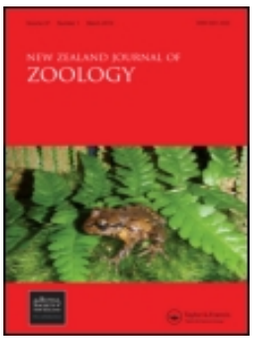

New Zealand Journal of Zoology

ISSN: 0301-4223 (Print) 1175-8821 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzz20

Brodifacoum residues in target and non-target animals following large-scale poison operations in New Zealand podocarp-hardwood forests

Elaine C. Murphy , B. Kay Clapperton , Philip M.F. Bradfield & Hazel J. Speed

To cite this article: Elaine C. Murphy , B. Kay Clapperton , Philip M.F. Bradfield & Hazel J. Speed (1998) Brodifacoum residues in target and non#target animals following large#scale poison operations in New Zealand podocarp#hardwood forests, New Zealand Journal of Zoology, 25:4, 307-314, DOI: 10.1080/03014223.1998.9518160

To link to this article: http://dx.doi.org/10.1080/03014223.1998.9518160

New Zealand Journal of Zoology, 1998, Vol. 25: 307–314
0301–4223/2504–0307 $7.00/0

Brodifacoum residues in target and non-target animals following large-scale poison operations in New Zealand podocarp-hardwood forests

ELAINE C. MURPHY
Department of Conservation
Private Bag 68–908
Newton
Auckland, New Zealand

B. KAY CLAPPERTON
49 Margaret Ave
Havelock North, New Zealand

PHILIP M. F. BRADFIELD
Department of Conservation
Te Kuiti Field Centre
P.O. Box 38
Te Kuiti, New Zealand

HAZEL J. SPEED
Department of Conservation,
Pureora Forest Park
RD7,
Te Kuiti, New Zealand

Abstract Ship rats in a North Island podocarp-hardwood forest were poisoned using brodifacoum in cereal baits presented in bait stations. Livers from 68% of 25 rats captured during and up to three months after poisoning contained brodifacoum residues. Following a rat- and possum-poisoning operation in another podocarp forest, 78% of 40 stoats, 71% of 14 weasels, and 56% of 16 ferrets trapped contained brodifacoum residues. Residue levels in stoats were greater during the three months following the removal of baits than during the poison operation. Female stoats were more likely to contain brodifacoum residues than males, perhaps the result of differences in the dietary habits of the sexes. Brodifacoum was also detected in the livers of the only morepork and in two out of 10 magpies sampled by shooting, but was absent from the livers of four robins, five tomtits, six whiteheads, one bellbird, one fantail, one harrier and four red deer. All five pigs and two cats either shot, caught or found dead contained the toxin residues. This study emphasises the potential ecological and human health risks that flow-on from the use of anticoagulant poisons in New Zealand forests.

Keywords brodifacoum; secondary poisoning; stoats; mustelids; non-target species; ship rats

INTRODUCTION

The anticoagulant poison brodifacoum is becoming more widely used as a control tool in New Zealand forests against ship rats (*Rattus rattus*) and brushtail possums (*Trichosurus vulpecula*) (Innes et al. 1995). Successful eradication programmes on islands have demonstrated its effectiveness on rodents, and also suggest consequent hazards for rodent predators (Taylor & Thomas 1989, 1993). These predators in forests include stoats (*Mustela erminea*), weasels (*Mustela nivalis*), ferrets (*Mustela furo*), cats (*Felis catus*), and moreporks (*Ninox novaeseelandiae*). The effects of poisoning programmes on predators can include changes both in diet and in numbers (Murphy & Bradfield 1992; Murphy, Clapperton, Bradfield & Speed in press). The latter can be caused indirectly by the effects of reduced numbers of prey, or directly by secondary poisoning.

Secondary poisoning has been suggested as a control strategy against mustelids and cats. A brodifacoum poisoning operation targeting rabbits in a pastoral habitat killed stoats, ferrets and cats (Alterio 1996). Stoats and weasels have also been killed after brodifacoum poisoning for rats, mice (*Mus musculus*) and possums in beech forest (Alterio et al. 1997; Brown et al. in press). The effects of secondary poisoning on mustelids need to be assessed in other forest types, as stoat diet varies with habitat (King & Moody 1982). We need to know what levels of brodifacoum are present in surviving

Z97044
Received 15 December 1997; accepted 1 May 1998

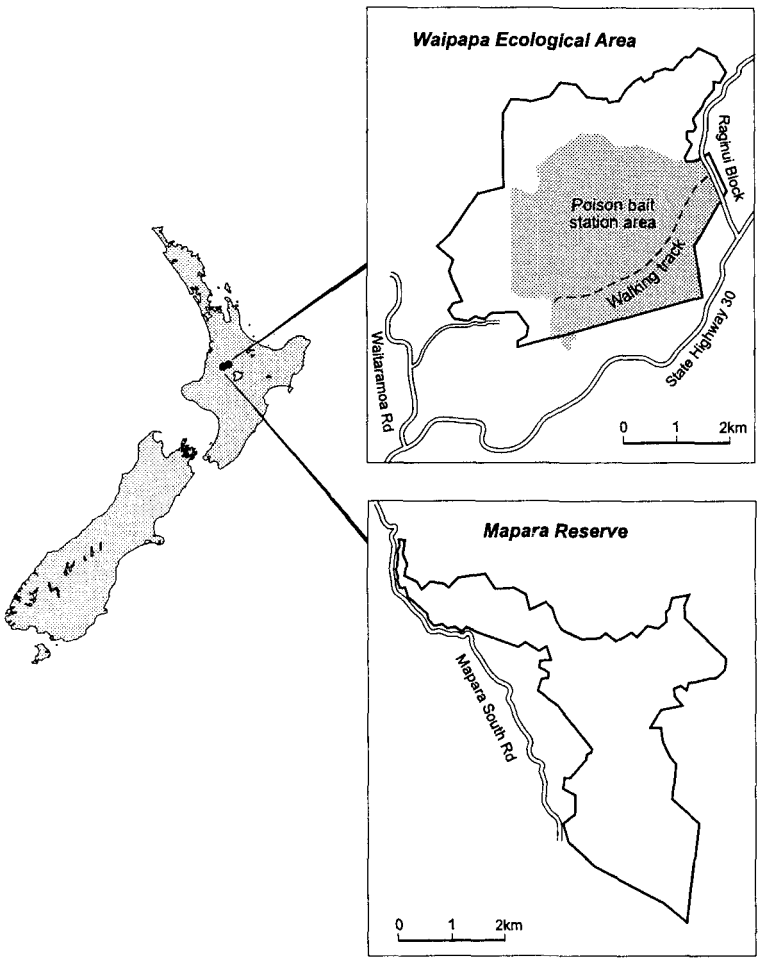

Fig. 1 Map of the study areas. The Waipapa Ecological Area is within the North Block of Pureora Forest Park. Mapara Reserve is surrounded by farmland.

rodents, and for how long after a poisoning operation poisoned carrion, and rodents with sublethal doses, are available as prey.

Other species of mammals and birds are also potentially at risk from poisoning, either from scavenging carcasses, preying upon live rodents containing brodifacoum, or directly from consumption of baits (Eason & Spurr 1995). While anticoagulant poisons may be very effective in controlling populations of pest species, the possible implications for the conservation of our native fauna, and the possibility of flow-on effects to human health, must also be assessed before the full effect of a poisoning operation can be assessed.

Here we assess brodifacoum levels in rat livers during and following a poisoning operation using bait stations, to determine whether or not and for how long the risk of secondary poisoning exists. We assess brodifacoum levels in captured mustelids from a second forest site also subjected to brodifacoum poisoning, to determine what proportion of animals are exposed to secondary poisoning. We report on brodifacoum levels in a range of non-target birds and mammals to assess the risk to other species. The poison operations at both sites were undertaken by the Department of Conservation to control rats and possums, and the data we collected were incidental to these operations. No information on brodifacoum residues in possums was collected.

METHODS

Rats

Rats were collected from Waipapa Ecological Area, Pureora Forest Park, North Island (38°25′S, 175°35′E; Fig. 1) during and following a poison operation for rats and possums conducted between

18 December 1995 and 16 April 1996. The study site consisted of 2500 ha of lowland forest dominated by a dense tawa (*Beilschmiedia tawa)* canopy, with emergent podocarps.

Poison baits were placed in 'Philproof' bait stations set every 150 m on a grid system and every 50 m around the perimeter of the grid. 'RS5' pellets containing 0.15% w/w 1080 were placed in the stations on 18–19 December. After two weeks, the baits in the perimeter stations were replaced with 'Talon Possum Bait' (20 ppm brodifacoum). Baits were changed in the internal bait stations from 1080 to Talon on 24 January. All stations were refilled with Talon on 26 February and 26 March. All baits were removed on 16 April. In total, 580 kg of Talon bait was placed in bait stations and of that, 192 kg was calculated to have been consumed. Speed and Bancroft (1997) provide details on placement of bait station lines, how much bait was placed in each bait station and how much remained.

Rats were kill-trapped in Mark 6 Fenn traps set either singly or in pairs under wooden or plastic covers. Thirty trap sites were located at 150 m intervals along a walking track (Fig. 1). Traps were unbaited from 31 January until 25 May. These traps were set again 24–27 June, checked daily and baited with peanut butter. Five standard rat snap traps, baited with peanut butter, were set 100 m apart further along the walking track and checked daily from 16 July until 18 July.

All carcasses were collected and stored frozen until assessment. The liver of each carcass was removed and sent to the National Chemical Residue Analytical Laboratory (Ministry of Agriculture and Fisheries, Wallaceville Animal Research Centre, Upper Hutt, New Zealand) for brodifacoum residue analysis. The least detectable level (LDL) of the Anticoag.v2 residue analysis method used was 0.03 mg/kg.

Non-target species

Four red deer (*Cervus elaphus scoticus*) (three stags and one hind), were shot in the Waipapa Ecological Area in March/April 1997 and four robins (*Petroica australis*) were shot in June 1997. 'Talon 50 WB' (50 ppm brodifacoum) was placed in bait stations (spacing as for 1995/96) in September 1996, refilled three times over the spring/summer and all bait removed in March 1997.

Mustelids and other non-target species were collected from Mapara Wildlife Management Reserve, King Country (38°33′S, 175°17′E), about 30 km from the Waipapa Ecological Area (Fig. 1). The reserve contains a diverse range of mature and regenerating podocarp-hardwood forest. 'Talon Possum Baits' (20 ppm brodifacoum) were used for rat and possum control operations there between September 1993 and April 1994, August 1994 and April 1995, and September 1996 and April 1997. In the 1993/94 year, Talon was placed in 473 bait stations placed roughly 200 m apart across the entire 1432 ha reserve. Four types of stations were used: Coon Trol, Indac "Pelifeed", Carter Holt Harvey Bait Station, and Animal Control Products "D Type". The stations were filled five times, the last renewal on 11–12 January 1994. Some baits remained available for 1–3 months after this. In total, about 1,600 kg of bait was placed in the bait stations. The amount of bait left in the stations was not recorded, but it was noted by the fourth round the bait take had dropped dramatically. In the 1994/95 year, bait stations in the southern third of the reserve were sited 100 m apart and bait stations were filled only four times; otherwise the methods were the same as the previous year. All baits were removed in April 1995. In the 1996/97 year, placement of bait stations was as for 1994/95, bait stations were filled three times from September and all bait was removed in April 1997.

Mustelid trapping had been on-going at Mapara since 1990, using 142 Mark 4 Fenn traps set 150–300 m apart along a 24 km trapline (Murphy & Bradfield 1992). Trapping continued until May 1995. Traps were unbaited and were checked once or twice a week. Fifteen birds were shot within the study area in August 1995. These included five tomtits (*Petroica macrocephala*), five whiteheads (*Mohoua albicilla*), one bellbird (*Anthornis melanura*), one fantail (*Rhipidura fuliginosa*), one harrier, one morepork, and one Australian magpie (*Gymnorhina tibicen*). One whitehead was found dead under a bait station in September 1996 and nine magpies were shot in June 1997. Five pigs (*Sus scrofa*) and two cats were also collected. Two of the pigs were found dead and one piglet was caught by hand in January 1995, and two were shot in August 1995. One cat was caught in a Fenn trap and the other was found dead within the study area in January 1994.

Stoat livers were analysed either by Landcare Research using the HPLC test (LDL=0.02 mg/kg) or by the Ministry of Agriculture and Fisheries using the Anticoag.v2 test (LDL=0.05). Weasels and ferrets were all analysed using the Anticoag.v2 method (LDL=0.03). Other non-target species were analysed by one of the above methods, with LDL dependent upon the sample of liver available. For the

larger birds and all the mammals LDL=0.005–0.004. Least detectable levels for the passeriformes are provided in Table 2.

Stoat data were square-root-transformed and analysed using a general linear model. The factors in the model were sex, time period (during or following poisoning) and the interaction between these factors. Rat data were also square-root-transformed. Proportion data were analysed using the G test for the log-likelihood ratio, using Williams' correction (G_{adj}) for single classifications.

RESULTS

Rats

In total 33 rats were kill-trapped in the poison area at Waipapa between 31 January and 18 July 1996, 25 of which were sampled for brodifacoum. Brodifacoum was detected in the livers of 17 (68%) of these. The proportion of rats captured during poisoning that contained poison residues was 75%, compared with 61% in the period within three months following the removal of poison baits. The mean concentration of brodifacoum in the nine rats captured during the poisoning operation was higher than the mean level of the eight poisoned rats in the post-poison period: 0.87 mg/kg and 0.17 mg/kg, respectively ($t=2.22$, d.f.=15, $P < 0.05$; Fig. 2). The last rat which contained poison residue (0.18 mg/kg) was captured on 17 July 1996, 13 weeks after all baits were removed from the bait stations. During and following poisoning a larger proportion of males than females contained poison residues, but this difference was not quite significant ($G_{adj}=3.4$, d.f.=1, $P = 0.06$). Concentrations in males ranged between 0.05 and 1.50 mg/kg during the poisoning operation, and between 0.05 and 0.36 mg/kg following the removal of poison baits. The corresponding ranges for females were 0.08 to 2.90 and 0.02 to 0.39 (Table 1).

Non-target species

Thirty-one of the 40 (77.5%) stoats sampled during or after the poison operations in Mapara contained detectable levels of brodifacoum in their livers (Fig. 3A). The mean residue level of these 31 animals was 0.37 mg/kg. The percentage of animals containing poison residues was 73.3% during the poison operations and 90% in the post-poison period ($G_{adj}=1.33$, d.f.=1 $P > 0.05$). Mean poison residues were not statistically lower during the poisoning period (0.30 mg/kg) than in the following three months (0.51 mg/kg) ($F_{1,27}=2.7$, $P = 0.11$). Mean residue levels of

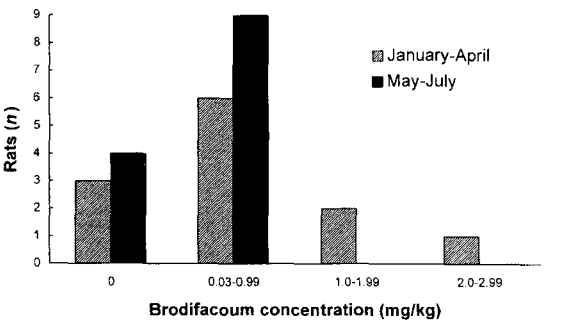

Fig. 2 Frequency distribution of brodifacoum residue levels in the livers of 25 rats kill-trapped in Waipapa Ecological Area during (January-April) and following (May-July) a Talon poison bait station operation in 1996.

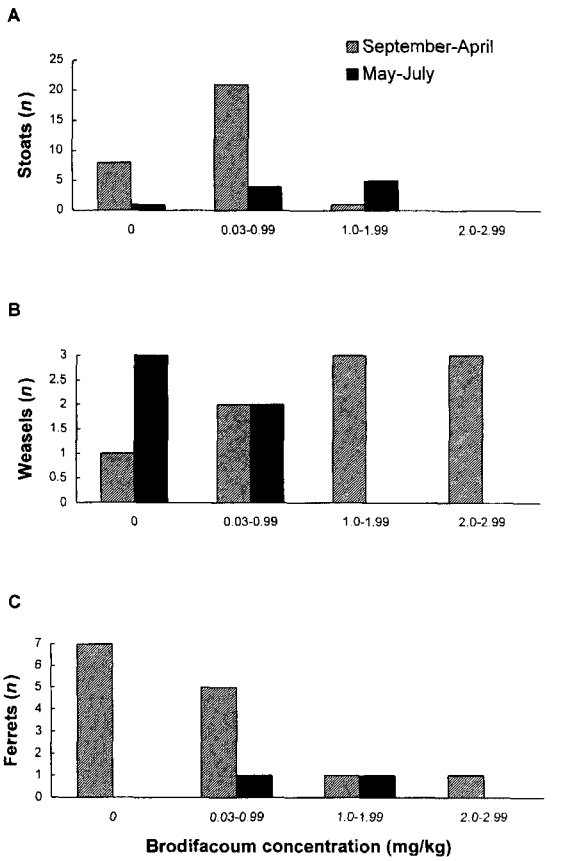

Fig. 3 Frequency distribution of brodifacoum residue levels in the livers of (**A**) 40 stoats, (**B**) 14 weasels, and (**C**) 16 ferrets kill-trapped at Mapara Wildlife Management Reserve during (September-April 1993/94 and 1994/95) and following (May-July 1993/94) Talon poison bait station operations in 1993/94 and 1994/95.

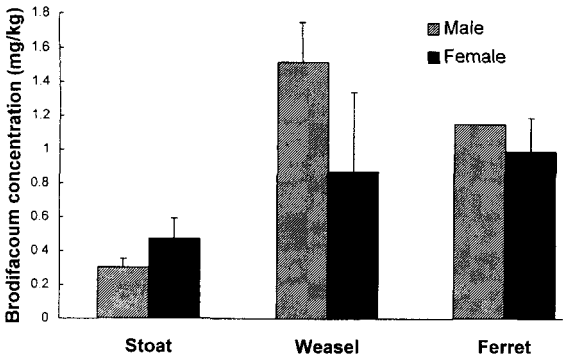

Fig. 4 Mean (+1SE) concentrations of brodifacoum detected in the livers of stoats (M=17; F=14), weasels (M=6; F=4) and ferrets (M=1; F=8) kill-trapped at Mapara Wildlife Management Reserve during (September-April 1993/94 and 1994/95), and following (May-July 1993/94) Talon poison bait station operations.

Table 1 Concentrations of brodifacoum detected in the livers of male and female rats kill-trapped at Waipapa, Pureora Forest (A) during and (B) in the three months following a Talon bait station poisoning operation All baits were removed from the stations on 16 April 1996. The least detectable level was 0.03 mg/kg. ND=not detected.

Date	Sex	Weight (g)	Concentration (mg/kg)
A During poisoning			
31 January	F	95	ND
8 February	F	110	2.90
8 February	F	185	0.08
12 February	M	140	0.96
12 February	M	155	0.44
23 February	M	135	0.05
21 March	M	>135*	ND
25 March	M	70	0.27
25 March	M	95	1.50
27 March	F	135	ND
29 March	M	85	0.17
1 April	M	200	1.43
B Following poisoning			
19 April	M	145	0.14
3 May	F	140	ND
25 May	M	105	0.08
24 June	M	180	0.36
25 June	F	150	0.04
27 June	M	140	0.05
27 June	M	180	0.08
7 July	M	185	ND
16 July	F	140	0.39
17 July	F	150	ND
17 July	M	180	0.18
18 July	F	130	ND
22 July	M	140	ND

* Head was missing

animals with positive results did not differ significantly between the sexes ($F_{1,27}$=1.51, P = 0.23), (Fig. 4), but a higher proportion of the females (93.3%) than of the males (68%) contained brodifacoum residues (G_{adj}=3.88, d.f.=1, $P < 0.05$).

Brodifacoum residues were detected in the livers of ten of the 14 (71.4%) weasels analysed (Fig. 3B). The mean residue level for these ten animals was 1.26 mg/kg. Mean residue levels in this small sample tended to be higher in males than in females (Fig. 4).

Of the 16 ferrets analysed, nine (56.3%) had detectable brodifacoum residues in their livers (Fig. 3C). The mean residue level for these nine animals was 1.01 mg/kg. While eight out of ten females had positive results, only one of the six males did. The residue level for that male was similar to the mean level of the female ferrets (Fig. 4)

Only the morepork and two magpies out of the birds sampled from Mapara contained brodifacoum residues in their livers (Table 2). The four robins collected from Waipapa had no detectable residues. Brodifacoum was detected in all five of the pigs and both cats but not in the four red deer.

DISCUSSION

Brodifacoum has a very long biological half life (150–200 days), which means that sublethal doses may accumulate and become fatal over a long period (Godfrey 1985). It is extremely persistent in liver and to a lesser extent, muscle tissue (Eason et al. 1996). The relationship between the dose of brodifacoum ingested and the level retained in the liver is complex, varies among individuals and is poorly understood (Hegdal & Colvin 1988; Colvin et al. 1991). This means that residue levels in liver are difficult to interpret, as residue loads may not be closely correlated with mortality (Hegdal & Colvin 1988). However, the presence of brodifacoum residues in the majority of rats during the poisoning operation is a hazard for mustelids and other non-target species, which are thereby exposed to secondary poisoning. Mustelids are more likely to consume the poison by eating poisoned prey than by eating the bait directly (Richardson 1995; E. B. Spurr pers. comm.). Alterio et al. (1997) showed that rats killed by eating Talon baits contained high levels of residue, more than enough to ensure that mustelids scavenging these carcasses would be exposed to secondary poisoning. The present study confirms that live rats are another source of secondary

poisoning. Rats range normally for 3–5 days after consuming a fatal dose of brodifacoum (Hooker & Innes 1995), so they remain available as tempting but dangerous prey for mustelids. Haemorrhaging rats may leave trails of blood, stray from cover and have slower reactions than normal, making them more vulnerable to predation (Cox & Smith 1992).

Rats are an important component of the diet of stoats in podocarp forests (King & Moody 1982; King et al. 1996). The persistence of brodifacoum levels in living rats for at least three months after the removal of poison baits means that they provide a continuing source of secondary poisoning for mustelids, long after the end of the poisoning programme. As trapping ended in July, our persistence estimate for rats is a minimum, but Eason et al. (1996) found that substantial sub-lethal concentrations of brodifacoum were retained in the livers of possums for eight months.

Possums are another potential source of secondary poisoning for mustelids, as they are also killed by brodifacoum bait station poison operations (Henderson et al. 1994). They can take up to 52 days to die after poison deployment, and carcasses may be scavenged for several weeks after they have died (Alterio & Moller in press). However, in most areas where possums are controlled with brodifacoum they are maintained at low densities (e.g. Bradfield & Flux 1996), so they may not very often be available as a source of secondary poisoning.

Our mustelid data cover only animals that survived the secondary poisoning until they were caught. They do not indicate the percentage of mustelids killed by secondary poisoning. The residue levels we found in trapped stoats were on average between one half to one third of those from stoats killed by consumption of brodifacoum in rabbits and/or rodents (Alterio 1996; Alterio et al. 1997; Brown et al. in press). The lowest level (0.44 mg/kg) they recorded in a dead stoat was exceeded in 26% of our sample. Residue levels in 70% of our weasels and 11% of our ferrets also exceeded those reported for these species lethally poisoned (Alterio 1996; Alterio et al. 1997). As noted above, residue levels in liver are difficult to interpret, as residue loads are not necessarily closely correlated with mortality (Hegdal & Colvin 1988).

The lower percentage of ferrets with detectable residue levels compared with stoats and weasels reflects to some extent the difference in diet amongst the species in the study area. Rodents accounted for 59% of identifiable items consumed by stoats, and 81% for weasels, but only 44% for ferrets caught at Mapara between 1989 and 1995. Possums did not

Table 2 Concentrations of brodifacoum detected in the livers of non-target species (excluding mustelids) collected by various methods during or four months after a Talon poisoning operation at Mapara Reserve. LDL=least detectable level. ND=not detected.

Species	n	Concentration (mg/kg)	LDL (mg/kg)	Collection method
Birds				
Tomtit	5	ND	0.3–0.1	Shot
Whitehead	5	ND	0.2–0.05	Shot
Bellbird	1	ND	0.1	Shot
Fantail	1	ND	0.2	Shot
Harrier	1	ND	0.02	Shot
Morepork	1	0.61		Shot
Magpie	1	0.41		Shot
Magpie	1	0.08		Shot
Magpie	8	ND		Shot
Pigs				
Piglet	2	0.007		Caught
		0.21		Found dead
Adult	3	1.7		Found dead
		1.6		Shot
		0.009		Shot
Cats	2	1.4		Found dead
		0.39		Caught

appear to be important in the diet of any of the mustelids analysed – possum remains were identified in only 1% of stoats caught and not at all in ferrets or weasels (Murphy et al. in press).

Our finding that female stoats were the most likely to contain poison residues may also be a result of dietary differences between the sexes. Female stoats at the Mapara study site ate more rodents than did males (Murphy et al. in press). Exposure to anticoagulant rodenticides was also found to be more prevalent in female stoats than in males in an English study (McDonald et al. in press). The differences between male and female stoats in percentage poisoned and in mean residue levels need to be verified by repeat studies. If female stoats are more affected than males by secondary brodifacoum poisoning, then this could have implications for secondary poisoning as a potential management tool. An effective method of killing female stoats would be very valuable, especially if it could be employed before juvenile stoats leave the natal nest, when adult females are difficult to catch (Dilks et al. 1996). Later in the year it would still be a useful alternative to trapping, as juvenile females are less often caught than males (King 1983; Dilks et al. 1996).

Our lack of evidence for brodifacoum residues in any of the five species of passerine birds sampled is consistent with their absence from the list of birds at risk from brodifacoum poisoning published by Eason & Spurr (1995). Robins were killed however, when brodifacoum baits were hand-broadcast in a South Island beech forest (Brown 1997). The presence of brodifacoum residues in the morepork is not surprising, as this species preys on rats (Saint Girons et al. 1986). They also prey heavily on insects, especially weta (Orthoptera) (Lindsay & Ordish 1964). Weta will consume poison baits, but Morgan & Wright (1996) found no evidence of brodifacoum residues in any insects after either aerial or bait-station Talon-poison operations. Three of 14 morepork radio-tracked through an aerial application of brodifacoum on Mokoia Island, Lake Rotorua (to eradicate mice) were found dead, and the likely cause of death was through secondary poisoning (B. Stephenson pers. comm.). Secondary poisoning with brodifacoum has been shown to kill other species of owls (Mendenhall & Pank 1980; Hegdal & Colvin 1988). The ability of a toxin to kill individual owls does not necessarily translate into a reduction in owl populations from secondary poisoning, however, as populations may be resilient enough to withstand the additional mortality (Hegdal & Colvin 1988). Long-term studies are needed to determine the effect of the use of brodifacoum on morepork populations.

The positive results of residue testing of all five pigs highlight the wide-ranging effects of the use of brodifacoum in forest ecosystems. It poses a potential threat to human health via wild pork consumption, as discussed by Eason et al. (1996). More research is needed on the persistence of brodifacoum in the environment and its effects on non-target species. As brodifacoum is cumulative, some species may accumulate lethal levels of the toxin over two, three or more years of poison use.

ACKNOWLEDGMENTS

We thank Alan Jones for assistance with rat trapping, and Graham Ussher and Lloyd Robbins for their help in animal autopsies. We also thank Phil Thomson and Doug Taucher for collecting some of the birds, Ross Whiting and Doug Taucher for collecting the pigs and Alan Jones, Dave Wills and Hamish McDougall for collecting the deer. We thank Chris Edkins for drafting the map, Amanda Campbell for library assistance, and John Dowding and Terry Greene for comments on the draft manuscript. We are grateful to Nic Alterio, Grant Singleton and the editor for their useful comments following submission of this manuscript.

REFERENCES

Alterio, N. 1996: Secondary poisoning of stoats (*Mustela erminea*), feral ferrets (*Mustela furo*), and feral house cats (*Felis catus*) by the anticoagulant poison, brodifacoum. *New Zealand journal of zoology 23*: 331–338.

Alterio, N.; Brown, K.; Moller, H. 1997: Secondary poisoning of mustelids in a New Zealand *Nothofagus* forest. *Journal of zoology, London 243*: 863–869.

Alterio, N; Moller, H. in press: Restoration of New Zealand's mainland ecological communities by secondary poisoning of introduced mammalian predators. *Proceedings 18th vertebrate pest conference, California.*

Bradfield, P.; Flux, I. 1996: The Mapara kokako project 1989–1996, a summary report. Department of Conservation, Waikato Conservancy, Hamilton.

Brown, K. P. 1997: Impact of brodifacoum poisoning operations on South Island robins *Petroica australis australis* in a New Zealand *Nothofagus* forest. *Bird Conservation International 7*: 399–407.

Brown, K. P.; Alterio, N.; Moller, H. in press: Multi-predator control at low mouse (*Mus musculus*) abundance in a New Zealand *Nothofagus* forest. *Wildlife Research.*

Colvin, B. A.; Jackson, W. B.; Hegdal, P. L. 1991: Secondary poisoning hazards associated with rodenticide use. *In*: Magallona, E. D. *ed. Proceedings of the International Congress on Plant Protection 11*: 60–64.

Cox, P.; Smith, R. H. 1992: Rodenticide ecotoxicology: Pre-lethal effects of anticoagulants on rat behaviour. *In*: Borrecco, J. E.; Marsh, R. E. *ed. Proceedings of the 15th Vertebrate Pest Conference.* Davis, University of California. Pp. 165–170.

Dilks, P. J.; O'Donnell, C. F.; Elliott, G. P.; Phillipson, S. M. 1996: The effect of bait type, tunnel design, and trap position on stoat control operations for conservation management. *New Zealand journal of zoology 23*: 295–306.

Eason, C. T.; Spurr, E. B. 1995: Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. *New Zealand journal of zoology 22*: 371–379.

Eason, C. T.; Wright, G. R.; Batcheler, D. 1996: Anticoagulant effects and the persistence of brodifacoum in possums (*Trichosurus vulpecula*). *New Zealand journal of agricultural research 39*: 397–400.

Godfrey, M. E. R. 1985: Non-target and secondary poisoning hazards of "second generation" anticoagulants. *Acta zoologica fennica 173*: 209–212.

Hegdal, P. L.; Colvin, B. A. 1988: Potential hazard to eastern screech-owls and other raptors of brodifacoum bait used for vole control in orchards. *Environmental toxicology and chemistry 7*: 245–260.

Henderson, R. J.; Frampton, C. M.; Thomas, C. D.; Eason, C. T. 1994: Field evaluation of cholecalciferol, gliftor, and brodifacoum for the control of brushtail possums (*Trichosurus vulpecula*). *Proceedings of the 47th New Zealand Plant Protection Conference*: 112–117.

Hooker, S.; Innes, J. 1995: Ranging behaviour of forest-dwelling ship rats, *Rattus rattus*, and effects of poisoning with brodifacoum. *New Zealand journal of zoology 22*: 291–304.

Innes, J.; Warburton, B.; Williams, D.; Speed, H.; Bradfield, P. 1995: Large-scale poisoning of ship rats (*Rattus rattus*) in indigenous forests of the North Island, New Zealand. *New Zealand journal of ecology 19*: 5–17.

King, C. M. 1983: The relationship between beech (*Nothofagus* sp.) seedfall and populations of mice (*Mus musculus*), and the demographic and dietary responses of stoats (*Mustela erminea*), in three New Zealand forests. *Journal of animal ecology 52*: 141–166.

King, C. M.; Moody, J. E. 1982: The biology of the stoat (*Mustela erminea*) in the National Parks of New Zealand II. Food habits. *New Zealand journal of zoology 9*: 57–80.

King, C. M.; Flux, M.; Innes, J. G.; Fitzgerald, B. M. 1996: Population biology of small mammals in Pureora Forest Park: 1. Carnivores (*Mustela erminea, M. furo, M. nivalis,* and *Felis catus*). *New Zealand journal of ecology 20*: 241–251.

Lindsay, C. J.; Ordish, R. G. 1964: The food of the morepork. *Notornis 11*: 154–158.

McDonald, R. A.; Harris, S.; Turnbull, G.; Brown, P.; Fletcher, M. in press: Anticoagulant rodenticides in stoats (*Mustela erminea* L.) and weasels (*M. nivalis* L.) in England. *Environmental Pollution.*

Mendenhall, V. M.; Pank, L. F. 1980: Secondary poisoning of owls by anticoagulant rodenticides. *Wildlife Society bulletin 8*: 311–315.

Morgan, D. R.; Wright, G. R. 1996: Part 1: Monitoring for toxic residues. In: Environmental effects of rodent Talon baiting. *Science for Conservation: 38.*

Murphy, E.; Bradfield, P. 1992: Changes in diet of stoats following poisoning of rats in a New Zealand forest. *New Zealand journal of ecology 16*: 137–140.

Murphy, E. C.; Clapperton, B. K.; Bradfield, P. M. F.; Speed, H. J. in press: Effects of rat-poisoning operations on abundance and diet of mustelids in New Zealand podocarp forests. *New Zealand journal of zoology.*

Richardson, S, J. 1995: The susceptibility of ferrets (*Mustela furo*) to primary and secondary poisoning, and their ability to develop aversions to Compound 1080 under laboratory conditions. Unpublished B.Sc (Hons) dissertation, University of Otago, New Zealand.

Saint Girons, M-C.; Newman, D. G.; McFadden, I. 1986: Food of the morepork (*Ninox novaeseelandiae*) on Lady Alice Island (Hen and Chickens Group). *Notornis 33*: 189–190.

Speed, H. J.; Bancroft, F. J. 1997: Waipapa restoration project October 1995 – May 1996. Department of Conservation, Waikato Conservancy, Hamilton.

Taylor, R. H.; Thomas, B. W. 1989: Eradication of Norway rats (*Rattus norvegicus*) from Hawea Island, Fiordland, using brodifacoum. *New Zealand journal of ecology 12*: 23–32.

Taylor, R. H.; Thomas, B. W. 1993: Rats eradicated from rugged Breaksea Island (170 ha), Fiordland, New Zealand. *Biological conservation 65*: 191–198.