Twenty-one healthy and active mice were captured over two nights of trapping using a variety of traps set in bush verging on open grassland, and in a rubbish pile, near the main hut on Mokoia Island. The animals were conveyed to a laboratory, where they were weighed before being housed in individual enclosures. To avoid unnecessary stress to the mice, they were not aged or sexed. They were then randomly allocated to either an experimental or a control group, with the control group receiving the extra mouse.

Enclosures conformed to Environmental Protection Agency (EPA) guidelines (Buckle & Smith 1994), had a floor area of 200 × 300 mm and were constructed of plywood and fine aluminium mesh. Wood shavings were provided for nest material, and water containers were kept constantly full. A small plastic tunnel was placed in each enclosure for mice to shelter in. The tunnels proved ideal as mice could easily be removed from their enclosures for daily weighing and inspection.

For the first five days all mice, in both experimental and control groups, were supplied with a diet of seeds and cat-food sourced from the local pet shop. They were weighed daily and those weighing more than 10 g with stable or increasing body weights—all mice caught—were included in the trial.

2.3 BAIT PALATABILITY

The relative palatability of Pestoff 20R was assessed using a standard two-choice test (Grote & Brown 1971) in which mice in the experimental group were provided with 10 g of the test bait (Pestoff 20R) and 10 g of a standard diet (the

EPA-approved non-toxic 'Challenge Diet' (EPA 1982). Mice in the control group were provided with 10 g of a non-toxic version of the test bait (non-toxic Pestoff 20R) and 10 g of the Challenge Diet. Palatability was calculated each day as the percentage of test bait eaten relative to the total bait eaten.

The bait palatability trial continued for 14 days after which time survivors in the experimental group were returned to the diet of seeds and cat-food and monitored on a daily basis for a further seven days for signs of poisoning. Any survivors remaining after this time were killed.

2.4 BAIT EFFICACY

Due to time constraints, ten days after the start of the bait preference trial, mice in the control group were switched to a no-choice trial consisting of a diet of the test bait (Pestoff 20R) only. Monitoring of bodyweight and bait consumption was continued for all animals. Mortality was monitored on a daily basis. This trial was performed with the intention of assessing time to death in mice following the consumption of a lethal dose. A lethal dose was calculated to be approximately 0.4 g Pestoff 20R rodent bait for a mouse weighing 10 g, based on an LD_{50} of 0.4 mg/kg for broadifacoum (Haydock & Eason 1997).

At this point in the trial, Mouse 20 was withdrawn from the control group and continued on its control diet of Challenge Diet and the non-toxic test bait; the animal had by that stage consumed none of the test bait and it was watched to see if this trend would continue.

2.5 ANIMAL CONDITION, BEHAVIOUR, AND MORTALITY

Bodyweight was checked daily and mice were checked for excessive weight loss (> 20%), and abnormal symptoms or behaviour. Activity levels, appearance, external signs of bleeding, and self-mutilation were among the signs checked. Mortality was assessed every 24 hours.

2.6 DATA ANALYSIS

Initial palatability on day one, overall palatability, and time to death were compared using one-way analysis of variance, ANOVA. Palatability of Pestoff 20R was expressed in terms of percentage of total consumption: the ratio of consumption of test bait (Pestoff 20R) to (consumption of test bait consumption + Challenge Diet). A value greater than 50% indicates that the test bait (Pestoff 20R) is preferred to the Challenge Diet.

Analysis of the no-choice trial included calculating time to death from ingestion of a lethal dose, and from the date that bait was first provided. Time to death from the date that bait was first provided was then compared using one-way ANOVA with that for mice in the two-choice experimental group.

2.7 ETHICS APPROVAL

Don Newman and Ken Kissling of the DOC Animal Ethics Committee provided provisional ethics approval for this trial.

3. Results

3.1 BAIT PREFERENCE

Initial palatability

Results were conclusive in both experimental and control groups for bait palatability over the first 24 hours. In both groups, mice generally showed little interest in the test bait. The low percentage palatability of Pestoff 20R compared with the EPA Challenge Diet is illustrated in Fig. 1.

Consumption of the test bait was significantly less than consumption of Challenge Diet for mice in the experimental group ($F = 72.84$, $p < 0.001$). In this group, one mouse preferred the test bait to the Challenge Diet (Mouse 6, initial palatability, 62.7%) while a second mouse consumed a significant amount (Mouse 1, initial palatability 31.4%). However, initial palatability figures for the remaining eight mice were very low, ranging from 0% to 6.2%.

In the control group the results were similar. One mouse preferred the non-toxic test bait (Mouse 14, initial palatability, 51.4%) while a second mouse initially consumed a large amount (Mouse 16, initial palatability, 41.8%). However, eight mice in the control group also showed little initial interest in the non-toxic test bait, with initial palatability figures ranging from 0% to 8.7%. Consequently, initial consumption of the non-toxic test bait was significantly less than consumption of Challenge Diet ($F = 83.11$, $p < 0.001$).

Overall there was little variation in palatability over time for individual mice. Mice that displayed a preference for either the test bait or the Challenge Diet in the first 24 hours continued to display the same preference throughout the trial. However, there was substantial variation in palatability between individual mice. The majority of mice distinctly preferred the Challenge Diet, although a few individuals preferred the test bait.

The variability in percentage palatability over time for the experimental group illustrated in Fig. 1 can be attributed to this high variability between mice. For example on day 6, the death of Mouse 6 (which had high palatability figures) led to a decline in percentage palatability for the group to almost zero. Also following the death of Mouse 6, interest by the rest of the group in the test bait seemed to increase, with a large rise in palatability at day 7. Although the test bait was still by no means the preferred choice, palatability remained at relatively high levels until day 12, when more mice had died.

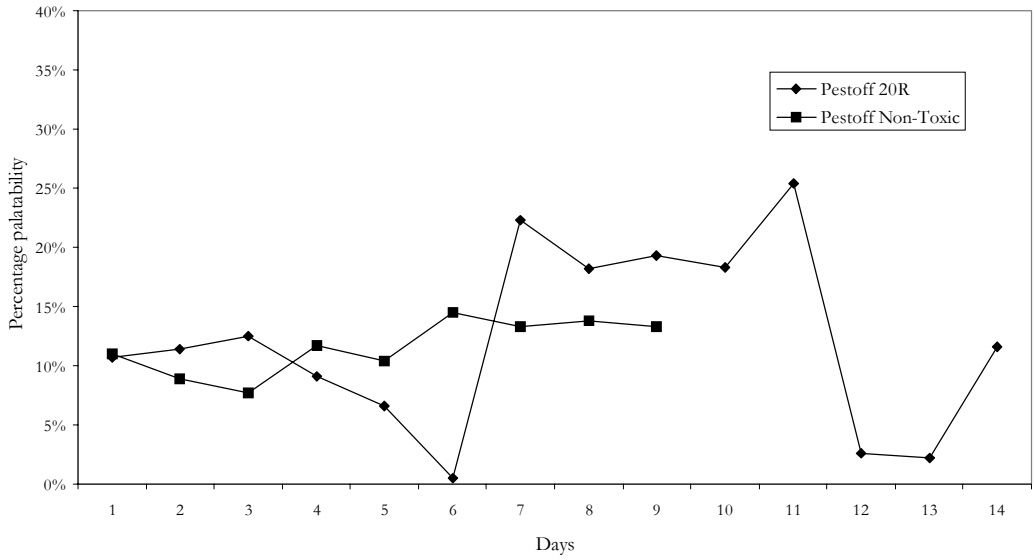

Figure 1. Mean palatability of Pestoff 20R (both toxic and non-toxic) compared with Challenge Diet over 14 days of exposure for mice from Mokoia Island.

Overall palatability

Analysis of bait consumption for the duration of the trial showed little difference, if any from the palatability figures recorded over the first 24 hours. Over the 14 days of the trial, consumption of the test bait remained significantly less than for the Challenge Diet ($F = 69.04$, $p < 0.001$). Mouse 6 was the only mouse in the experimental group to show a preference for the test bait (overall palatability 59.6%), while Mouse 1 consumed a larger amount than the other mice (overall palatability 38.0%). The other eight mice consumed only very small proportions of bait, with overall palatability scores ranging from 1.1% to 11.3%.

Results in the control group for the 10 days of bait palatability testing were similar. Mice in this group showed little inclination to consume the non-toxic test bait, with Mouse 14 the only individual to prefer it (overall palatability, 79.7%), followed by Mouse 16 (palatability 20.3%). Overall palatability for the remaining mice ranged from 0.2% to 5.5% and the overall consumption of non-toxic test bait was subsequently significantly less than for the Challenge Diet ($F = 48.51$, $p < 0.001$) (see Fig. 1).

3.2 BAIT EFFICACY

Two-choice test

Despite the low consumption rate of the test bait, nine of the ten mice in the experimental group ingested lethal doses over 14 days and died (see Fig. 2). For the control group, 7 out of the 11 mice would have ingested lethal doses over the 10 days of the trial had their test bait been toxic.

However, with most mice in both groups consuming small amounts of the test bait, time to death for mice in the experimental group was correspondingly slow. Mouse 6 was the first to die, having consumed lethal doses over the first

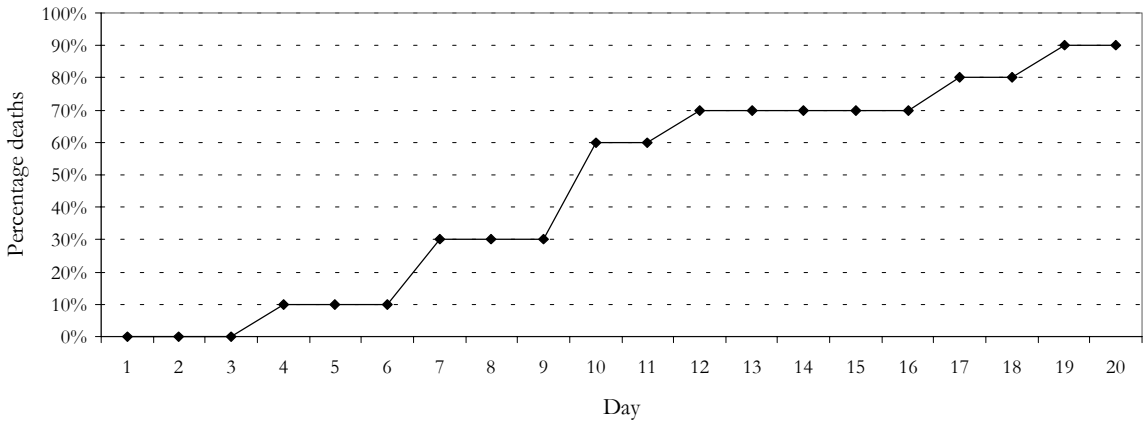

Figure 2. Time to death for mice in the experimental group (Pestoff 20R and Challenge Diet).

24 hours of the trial. As shown in Fig. 2, mortality climbed sporadically and slowly after the initial death on day 4 to an eventual total mortality for the trial of 90% (nine out of the ten mice) after 20 days. The surviving mouse was still alive some days after this. Mortality in the control group was 0% for the duration of the bait palatability trial.

Mice showed little outward sign that they had consumed a lethal dose of brodifacoum; blood in the nose and mouth was observed in only one mouse. However, poisoned mice did tend to become very pale in the nose and paws and this appeared to be the most diagnostic external feature of anticoagulant poisoning. The paleness is presumed to be a result of internal haemorrhaging.

No-choice test

Surprisingly, not all mice in the no-choice trial took bait on the first day. Mouse 18 failed to consume any bait on day one. However, all mice did eventually take bait and all died 4–7 days after consuming a lethal dose (see Fig. 3). Time to death from ingestion of a lethal dose for mice in the no-choice test (mean 5.8,

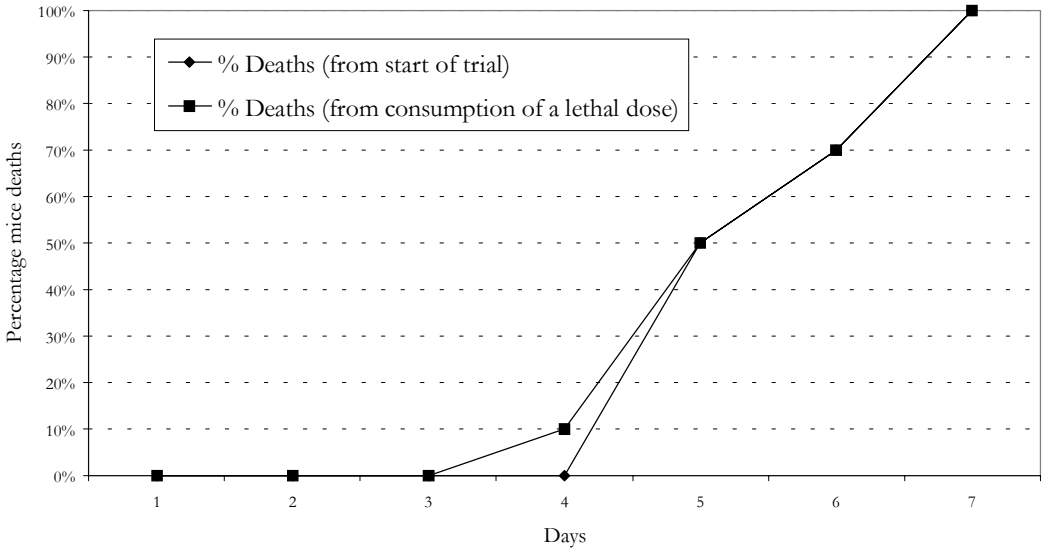

Figure 3. Time to death for ten mice exposed to a no-choice trial consisting of a diet of Pestoff 20R only.

range 5–7) was not significantly different from that in the two-choice test (mean 4.3, range 1–10) ($F = 2.21$, $p = 0.15$).

4. Discussion

4.1 BAIT PREFERENCE

In laboratory conditions, mice from Mokoia I. found Pestoff 20R rodent bait significantly less palatable than the EPA Challenge Diet. This result differs markedly from results observed for Norway rats by Ross et al. (2000). As can be seen in Table 1, both initial and overall percentage palatability values for Pestoff 20R for Norway rats were substantially higher than those recorded for mice during this trial.

We also recorded a much higher degree of variability between individuals than that recorded by Ross et al. (2000) (see Table 1). Of particular significance is the fact that some mice consumed so little bait during the course of the trial they did not ingest a lethal dose. One mouse in the control group did not consume any bait.

Rowe & Bradfield (1976) recorded similar results for pen trials of family groups of warfarin-resistant mice (*Mus musculus*) from the UK. Plain food and (WBA 8119) brodifacoum baits, at the same toxicity as those used in our experiment, were offered for up to 21 days. One mouse survived out of a total of 72.

Although this is not conclusive evidence that mice on Mokoia I. will find the bait unpalatable, it raises concerns about the effectiveness of an eradication attempt using this bait type. The result also confirms that rodent species are inherently different in their dietary preferences and behaviour, and that trials need to be carried out under natural conditions.

One major factor that could not be explored during our trial was the impact of social interactions on bait consumption. Social interaction or peer pressure may well be important in the eradication of rodent populations, as individuals in some species will actively choose to eat the same food as their peers, e.g. Norway rats (Taylor & Thomas 1989). Observations that bait take steadily increased over time followed by sporadic peaks during mouse eradication programmes (Brown 1993) may lend weight to this hypothesis. Certainly, little

TABLE 1. PALATABILITY OF PESTOFF 20R FOR MICE FROM MOKOIA I. COMPARED WITH NORWAY RATS.

	INITIAL PERCENTAGE PALATABILITY (RANGE)	OVERALL PERCENTAGE PALATABILITY (RANGE)
Mice (experimental group)	11% (0%–63%)	12% (1%–60%)
Mice (control group)	11% (0%–51%)	12% (0%–80%)
Norway rats (Ross et al. 2000)	27% (10%–28%)	24% (7%–32%)

variability in palatability over time was observed for individual mice during our experiment. An experiment with all mice grouped together rather than in separate enclosures would test this hypothesis.

Another factor that was unable to be tested was the relative palatability of Pestoff 20R compared with the diet mice would be exposed to on Mokoia I. Lack of knowledge about the diet of Mokoia I mice prevented us using a natural diet in the laboratory. However, by comparing the palatability of Pestoff 20R to a standardised diet, the same experiment could be carried out to test other bait types and mouse populations, for example, an in situ experiment on Mokoia I. comparing palatability of Challenge Diet to a natural diet.

4.2 BAIT EFFICACY

We did not detect any evidence of resistance to brodifacoum for any mice in this experiment. Following the ingestion of a lethal dose all mice died within 1–10 days (mean 5.2). Additionally, there were no significant differences in time to death following the ingestion of a lethal dose for either two-choice and no-choice trials despite consumption of bait being substantially less in the former. This corresponded to the 6-14 days recorded by Dubock & Kaukeinen (1978) for no-choice trials using brodifacoum at a concentration of 2 mg/kg. The 4–19 days to death noted for mice in our experimental group was also comparable to the 3–18 days observed for mice exposed to a two-choice experiment by Rowe and Bradfield (1976), using a brodifacoum bait of the same toxicity .

5. Conclusions and recommendations

In laboratory conditions, mice from Mokoia I. found Pestoff 20R rodent bait significantly less palatable than the EPA Challenge Diet. A high degree of variability in palatability was recorded between mice, which, however, displayed little variability in palatability over time.

Mice from Mokoia Island are not resistant to brodifacoum, and those which consume a lethal dose of brodifacoum will die within 10 days.

We recommend that, before the planned eradication attempt, a second trial is carried out on Mokoia I. to test the relative palatability of Pestoff 20R compared with natural food sources.

Research should also be done to determine the bait types most palatable to mice.

In addition, research is needed on the social interactions of rodent populations and the impact these might have on the success of eradication programmes.

6. Acknowledgements

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