Controlling small mammal predators using sodium monofluoroacetate (1080) in bait stations along forestry roads in a New Zealand beech forest

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Abstract: A single five night pulse of sodium monofluroacetate (0.15% 1080) applied in bait stations at two different spacing intervals, 100 and 200 m, along forestry roads in New Zealand beech forest, killed all four of the resident radio-tagged stoats (*Mustela erminea*) and all three of the resident radio-tagged wild house cats (*Felis catus*) by secondary poisoning. Gut contents of predators indicated that house mice (*Mus musculus*), ship rats (Rattus rattus) and brushtail possums (*Trichosurus vulpecula*) were important sources of the toxin. High kills of predators, possums and rats at both 100 and 200 m spacing regimes suggest that greater efficacy of controlling these pests would be achieved with the latter method.
Evidence suggests that routine management of possums and rats using 1080 and brodifacoum has resulted in widespread control of small mammalian carnivores by secondary poisoning in New Zealand forests. However, aerial application of poison can kill large numbers of tomtits (*Petroica macrocephala*) and robins (*Petroica australis*) and few other native bird species have been adequately monitored through such operations. Reducing risks to native wildlife is responsible ecological management. Use of bait stations along forestry roads or tracks may be fundamental in mounting cost-effective large-scale ground-based protection of native wildlife through safer predator controls.

Keywords: Stoat; *Mustela erminea*; house cat; *Felis catus*; sodium monofluroacetate; 1080; secondary poisoning; pest control; conservation.

Introduction

The introduced stoat (*Mustela erminea*[1]), ship rat (*Rattus rattus*), and brushtail possum (*Trichosurus vulpecula*) are significant predators of indigenous wildlife in New Zealand forests (Innes and Hay, 1991; O'Donnell *et al.,* 1996; Brown, 1997a) and such mammals are responsible for the decline or extinction of several native birds (King, 1984; Holdaway, 1989; Innes and Hay, 1991; Clout and Saunders, 1995). In the 1990's one of the main challenges for conservation managers was the restoration of New Zealand's mainland ecological communities (Clout and Saunders, 1995). Large-scale control of rats and possums by aerial or bait station poisoning operations and control of mustelids by kill-trapping in several mainland forests was attempted (Henderson *et al*., 1994; Innes *et al*., 1995; Murphy *et al*., 1998), resulting in increased breeding success and recruitment into kokako populations (*Callaeas cinerea wilsoni*[2]) (Innes *et al*., 1999). Poisoning has the potential to greatly reduce the cost of controlling stoats compared with traditional methods of trapping because fewer visits to the control area are required and especially because stoats are often difficult to trap (King, 1989).

Secondary poisoning has killed introduced mammalian predators in New Zealand forests. In South Island beech forest, 100% of the resident radio-tagged stoats were poisoned following brodifacoum poisoning operations that killed rodents and possums (Alterio *et al*., 1997; Brown *et al*., 1998). Gillies and Pierce (1999) found that radio-tagged small mammalian carnivores died of secondary poisoning during sodium monofluroacetate (1080) bait station poisoning operations in North Island podocarp forest. Similarly, all the radio-tagged stoats died shortly after aerial application of 1080 for rodent and possum control in North Island podocarp forest (Murphy *et al*., 1999). Rats were found in the gut of the majority of poisoned stoats in that study. Alterio and Moller (2000) demonstrated that placement of brodifacoum in bait stations along forestry roads successfully poisoned

[1] Nomenclature of mammals follows King (1990)
[2] Nomenclature of birds follows Turbott (1990)

stoats in South Island podocarp forest. However, possums appeared to be an important source of poison for the stoats in that study. Both 1080 and brodifacoum killed rats in all trials where they were monitored (Innes *et al*., 1995). Placement of bait station along forestry roads allowing servicing by vehicles may provide cost-effective large-scale ground-based predator control in New Zealand's mainland forests. This research tested the efficacy of killing stoats and wild cats by placing 1080 in bait stations along forestry roads at 100 and 200 m intervals in New Zealand beech forest, 8-9 months after moderate seedfall when both rodents and possums were common. The efficacy of the two poisoning regimes at killing possums and rodents was also assessed.

Study area and methods

The study used forestry roads in two blocks of beech forest at Station Creek (42°13'S, 172° 15'E), 5 km SE of Maruia, South Island, New Zealand. The two sites were separated by 2 km. The topography consisted of a series of ridges, moderately steep slopes and deep gullies running into river valleys. The beech forest consisted of mainly red (*Nothofagus fusca*[3]) and silver beech (*N. menziesii*) with some mountain beech (*N. solandri*) and supported several threatened species of native birds.

Thirty Edgar traps (King and Edgar, 1977) were placed at 150 m intervals along forestry roads on each block and were set for 16 nights between 19 January 1999 and 4 February 1999 to live-capture stoats and cats. Traps were baited with portions of lagomorph carcasses and all traps were rebaited every 2-3 days. Possums were live-trapped in 30 collapsible 30 x 26 x 28 cm wire-mesh cages (Grieves Wrought Iron and Wireworks, PO Box 18 858, Christchurch, New Zealand) placed at 75 m intervals along roadsides in each block. Traps were baited with apple coated with a eucalyptus/flour lure and set for 6 nights between 20 January and 26 January 1999. The number of "effective trap nights" (etn) was calculated following the method by Nelson and Clark (1973). All stoats and cats caught were sexed, ear-tagged, radio-collared and released. Possums were also sexed, ear-tagged, radio-collared and released. Stoats and cats were fitted with 2-stage c. 10 g radio-transmitters with brass loop aerials and possums with 2-stage c. 27 g radio-transmitters with brass loop or whip aerials. Fifteen of the possum transmitters contained mortality sensors which increased from 40 to 80 pulses per minute once the sensor was triggered (i.e. after the transmitter was stationary for 13.5 hours). Radio-transmitters were supplied by Sirtrack Limited, Private Bag 1403, Havelock North, New Zealand. After poisoning, survival of the radio-tagged stoats and cats was determined by close approach to the animal using a hand-held three-element Yagi antenna and a Telonics TR4 receiver (Telonics, Mesa Arizona, United States of America).

Thirty footprint tracking tunnels (King and Edgar, 1977) were placed at 75 m intervals along roadsides (within 5 m of the road edge) of both blocks to measure the relative abundance of rodents. Hansells blue food grade colouring was sprayed on the foam pads and tunnels were baited with a mixture of peanut butter and rolled oats placed in the middle and at each end of the tunnel. Tracking tunnels were run for three consecutive nights, twice before and after poisoning. Mann-Whitney U tests compared the average proportions of tracking tunnels visited by mice and rats between the pre- and post-poisoning periods in each block.

RS5 cereal pellets with a cinnamon lure manufactured by Animal Control Products Ltd, 10 Hayes street, Waimate, New Zealand were applied in 49 Philproof(tm) bait stations fixed on the ground to trees along forestry roads at 100 m intervals at Site A; and in 32 Philproof bait stations placed at 200 m intervals at Site B. Philproof bait stations were manufactured by Phil Thomson, Bankier Rd, RD1, Taupiri, New Zealand. They are moulded plastic hoppers (15 x 18 x 12 cm front and 15 x 18 x 24 cm back dimensions) with delivery trays (17 x 25 x 18 cm) and openings (13 x 7 x 9 cm) which allow rats, mice and possums to feed on the baits. 500g of pre-feed non-toxic pellets were placed in each bait station on 22nd, 26th and 30th January 1999 and 0.15% (1.5 g of 1080/kg of bait) toxic pellets were applied on 4 February 1999. Each bait station contained approximately 500 g of toxic baits. No further toxic bait was added. Bait stations were scored as being empty, quarter, half, three-quarters or full of pellets on each visit (26th January 1999; 30th January 1999; 4th February 1999) and when bait stations were removed on the 9th of February 1999.

After poison was deployed, stoats and cats were radio-tracked twice per day. Predators were closely approached using a hand-held 3-element Yagi antenna and a Telonics TR4 receiver after 4 consecutive constant radio-signals were recorded at the same approximate location.

Mammal remains in the guts of the dead predators were identified from bones and hair scale patterns, and bird remains from feathers (Day, 1966).

Liver samples taken from dead predators were assayed for 1080 by the National Chemical Residue Laboratory, AgriQuality New Zealand Limited, PO Box 40063, Upper Hutt, New Zealand. 1080 levels

[3] Nomenclature of beech follows Wardle (1984)

Table 1. Percent of bait stations at Site A (n=49: spaced at 100 m intervals) and B (n=32: spaced at 200 m intervals) that were scored empty, 1/4 full, 1/2 full, 3/4 full and full following the first (22.1-26.1.99), second (26.1-30.1.99) and third pre-feeds (30.1-4.2.99) and following the application of sodium monofluroacetate (0.15% 1080) toxic RS5 cereal baits (4.2-9.2.99) at Station Creek, South Island, New Zealand.

	PERCENT OF BAIT STATIONS							
	1st pre-feed		2nd pre-feed		3rd pre-feed		Toxic baiting	
	Site		Site		Site		Site	
	A	B	A	B	A	B	A	B
Empty	39	38	98	84	100	97	18	41
1/4	14	15	0	3	0	3	32	41
1/2	27	9	0	3	0	0	22	15
3/4	4	3	0	0	0	0	12	3
Full	16	35	2	10	0	0	16	0

were estimated using the 1080Tox.v2 method (Detection Limits ± 0.1 mg/kg) (Hoogenboom and Rammell, 1987) or the TMF-01 method (Detection Limits ± 0.002 mg/kg) adapted from Ozawa and Tsukioka (1989).

Results

Poisoning operation

Baits were consumed in 84%, 98% and 100% of the bait stations at Site A and 65%, 90% and 100% of the bait stations at Site B during the three respective pre-feeding periods (Table 1). Of these stations, 39%, 98% and 100% were empty at Site A and 38%, 84% and 97% were empty at Site B respectively. Five nights after poison was applied only 18% of bait stations were empty at Site A. In contrast at Site B, 41% of bait stations were empty (Table 1). Overall, 14.0 kg and 12.75 kg of toxic pellets were consumed on Sites A and B respectively. The bait stations were spread through 4.8 km of forest on Site A and 6.2 km of forest at Site B, giving 2.9 kg km-1 and 2.1 kg km-1 of 1080 toxic baits released at Sites A and B respectively.

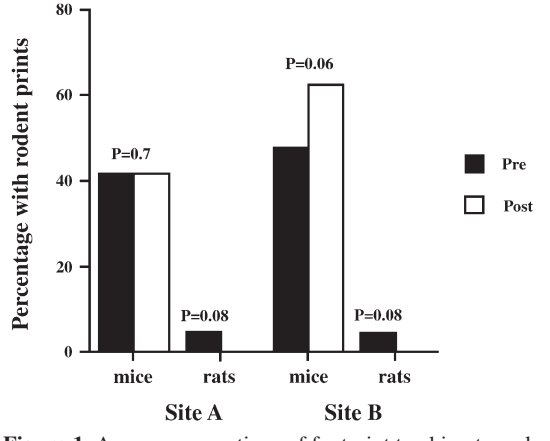

Figure 1. Average proportions of footprint tracking tunnels tracked by mice and rats pre- and post-sodium monofluroacetate (0.15% 1080) poisoning on Site A and B (n=30 in each site, set twice before and after poisoning) at Station Creek, South Island, New Zealand. Bait stations were spaced at 100 and 200 m intervals at Site A and B respectively. Mann-Whitney U-tests comparing the average proportion of tracking tunnels visited by rodents between the pre- and post-poisoning phases within each area.

Rodents

Footprints left in tracking tunnels showed rats and mice were present in both blocks (Fig. 1), but mice (tracked 45 % of the tunnels) were more abundant than rats (tracked 5% of the tunnels) before poisoning (P=0.0001). There was no difference in rodent tracking rates between blocks before poison was deployed (P=0.4 for mice; P=0.9 for rats). After poisoning mice tracked similar numbers of tunnels at Sites A (P=0.7) and B (P=0.06), despite the presence of mouse droppings in many of the bait stations. In fact, the trend for mice tracking appeared to increase after poisoning at Site B. No significant change in rat numbers was detected at either site (P=0.08) following poisoning, despite no rat prints recorded in tunnels.

Possums

Thirty-four possums were caught: 14 (9M, 5F) and 20 (11M, 9F) during 167 (8.4 possums/100 etn) and 162 (12.3 possums/100 etn) etn on Sites A and B respectively. There was no significant difference in trapping rates between areas (χ^2=1.0, d.f.=1, P=0.3). All adult females trapped were without pouched young, and only 3 juvenile possums were trapped.

All 15 radio-tagged possums with mortality sensors (n=7 Site A; n=8 Site B) were dead the day after 1080 was applied. Three of 10 radio-tagged possums without mortality sensors were not detected after poisoning. Accordingly, 1 of 12 radio-tagged possums survived the poisoning operation at Site A and 2 of 13 survived at Site B. All radio-tagged possums were approached 6 nights after the poisoning operation to score scavenging events. Only the hind leg of one radio-tagged possums was scavenged. Six unmarked possums were also found dead at Sites A and B and none of these animals were scavenged. All marked and unmarked animals found dead were within 30 m of the road. The fate of six possums marked only with ear-tags was undetermined.

Stoats and wild cats

Twelve stoats (6M, 6F) were trapped during 920 etn (1.3 stoats/100 etn) before the poisoning operations. However, one female stoat was found dead in a trap, another female moved 3 km away, four stoats (3M, 1F) were not detected after being released and two stoats (1M, 1F) were not radio-tracked within the poisoned zone after poison was applied. Accordingly, two radio-tagged male stoats were resident on Site A and two radio-tagged female stoats were resident on Site B during the poisoning operations.

Three juvenile female cats were also caught in the Edgar traps at Site B. No cats were trapped at Site A, but an adult tabby and juvenile black cat were sighted at Site A before poisoning. A black juvenile cat was also seen at Site B.

All the radio-tagged predators (4 stoats and 3 cats) tracked within the poisoned blocks died between 3-8 days after the poisoning operations. Stoat livers contained between 0.02-3.1 mg/kg of 1080 and the livers of cats contained between 0.02-0.16 mg/kg of 1080 (Table 2). All the poisoned stoats and cats were found less than 100 m from the road in the poisoned blocks, although female stoat 31 was found 2.4 km from where captured. This female was not detect until found dead. She was found with an unmarked dead possum, but there was no evidence of scavenging. None of the other poisoned predators were found with possum or rodent carcasses. However, remains of rodents where found in the gut of each poisoned stoat, although one stoat had also eaten possum (Table 2). The gut of one cat was empty and the other two cats contained rat and possum/bird remains respectively (Table 2).

Discussion

Efficacy of the 1080 poisoning method

This study had no non-treatment comparisons because they are very expensive to establish (capture of stoats can be difficult in New Zealand beech forest). Nevertheless, the mortality of the radio-tagged stoats, cats and possums during the two poisoning operations can be unequivocally interpreted as being caused by the application of 1080 because: (a) several other studies have demonstrated secondary poisoning of predators when using 1080 (Gillies and Pierce, 1999; Murphy *et al*., 1999), (b) rodents and possums are routinely controlled with 1080, (c) 1080 is an acute toxin and death of stoats, cats, rats and possums occurred very quickly after poison was deployed, (d) predator guts contained rodent and possum remains, (e) large proportions of radio-tagged animals died making the experimental effect obvious, but mainly because (f) liver samples from the dead radio-tagged stoats and cats contained 1080. No other sources of 1080 existed.

Most bait stations were empty after the second pre-feed of non-toxic baits. Despite double the application rate of toxic baits at Site A compared with Site B, only 2.9 kg km-1 and 2.1 kg km-1 of 1080 baits were released into the respective environments. Predators died within 8 days after 1080 was applied and all contained 1080. Lower levels of 1080 are detected

Table 2. Details of radio-tagged predators found dead following application of sodium monofluroacetate (0.15% 1080) in bait stations placed along forestry roads at 100 m intervals at Site A and 200 m intervals at Site B at Station Creek, South Island, New Zealand. Levels of 1080 in the livers of predators were estimated by the 1080Tox.v2 method* (Detection Limits ± 0.1 mg/kg) or by the TMF-01 method (Detection Limits ± 0.002 mg/kg).

Predator	Site	Sex	Weight (g)	Days after poison was applied found dead	1080 (mg/kg)	Gut contents
Stoat 27	A	M	330	4	0.02	Rat
Stoat 67	A	M	350	5	0.25*	Possum/Mouse
Stoat 21	B	F	185	3	0.03	Mouse
Stoat 31	B	F	195	8	3.1*	Mouse
Cat 39	B	F	980	8	0.02	Empty
Cat 65	B	F	585	7	0.16	Rat
Cat 77	B	F	975	6	0.02	Possum/Bird

in liver than muscle tissue (Dr. A. Erasmuson, National Chemical Residue Laboratory, Upper Hutt, N.Z., *pers. comm.*). Since 1080 is a fast acting poison the gut contents of the poisoned stoats and cats suggest that rodents (particularly mice) and possums were sources of the toxin.

No statistically significant reduction in rodent tracking rates occurred after the poisoning operations, but mice and rats were almost certainly poisoned. Mouse droppings were observed in many bait stations, rats were not detected after the poisoning operations and poisoned predators contained rodents in their guts. High kills of radio-tagged possums were achieved at both Sites A (92%: 11 of 12 poisoned) and B (85%: 11 of 13 poisoned), even though 1080 baits were only available for a five night period.

The high kills of predators, possums and rats achieved at both study sites suggest that bait stations spaced at 200 m apart along forestry roads in New Zealand beech forest will probably achieve higher efficacy of control of these pests than bait stations spaced 100 m apart. Repeat trials using 1080 in bait stations along forestry roads would be useful to determine (a) the area cleared of predators, (b) how long the area remained cleared and (c) the minimum baiting regime required to control small mammal predators in New Zealand forests.

Methods of secondary poisoning in beech forest

Brown *et al.* (1998) found that radio-tagged stoats died, probably from eating poisoned possum carcasses, after brodifacoum was applied in bait stations in South Island beech forest. In other trials, stoats scavenging brodifacoum poisoned possums died 1-2 weeks later in South Island podocarp forest (Alterio and Moller, 2000). Four times as many possums were trapped in the present beech forest study compared with the podocarp forest study described above (i.e. 10.3 possums/100 etn at Station Creek compared with 2.6 possums/100 etn at Saltwater forest: χ^2=27.6, d.f.=1, P=0.0001). Both studies used standardised possum trapping protocols, so using brodifacoum in bait stations along forestry roads in beech forest should also kill stoats.

Rodent numbers fluctuate widely in beech forest in relation to infrequent and irregular seedfalls (King, 1983; Fitzgerald *et al.*, 1996; King and Moller, 1997). This 1080 poisoning trial occurred 8-9 months after moderate seedfall when mice and rats were common. Rodents appeared to be an important source of toxin to the poisoned predators so it is unknown whether the result reported here will be repeated in non-mast years when rodents are scarce.

The efficacy of secondary poisoning of predators in New Zealand forests is probably dependent on the availability of poisoned rodents and possums (Alterio and Moller, 2000; Gillies and Pierce, 1999). However, the distribution of poisoned carcasses may also be important. For example, possums here died less than 30 m from the roadsides where bait stations were placed. Reduced spread of poisoned carcasses could effect the overall efficacy of the poisoning operations because there may be less chance of predators encountering sources of poison. In this study, two radio-tagged stoats were located to within 200-300 m of the poisoned zone, but were not killed. Replicated paired poisoning trials using 1080 and brodifacoum in bait stations along forestry roads are required to determine the efficacy of each poison at controlling predators in mast and non-mast years (when rodents are abundant and scarce) in New Zealand beech forests.

Implications for conservation

Large-scale aerial or bait station poisoning operations are routinely used to control rats and possums in New Zealand forests (Henderson *et al.*, 1994; Innes *et al.*, 1995; Murphy *et al.*, 1998). Mustelids and cats have been killed as a result of secondary poisoning following such operations (Alterio *et al.*, 1997; Brown *et al.*, 1998; Gillies and Pierce, 1999; Murphy *et al.*, 1999). The Department of Conservation does not advocate such methods of controlling stoats because the poisons are not registered for use in this way and because of potential hazards to other non-target animals and to humans (Dr. R. Hay, Department of Conservation, Wellington, N.Z., *pers. comm.*). This study confirms that even low amounts of 1080 released into the environment can result in secondary poisoning of introduced predators. Reducing risks of toxic residues to native wildlife and to humans is responsible ecological management. By deploying minimum baiting strategies some of the above concerns may be alleviated and such strategies will also have the added benefit of saving on poison costs.

The Department of Conservation is the main agency using 1080 and brodifacoum in New Zealand's natural forest estates. Use of such poisons kills non-target predators and methods of secondary poisoning could be an especially useful way of restoring New Zealand's mainland ecological communities because several introduced mammalian pests are killed in the same poisoning operation. However, large proportions of marked tomtits (*Petroica macrocephala*) or robins (*Petroica australis*) were poisoned by aerial application of 1080 on carrot baits in North Island podocarp forest (Powlesland, 1998; Powlesland *et al.*, 1999). Similarly, a large proportion of marked robins were poisoned when cereal pellet baits containing brodifacoum were hand-broadcast in one area of South Island beech forest (Brown, 1997b). Few other native species have been adequately monitored through poisoning operations to

assess the risks of direct or indirect poisoning. However, Brown (1997b) showed that the risks of directly poisoning robins were almost entirely eliminated by applying poison in bait stations. Reducing risks to native wildlife is responsible ecological management. Use of bait stations restricts direct access of non-targets to baits and by mounting poisoning operations along forestry roads or tracks cost-effective large-scale ground-based control of introduced predators may be achieved with minimal risks to native wildlife.

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