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SECONDARY POISONING OF STOATS AFTER AN AERIAL 1080 POISON OPERATION IN PUREORA FOREST, NEW ZEALAND

Summary: Stoats were monitored by three methods through an aerial 1080 poisoning operation at Waimanoa, Pureora Forest in August 1997. Tracking rates and number of live captures were used as indices of abundance, and radio-transmitters were used to follow individual animals. All 13 stoats with radio-transmitters within the poisoned area died between 2-18 days after the operation. No mustelids were tracked or live-trapped after the operation for three months. Of the radio-tracked stoats that died, rat remains occurred in 67%, passerine birds in 17%, cave weta in 17% and possum in 8%. Residues of 1080 were found in 12 of the 13 dead stoats. Our findings have important implications for the management of threatened species. Stoats are known to be a major factor in the continuing decline of some native birds. Previously, the potential of secondary poisoning to control stoats (and other predators) in New Zealand had focused on the use of anticoagulants, as these compounds persist and can accumulate in predators over a longer period. However, our results suggest that secondary poisoning with an acute toxin can also be highly efficient. This may also have greater public acceptability.

Keywords: Stoats; *Mustela erminea*; 1080; sodium monofluoroacetate; secondary poisoning; rats; radio-tracking.

Introduction

The endemic fauna of New Zealand evolved in the absence of mammalian predators and has proved particularly vulnerable to some of the mammals introduced since human settlement. Introduced mammalian predators have been responsible for many extinctions and declines in New Zealand's native fauna (King, 1984; Clout and Saunders, 1995). Stoats (*Mustela erminea*[1]) were introduced from England in the 1880s in an attempt to control rabbits (*Oryctolagus cuniculus*). They are widely distributed in a variety of habitats in both North and South Islands, from sea-level to sub-alpine areas, and are one of the most common carnivores in forests (King, 1990). They have become the most intractable of the critical conservation pests in New Zealand.

Impacts on threatened and endangered birds are of particular concern. Predation of young kiwis (*Apteryx* spp.[2]), chiefly by stoats, is the most important factor contributing to the demise of mainland kiwi populations (McLennan *et al*., 1996). Predation by stoats of nestling and breeding female kaka (*Nestor meridionalis*), an endemic forest parrot, is causing an overall decline, and in many instances local extinction, of the species (Wilson *et al*., 1998). Stoats are also causing declines of other hole-nesting endemic species (Elliott, Dilks and O'Donnell, 1996; O'Donnell, Dilks and Elliott, 1996) and are important predators of threatened shorebirds, such as New Zealand dotterels (*Charadrius obscurus aquilonius*) (Dowding and Murphy, 1996).

Large-scale poison operations (both aerial and ground) are used routinely to control Australian brushtail possums (*Trichosurus vulpecula*) and ship rats (*Rattus rattus*) in New Zealand forests, for both conservation purposes and to stop possums spreading bovine tuberculosis (Eason *et. al*., 1993a; Innes *et al*., 1995). Where they are common, ship rats are a major prey of stoats (King *et al*., 1996a; Murphy *et al*., 1998a) and when rat numbers are reduced, stoats have been shown to eat significantly more birds than when rats are abundant (Murphy *et al*., 1998a).

The aims of this study were (1) to measure stoat abundance and survival in relation to an aerial 1080 operation undertaken for possums and rats, (2) to determine the cause of death if there was any mortality, and (3) to monitor any re-invasion. The area used in this study was originally designated a non-treatment site for another study, examining the impact on mammalian predators of a ground-based brodifacoum operation to control rats and possums

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

(Murphy, 1997). The aerial 1080 operation reported here was a management decision made after our study had begun, and resources did not allow a third site to be set up as a non-treatment area.

Methods

Study area

Waimanoa is located in the northern section of the Hauhungaroa Range, approximately 40 km north-west of the town of Taupo. It is part of Pureora Forest Park and is dominated by the eroded mountain of Titiraupenga (1042 m) with the balance in generally rolling hill country which is occasionally incised by tributaries contained in steep-sided gullies. The area is largely forested, but much of it has been selectively logged and regenerating logging tracks are common. Remaining vegetation consists mainly of tall podocarps, tawa (*Beilschmiedia tawa* A. Cunn.), quintinia (*Quintinia* spp.), rewarewa (*Knightia excelsa* R. Br.), kamahi (*Weinmannia racemosa* Linn.) and hinau (*Elaeocarpus dentatus* J.R. et G. Forst.).

Poison operation

The poison operation covered 8577 ha and was undertaken by Environment Waikato at the request of the Animal Health Board, for bovine tuberculosis vector control purposes. It covered a similar area to that poisoned in 1993 with 1080 carrot bait. Pre-feed carrot baits were aerially spread on 5 and 6 August 1997 at a rate of 5 kg ha^{-1}. Toxic carrot baits, surface-coated with 1080, were aerially distributed at 10 kg ha^{-1} on 23, 29 and 30 August. To accommodate an on-going trial by Landcare Research on the effects of toxicity on red deer (*Cervus elaphus*) and possums, two concentrations were used. On 23 August, 0.15% w/w 1080 was distributed over 3500 ha and on 29 & 30 August, 0.08% w/w 1080 was distributed over 5077 ha (Fig. 1).

Mustelid indices

Tracking tunnels:
The proportion of baited tracking tunnels containing mustelid foot-prints was used as an index of mustelid abundance. Each tunnel consisted of a wooden base, a plastic removable tray (both 80 x 540 mm) and a white corrugated plastic cover (Corflute™), which extended 100 mm over each end of the base to prevent rain from soaking the papers. The tray was divided widthways into three equal-sized partitions. The central section contained a sponge impregnated with a 1: 4 solution of blue food dye diluted with water and the two outside partitions held pieces of brown paper. Animals walking through the tunnel left blue footprints on the paper, which provided a permanent record of prints. Ferret (*Mustela furo*), stoat and weasel (*M. nivalis vulgaris*) prints could not always be reliably distinguished, as there is an overlap in their size.

Three tracking tunnel lines were set up to provide an index of mustelid abundance (Fig. 1). Two lines were set alongside dirt roads (Waimanoa and Gorge) and one along a walking track (Titiraupenga). The Gorge Road line was within the

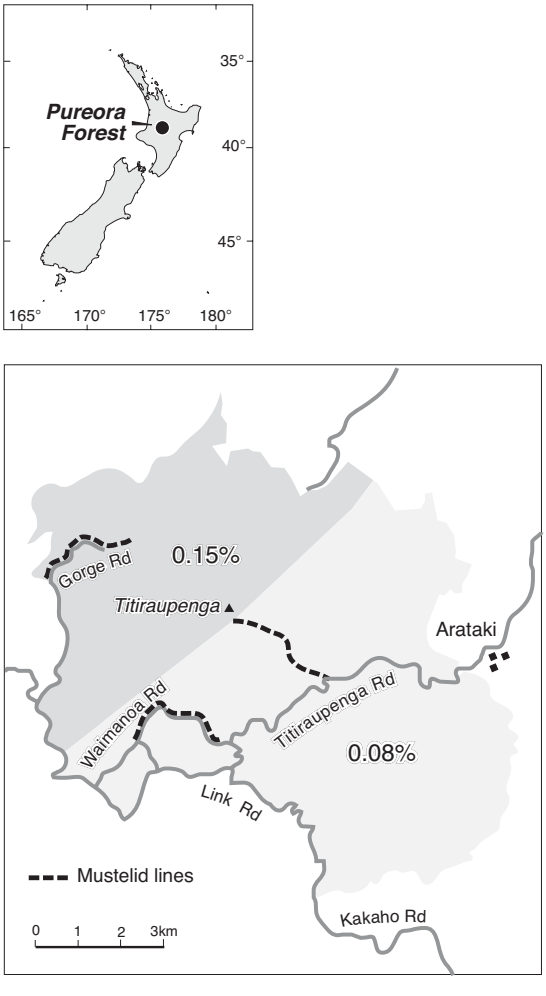

Figure 1: *Map of the Waimanoa study area in Pureora Forest. The three tracking tunnel lines are marked and the1080 poison area indicated by shading.*

0.15% 1080 drop area and the other two tracking tunnel lines were within the 0.08% 1080 operation area. Each line had 33 tunnels at 100 m spacings. The tunnels were set by inserting papers, and baiting the ink pad with a fresh piece of rabbit meat (about 1 cm^3). The Waimanoa line was first set in January 1997 and the Gorge and Titiraupenga lines in April 1997, subsequently they were all run together. The lines were run for two consecutive nights every 4-6 weeks. Although the lines were specifically set for mustelids, numbers of rat and mouse (*Mus musculus*) prints were also recorded.

Live-trapping

The number of individual stoats caught over three consecutive nights in 14 Edgar Mk 3 live-traps (King and Edgar, 1977) and 14 treadle traps (Gimpex N.Z. Ltd, Rotorua) was converted to the number caught per 100 trap nights (C/100TN) and used as a live-trapping index. The traps were arranged in pairs, one of each type 100 m apart with 200 m between each pair. Traps were set along Waimanoa Road, overlapping the tracking tunnel line, within the 0.08% 1080 area. In March 1997, eight possum cage traps (Greive Wrought Iron & Wirework, Christchurch, N.Z.) were also set and placed 300 m apart between the other traps.

Traps were baited with rabbit meat and checked daily. Stoats trapped were anaesthetised with halothane (Fluothane®, I.C.I. New Zealand Ltd., Lower Hutt), ear-tagged, weighed, sexed, and released at the capture site. A live-trapping index was undertaken in January, March, June, July, September, October and December of 1997 and in January, February and May of 1998.

Spearman's coefficient of rank correlation was used to test for significance. Probabilities ≤5% were considered significant.

Radio-tracking

Some stoats live-trapped were fitted with a two-stage radio-transmitter incorporated into a brass collar which acted as a loop aerial (manufactured by Sirtrack, Landcare Research, Havelock North, New Zealand). Transmitter packages weighed about 10 g and had a battery life of up to 3.6 months. Each animal's position and activity, whether stationary or moving (determined by signal fluctuation) were recorded at least daily after the poison operation, using a hand-held receiver (Telonics TR4) and 3-element Yagi aerial (Sirtrack, N.Z.). If a stoat was stationary on two consecutive visits, it was located exactly to check whether it was still alive. All the stoats caught and radio-tracked were within the area that was poisoned with 0.08% 1080.

Toxin and diet analysis

Stoats that died after the poison operation were collected and stored frozen. Muscle tissue from the leg 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 1080 residue analysis. One of two methods was used. The first method involved the extraction of the sample into acetone/water, then acidification and re-extraction with ethyl acetate. Benzyl dimethyl-phenylammonium chloride was added as the derivatizing agent and measured by gas chromatography with flame ionisation detection. The detection limit for 1080 was 0.1 mg kg^{-1}. The second method involved extracting the tissue with water and ethanol, followed by ion-exchange separation. The 1080 eluant is acidified and partitioned before derivatization with benzyl alcohol/benzyl chloroformate. Extraction follows, then determination by gas chromatography with mass spectrometry. The detection level for 1080 was 0.01 mg kg^{-1}.

For the diet analysis, the contents of the stomach and intestine were washed in a 0.5 mm sieve. Bird remains were assigned to orders by the structure of downy barbules and mammal remains identified from feet, pieces of tail or hair scale patterns (Day, 1966). Results of the diet analysis are presented as frequency of occurrence, i.e., the percentage of guts with food that contained each prey item.

Results

Mustelid indices

The Waimanoa tracking line always had greater than 50% of tunnels tracked by mustelids before the poison operation but the other two lines had much lower tracking rates (Fig. 2a). After the poison operation in August 1997, no mustelid tracks were detected in any of the lines until early December, when tracks were detected in the Titiraupenga and Gorge Road lines but not the Waimanoa line. By May 1998, the mustelid tracking rate at Waimanoa had returned to a level found prior to the poison operation.

Before the poison operation, rat tracking rates were lower in the Waimanoa Road line (between about 5-10%) than the other two lines (between about 10-37%; Fig. 2b). No rat tracks were recorded in September after the operation but one track was recorded in each of two lines in mid-October. Rat tracks were not consistently recorded in all three

lines until May 1998 and even then, the tracking rate was not high. Before the poison operation, there was a significant inverse correlation between stoat and rat tracking rates (Tied z = -2.64, Tied P = 0.01).

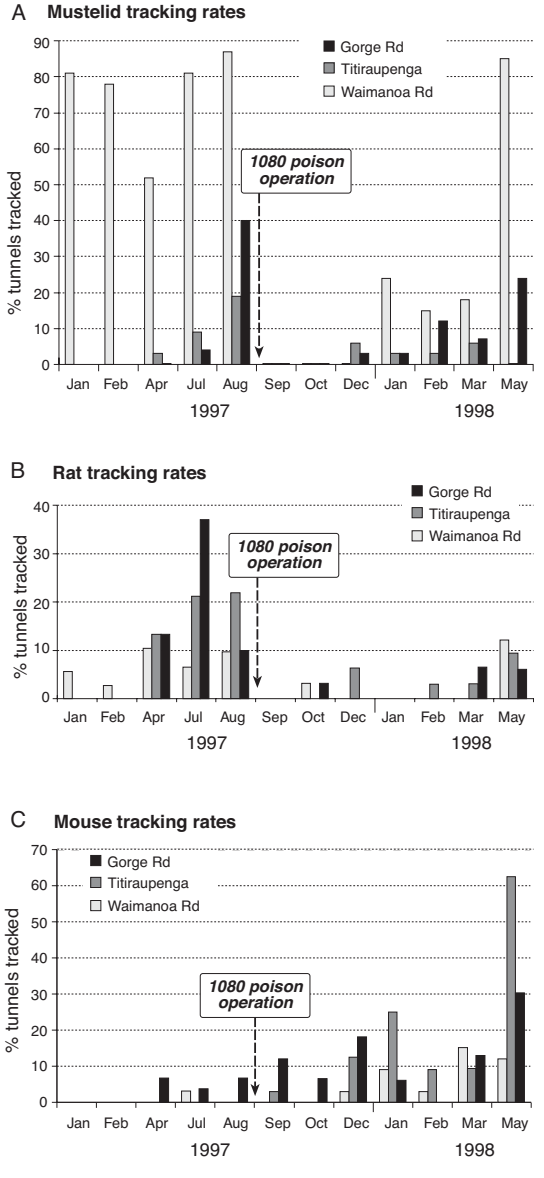

Figure 2: *Tracking tunnel indices for (a) mustelids (b) rats and (c) mice from the three lines within the Waimanoa study area. The Waimanoa Rd. line was first set in January 1997, and the Gorge Rd. and Titiraupenga lines in April 1997. The 1080 poison operation was in August 1997.*

Mouse tracks were not consistently recorded in the three tracking tunnel lines until December 1997 (Fig. 2c). They peaked in the Titiraupenga line in May 1998 when 62.5% of tunnels had mouse tracks.

The number of stoats live-trapped and captures per 100 trap-nights before and after the poison operation are given in Table 1. Only one ferret was live-trapped (a female caught in February 1998) and no weasels or cats were caught in any of the sessions. After the poison operation, no stoats were caught until 5-7 December (Table 1). The three stoats caught in December were all male, two adults and one juvenile. In January, two new male stoats were caught, one adult and one juvenile and both were recaught in May. In February, one new juvenile male stoat was caught but was never recaptured.

There was a significant correlation between the live-trapping and tracking tunnel indices (Tied z = 1.95, Tied P = 0.05). However, they did not always coincide. For example, there were no mustelid tracks detected in December 1997 on the Waimanoa Line but three stoats were caught in the live-traps. In May 1998, the tracking tunnel index had increased and was similar to that before the poison operation on Waimanoa Road, but only two stoats were live-trapped.

Radio-tracking, diet, and toxin analysis

At the time of the poison operation, 11 radio-collared stoats were known to be alive and within the 0.08% 1080 poisoned area. Stoats began to die within two days of the poison drop and after six days ten of them were dead. The eleventh was found dead 18 days after the operation (Fig. 3, Table 2). Two stoats that had radio-transmitters attached but were not known to be in the poisoned area at the time of the operation (Tag nos. 909 and 907), were found dead in the area seven days after the drop.

Table 1: *Numbers of stoats live-trapped over three consecutive nights along Waimanoa Road, Pureora Forest.*

Month	Number	Number of Caught trap nights /100 TN	Captures
Jan 97	9	83	10.84
Mar 97	5	97	5.16
Jun 97	5	84	5.95
Jul 97	9	81	11.11
Sep 97	0	84	0
Oct 97	0	84	0
Dec 97	3	84	3.57
Jan 98	2	83	2.41
Feb 98	1	81	1.24
May 98	2	81	2.47

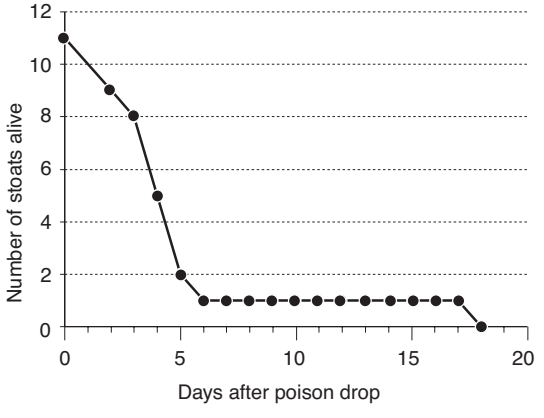

Figure 3: *Survival of the 11 radio-collared stoats known to be in the poison area at the time of the aerial 0.08% 1080-carrot operation in Waimanoa, August 1997.*

Of the 13 stoats that died after the poison operation, one had an empty gut. Of the twelve with prey remains, rats occurred in eight (66.7%); birds (passerines) occurred in two (16.7%), cave weta (Rhaphidophoridae) in two (16.7%), and possum in one (8.3%; Table 2). At least four cave weta were in one of the female stoats and at least two in the other.

Residues of 1080 were found in 12 of the 13 stoats that died (Table 2). There was no significant relationship between the 1080 concentration found in stoats and the number of days they died after the operation (Tied z = -1.22, Tied P = 0.22).

Discussion

Stoats were patchily distributed in the study area. Both the live-capture and tracking tunnel indices indicated a higher density of stoats in the Waimanoa Road area, than in the other two areas. This highlights the importance of replication, when an index of stoat abundance is required. When re-invasion of stoats occurred after the poison operation, the highest rates were again recorded on Waimanoa Road. The explanation for this is not known but is worth future investigation, as it could help us refine our stoat control techniques.

Where rats are common, they are a major prey of stoats (King *et al*., 1996a; Murphy *et al*., 1998a) and it is not known whether the inverse relationship between the stoat and rat index before the poison operation was due to an interaction between the animals, and/or a result of habitat preferences. Rats were found to be patchily distributed in a Northland forest (Dowding and Murphy, 1994), but in a study in the central North Island, there was no significant difference between rat capture rates in different habitat types (King *et al*., 1996b). In Fiordland, adult male stoats showed a preference for road side habitats, probably because they were scavenging road-killed animals (Murphy and Dowding, 1994). More research on spatial preferences/spacing of stoats and rodents is needed and the findings may have implications for trapline layout and/or placement.

As there was no non-treatment area, it is not known whether the increase in mouse tracks detected 3-9 months after the poison operation was related to the operation. However, mice increase 3-6

Table 2: *Details on the stoats radio-tracked at Waimanoa, Pureora Forest. The aerial 1080 poison operation over the area the stoats were in, was carried out on 30 August, 1997. 1080 residue concentration was measured in leg muscle tissue from dead stoats. ND = not detected.*

Tag No.	Sex	Body Wt. (g)	Date of first capture	Date found dead	1080 (mg kg^{-1})	Gut contents
179	F	255	22 Jan 97	3 Sep 97	0.14	rat
183	F	190	24 Jan 97	1 Sep 97	0.24	weta
903	F	240	29 Jul 97	1 Sep 97	0.44	weta
126	M	315	22 Jan 97	4 Sep 97	0.13	rat
165	M	370	22 Jan 97	3 Sep 97	0.33	rat
200	M	255	23 Jan 97	18 Sep 97	0.21	bird & possum
198	M	335	5 Mar 97	5 Sep 97	0.03	bird
910	M	265	17 Jun 97	4 Sep 97	0.03	empty
901	M	205	20 Jun 97	3 Sep 97	0.06	rat
909	M	300	27 Jul 97	6 Sep 97	0.11	rat
904	M	340	3 Aug 97	4 Sep 97	0.48	rat
907	M	395	15 Aug 97	6 Sep 97	0.39	rat
924	M	290	16 Aug 97	2 Sep 97	ND	rat

months after poison operations and this may be due to reduced competition and/or predation by rats (Clout *et al*., 1995; Innes *et al*., 1995).

For nine months after the poison operation, the only stoats caught were males. It is not known whether only males dispersed into the area, or whether both males and females re-invaded but that the females were not detected. Male stoats have also predominantly been caught after poison and trapping operations in other studies (Dilks *et al*., 1996; Brown, Alterio and Moller, 1998; Murphy *et al*., 1998a). In Sweden, male stoats moved more extensively than females in spring-summer, probably because they were searching for receptive females (Erlinge and Sandell, 1986). However, male stoats are often caught more frequently than females, irrespective of trapping system or stoat density (King and McMillan 1982; Alterio, Brown and Moller, 1997), as female stoats can be difficult to catch even when they are present (Dilks *et al*., 1996). A longer live-trapping period after the poison operation may have detected the presence of female stoats, as they are known to re-invade trapped areas (Murphy and Dowding, 1994, 1995) and are capable of dispersing long distances (Murphy and Dowding, 1995).

Although most indices are affected by factors other than just the abundance of the target animal, such as activity patterns and hunger, in most management operations it is not practical or necessary to measure actual density. The tracking tunnel indices in this study appeared to give a good indication of changes in stoat abundance, and were much less labour-intensive than live-trapping or radio-tracking.

The live-trapping, tracking tunnels and radio-telemetry all indicated that there was a dramatic reduction in stoat density over the poisoned area following the operation. This finding is similar to that of another study, where six cats, a stoat and a ferret monitored through a 1080 bait station operation to control possums and rodents all died from secondary poisoning (Gillies and Pierce, 1999). Other studies have also reported secondary poisoning of non-target species, particularly carnivores and raptors, following 1080-baiting campaigns (e.g., Hegdal *et al*., 1986; McIlroy and Gifford, 1991; Algar and Kinnear, 1996; Spurr and Powlesland, 1997). Numbers of stoats caught over a six-month period at Mapara Reserve appeared to be unaffected by whether there had been a poison operation or not (Murphy *et al*., 1998a). However, the continued trapping of stoats may have led to low numbers in the reserve, obscuring any initial effect of the poison operations.

The diet analysis of dead stoats in our study suggests that in most cases secondary poisoning was caused by stoats eating poisoned rats, although birds, weta and possums were also implicated. Operations using 1080 and targeted at rats and possums generally result in high kills of those animals (Eason, *et al*., 1993a; Innes *et al*., 1995) such that carcasses are readily available as food for stoats and other carnivores. Some passerine birds, particularly tomtits (*Petroica macrocephala*), are also known to suffer high mortality as a result of 1080 operations (Spurr and Powlesland, 1997) and residues of 1080 were detected in cave weta for up to two weeks after baits had been sown (Eason *et al*., 1993b).

In New Zealand, large scale 1080 operations in forests were initially undertaken purely for possum control (Eason, *et al*., 1993a). When it was realised that these operations were also killing rats (Innes *et al*., 1995), many subsequent control operations undertaken for conservation purposes were designed to take advantage of this (e.g., Bradfield and Flux, 1996; Speed and Bancroft, 1997; Pierce, 1997). The results from this study suggest that stoats, which are a major conservation pest, have probably also been controlled inadvertently during these operations. A number of experiments have shown increased fledging success of forest birds after rat and possum control (e.g., James and Clout, 1996; Innes *et al*., 1999) and attributed this increase to a decrease in predation from rats and possums. However, it is now known that stoat numbers can be effectively reduced by secondary poisoning with both brodifacoum and 1080, thus confounding the interpretation of which predators are important.

Previously, the potential of secondary poisoning to control stoats (and other predators) in New Zealand had focused on the use of brodifacoum, as this compound persists and can accumulate in predators over a longer period (Alterio *et al*., 1997; Brown *et al*., 1998). However, our results suggest that secondary poisoning with an acute toxin can also be highly efficient. This may have greater public acceptability, as recent data has shown that a number of non-target organisms, including brown kiwi (*Apteryx mantelli*), morepork (*Ninox novaeseelandiae*), and feral pigs (*Sus scrofa*) have been contaminated with brodifacoum where it has been used for rodent and possum control (Murphy *et al*., 1998b; Robertson *et al*., 1999).

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