Scientific Article

Acceptance by stoats (*Mustela erminea*) of 1080 (sodium monofluoroacetate) in small-volume baits and its effect on behaviour and time to death

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Abstract

AIMS: **To assess whether stoats (*Mustela erminea*) would eat small baits containing 0.1% sodium monofluoroacetate (1080); whether they would die from it; how long it would take to kill them; and to document the behaviour of 1080-intoxicated stoats.**

METHODS: **Stoats were offered 1-g baits of two semi-fluid formulations containing 0.1% 1080, presented in open dishes, and their subsequent behaviour was monitored by video and direct observation. Muscle samples from stoats that died were analysed for 1080 residues.**

RESULTS: **There was no significant difference between two types of bait with regard to acceptance, mortality, and time to death, and behavioural effects were similar; consequently, results from the two types of bait were combined. Twelve of 14 stoats offered the baits ate them voluntarily, and a 13th licked bait off its fur; all 13 died between 1 h 15 min and 4 h 7 min (mean 2 h 38 min) later. At first (range 29 min – 2 h 7 min, mean 1 h 1 min), their behaviour appeared to be normal. Ataxia and hyperactivity were the first behavioural signs of poisoning, and lasted 2 min – 1 h 40 min (mean 26 min). This was followed by recumbency with convulsions and rapid breathing (range 16 min to 2 h, mean 58 min), then recumbency with limited activity and progressively shallow breathing prior to death (range 1–51 min, mean 33 min). Stoats became non-responsive to a light being turned on, or to touch once recumbency became sustained.**

Residues of 1080 were found in muscle tissue of all 13 dead stoats, at concentrations ranging from 0.075 μg/g in a 287-g male that died 4 h 7 min after eating only 0.74 g of bait, to 2.5 μg/g in a 254-g female that died 2 h 42 min after taking a whole 1-g bait.

CONCLUSION: **Stoats will voluntarily take small (1-g) baits containing a lethal dose of 1080 at 0.1%, and die from it comparatively rapidly for a mammalian carnivore.**

KEY WORDS: ***Stoat, Mustela erminea, pest control, animal welfare, sodium monofluoroacetate, 1080, intoxication, behaviour***

Introduction

The prospects of restoring mainland populations of threatened species depend on finding new technology to control stoats, at sustainable cost and landscape scales, while also minimising the risk to non-target species and the welfare cost to the stoats. Conventional control technology using single-catch steel traps can provide some control of stoats (O'Donnell et al 1996), but is labour-intensive and expensive. Recent work has demonstrated the potential value of poisoning as an alternative to trapping, by injecting lethal doses into hen eggs placed in simple tunnel bait-stations. Captive stoats have taken sodium monofluoroacetate (1080), diphacinone and cholecalciferol when presented in hen eggs or experimental baits (Spurr et al 1998, 2002; Spurr 1999).

The technique of presenting 1080 or diphacinone to stoats in eggs has also been tested successfully in the field (Dilks and Lawrence 2000; Lawrence and Dilks 2000). The associated assumptions, that all stoats can break into a hen's egg and eat the whole of its contents, were usually, but not always, met. Some stoats would not enter a tunnel or take eggs at all. In early field trials, the concentration of toxin was very low, at 0.3 mg 1080 in a 50-g egg, equivalent to only 0.6 mg/kg for a 480-g male (Spurr 2000), a dose that may not kill larger stoats, especially if they do not eat the whole egg. However, all stoats died after eating one egg containing 1 mg 1080, equivalent for a large male stoat to the recommended dose of 2 mg/kg; very few males exceed 0.5 kg (Spurr and Hough 1997).

Future development of techniques for poisoning stoats could benefit from the development of smaller baits that could more conveniently be distributed in the field and which ensure that a lethal dose is consumed. However, a smaller bait would require a higher concentration of toxin, which raises concerns that stoats may detect the toxin and reject the bait, or eat only some of it and experience sublethal poisoning. The questions of the minimum size and type of bait in which stoats will accept an effective dose of an active agent need to be examined before new types of bait and their presentation can be tested in the field. Despite the existence of alternatives, 1080 remains an important toxin for stoats because, like most carnivores, stoats are extremely sensitive to it (Spurr 2000).

Use of 1080 in any bait is controversial, however, since it may have significant secondary effects on non-target species (Murphy et al 1999; Eason and Wickstrom 2001; Sharp and Saunders 2004a). Current attempts to mitigate this problem aim either to develop a target-specific toxin that can be broadcast, or to design

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1080 Sodium monofluoroacetate

a reliable means of target-specific delivery of a general toxin. Indeed, when offered in a robust, fully enclosed bait station, 1080 bait offers minimal threat to the environment and to non-target species (Green 2003).

In this study, we observed the reactions of captive stoats offered lethal doses of 0.1% 1080 presented in small, 1-g baits of two different semi-fluid formulations, the amounts they ate, and the consequences. Specifically, we aimed to assess whether stoats would eat baits containing 0.1% 1080; whether they would die from it; how long it would take to kill them; and to document the behaviour of 1080-intoxicated stoats. If confirmed to be effective and humane, we would use these small baits in a new automated bait dispenser designed to maximise efficiency of stoat control in areas containing kiwi (*Apteryx* spp) whilst minimising exposure of non-target species to toxin (CM King, unpubl. obs.).

Materials and methods

This study consisted of two experiments in which stoats were offered bait containing 0.1% 1080, and then their behaviour was observed closely by video and direct observation. The bait formulation was different for each experiment.

Experimental design

The Massey University Animal Ethics Committee, Palmerston North, New Zealand, approved this study. In order to minimise the use of experimental animals, the Committee supported our design of a stepwise strategy whereby we could use the results of each trial to determine whether the next trial would be necessary or not. Instead of testing a range of doses on a few animals each, Experiment 1 was commenced using only the recommended dose of 1 mg 1080 in 1 g of bait, i.e. 0.1% 1080, in an egg/flax-oil (*Linum usitatissimum*) mixture. The non-toxic formulation of this bait is known to be well accepted by wild stoats (Purdey et al 2003). This part of the trial represented the first attempt to test the variation in response of six individual stoats to a toxic formulation of this bait.

The protocol required that if the 0.1% dose was not accepted we would proceed to a second trial of the same formulation (Experiment 1a) but use the lower dose of 1 mg 1080 in 3 g of bait (0.03%). However, if all six stoats died in Experiment 1 the number of lethal trials could be minimised by proceeding directly to Experiment 2, offering 1 mg 1080 in 1 g of a different formulation, namely fresh homogenised bovine brain. Brain tissue was chosen as the alternative formulation to the fresh egg and flax-oil because wild stoats often eat the head of a prey animal first (King and Powell 2007), leaving the rest of the carcass if food is abundant; thus, we hypothesised that stoats might have a strong innate preference for brain material whenever they can access it. Both baits were prepared in advance and stored frozen until required.

The difference in acceptance of the two formulations of bait was assessed by measuring the total number of encounters, i.e. number of times a stoat closely approached or sniffed a bait, before a lethal dose was taken, and the time elapsed between first encounter and eating a bait. To make the experiment a realistic simulation of how stoats would encounter these baits in the wild, the toxic experimental baits were offered alone and without pre-baiting. This experimental design meant that the two formulations of high-concentration 1080 baits were not tested concurrently, reducing the rigour of any statistical comparison of the palatability of egg/flax-oil *vs* brain as bait materials.

Bait shyness, following exposure to sublethal doses of toxin, can seriously compromise pest control operations, but can be prevented by feed additives that modify the neurotransmitter receptors which facilitate associative memory formation and the acquisition of learned behaviours (Devine and Cook 1998). We incorporated a test of this possibility into our procedure, by adding an experimental memory-blocker, supplied by Dr Christian Cook, HortResearch, Ruakura, to the baits; the formulation of the memory-blocker is confidential.

Two experimental observation arenas, each 110 cm long x 90 cm wide x 55 cm high, were constructed. These were observable from an adjacent room via one-way glass. A hole in one side of each cage led to a dark nesting box, measuring 30 cm long x 20 cm wide x 20 cm high, containing familiar nesting material (straw) from the animal's previous cage. The nesting box remained available to the animals for the duration of the trial. The activity of stoats was recorded from above, both in the open areas of the cage and inside the nesting box, using 0.33-inch black and white x-view HAD CCD infrared video cameras (Sony, Beijing, China) surrounded by a ring of 12 infrared light-emitting diodes, connected to video recorders (Digitor, 12 V AC/DC VHS recorders; Dick Smith Electronics (NZ) Ltd, Auckland, NZ).

Experimental animals

Stoats were sourced from professional trappers in the central North Island of New Zealand during February and March 2003. Captured stoats were allowed an acclimatisation period of between 3 and 14 weeks. During this period, the stoats were housed individually in wooden cages, and had access to a nesting box of similar dimensions to the experimental observation arenas. The temperature in the surrounding room was maintained at 18 ± 2°C, and double-glazed windows provided natural light:dark cycles.

Before the trials began, all stoats received two dead laboratory mice (~24, range 18–34, g each) or one dead young laboratory rat (~38, range 32–48, g each) per day. The food was placed on a saucer in the centre of the arena so that the stoats became accustomed to feeding in the open. The amount of food offered was adjusted up or down for each stoat according to its intake, to ensure satiation but to avoid caching. Half of the daily food ration was presented in the morning and half in the evening. Water containing a commercial ferret vitamin supplement (L/M Animal Farms; Pleasant Plain, Ohio, USA) was available *ad libitum*. The combination of rodents and vitamin supplement is a standard diet for captive-held stoats, and one that maintains them in good health (McDonald and Larivière 2002).

After the settling-in period, but at least 4 days before commencing the experiments, each animal was examined under isoflurane anaesthesia, and its sex and weight were recorded. Stoats were transferred to the experimental observation arenas at least 48 h before poison was offered.

During both experiments, stoats were offered half their normal daily food intake by giving them one dead laboratory mouse each morning. In the evening, a measured 1-g portion of the semi-fluid bait was spooned onto the saucer. Each stoat was monitored continuously from the time the bait was first offered until it died, or until 72 h had elapsed, whichever occurred first. Although provision was made for veterinary advice to be available on whether to continue observations of any highly-stressed animals that had not died within 12 h, this was never required. Individuals that never took any toxin, or not enough to be visibly affected, were returned to their home cages after the third night.

Behaviours analysed

The behaviour of stoats towards their normal food was analysed from the video recordings. On ~90% of occasions, food was taken within 1 h of it being offered, both day and night. Apart from the rapid dash to take food from the saucer, most stoats rarely left their nesting box during daylight. The number of times each stoat encountered the experimental baits was counted and defined as one or all of the following: approached the edge of the dish; sniffed the bait closely; or jumped on or over the dish. The sum of these behaviours gave the total encounter rate. Also recorded were the total time that elapsed between the moment when a stoat first encountered the bait and when it started eating it, the time between eating the bait and death, and the behaviour of each stoat after eating the bait.

Direct observations were also made of three stoats that had eaten bait, in order to determine their responsiveness to external stimuli at various stages after eating the toxin, and to check determinations of time to death made for the other stoats only from the videotapes. Responsiveness was determined every 10–15 min for recumbent animals by gently prodding them with a steel rod. A distinct physical reaction was recorded as a positive response. Death was defined as the loss of palpebral and corneal reflexes, absence of a heart beat, and relaxation of the iris causing dilation of the pupil. Analysis of the videotapes of the three stoats that were observed directly indicated that time of death was 4–6 min after the last visible sign of respiratory movement on the video recordings.

Analysis of carcasses

Dead stoats were stored frozen. In order to ensure that none of the deaths observed were due to causes other than 1080 poisoning, samples were sent from each carcass to be checked for 1080 residues. Muscle tissue was dissected from the legs and back of all dead stoats, to provide a 20-g sample for each stoat. The samples were analysed by the Toxicology Laboratory at Landcare Research, Lincoln, using TLM005, the assay of 1080 in water, soil and biological materials using gas liquid chromatography (Lyver et al 2005). The detection limit of the method was 0.002 μg/g and the uncertainty (95% confidence interval) ± 17%. This analysis was selected because Murphy et al (1999) reported that 1080 was not detected in the carcass of 1/13 animals that had died after eating poisoned prey.

Statistical analysis

Comparisons of the number of times stoats encountered each type of bait before eating it, and the total time taken from first encounter to acceptance, were made using analysis of variance, using SAS v9.1 (SAS Institute Inc, Cary NC, USA).

Results

Experiment 1

The first two stoats (M1 and M2) were offered egg/flax-oil bait containing the experimental memory-blocking additive (Table 1). Despite 45 close encounters, M1 never attempted to taste the

Table 1. Details of experimental animals, toxic baits taken or not, and results of analyses of carcasses, for 14 stoats offered two different types of bait (E = egg/flax-oil; B = bovine brain) containing 0.1% sodium monofluoroacetate (1080).

Sex/ No.	Bodyweight (g)	Date received (dd/mm/yy)	Date of trial (dd/mm/yy)	No. encounters before eating (or licking) bait	Time from first encounter to eating bait (h:min)	Bait type, amount eaten (g)	Time to death (h:min)	1080 Residues (μg/g)
M1	403	14/03/03	11/04/03	>45	>72:00	E+MB, 0	Survived	–
M2	368	14/03/03	11/04/03	>49 (8)	>72:00	E+MB, <0.05	Survived	–
M3	287	14/03/03	15/04/03	23	51:43	E, 0.74	4:07	0.075
M4	366	17/03/03	15/04/03	9	7:12	E, 1.0	2:51	0.62
F5	254	17/03/03	14/04/03	2	1:46	E, 1.0	2:42	2.5
M6	319	17/03/03	14/04/03	0	0:00	E, 1.0	1:57	2.2
F7	252	22/03/03	05/06/03	145	55:14	E, ?[a]	2:17[b]	0.26
M9	350	26/03/03	05/06/03	5	3:04	E, 1.0	2:22	2.0
F8	254	22/03/03	30/06/03	21	10:08	B, 0.75[c]	3:46	1.4
M10	336	26/03/03	19/06/03	10	1:18	B, 1.0	3:03	1.5
F11	256	27/03/03	19/06/03	6	0:04	B, 1.0	1:54	2.0
M12	414	27/03/03	30/06/03	21	26:15	B, 1.0	1:33	1.9
M13	357	27/03/03	20/06/03	18	3:44	B, 1.0	3:07	1.8
M22	271	26/04/03	22/06/03	>54	>72:00	B, 0	Survived	–
M1[d]	403	14/03/03	12/06/03	2	<0:01	E, 1.0	1:15	1.6
M2[d]	368	14/03/03	12/06/03	10	10:48	E, 1.0	2:59	2.2

[a] Unable to determine the weight of bait consumed because it was smeared over the plate, cage, and stoat
[b] This individual did not take the bait as normal, but accidentally fell in it and died after licking its paws clean
[c] Estimated amount of bait taken
[d] Second test, using egg/flax-oil bait without additive
M = male; F = female; MB = proprietary bait additive

bait throughout the 3-day trial. M2 licked the bait after eight encounters, shook its head vigorously, and thereafter ate no more although continued to visit the dish periodically. M2 ingested far less than a lethal dose, and showed no adverse effects. Thereafter, only baits with no additive were offered.

All of the next six stoats that were offered egg/flax-oil bait without additive died of 1080 poisoning, but only five of them took the bait voluntarily, after an average of 7.8 (range 0–23) previous encounters. The mean time from first encounter to eating the bait was 12 h 45 min, median 3 h 4 min. The sixth stoat, F7, repeatedly (145 encounters) ignored the bait, but while climbing on the roof fell onto the dish, stepped in the bait, then groomed its feet clean, and later died.

Stoats M1 and M2, that had refused the bait when it contained the additive, were then offered the same formulation without additive, and both ate the bait and died within 3 h. Neither showed any hesitation suggesting a previous unpleasant experience; M1 took the bait only 17 seconds after first encountering it.

Experiment 2

Five of the six stoats offered 1080 in the bovine brain bait ate it and died, after an average of 15.2 (range 6–21) encounters. The mean time from first encounter to acceptance was 8 h 30 min, median 3 h 45 min. The sixth stoat (M22) did not take it after numerous encounters, and was removed when the 72-h time limit expired.

Comparisons between baits

There was great variation between individuals in the number of encounters with each bait before it was taken, which consequently did not differ significantly between the egg/flax-oil and brain baits for the five dead stoats that voluntarily took a lethal dose of each of these baits ($F_{1,9}$=2.1; p=0.185; Table 2). There was also no significant difference between the periods from first encounter to acceptance of the two baits ($F_{1,9}$=0.17; p=0.694). The two stoats that were tested twice (once with and once without the memory-blocker additive) were not included in this comparison because their previous experience of the same bait counted as pre-baiting. However, their responses were within the same range as the five that had no previous experience of that bait, and they showed no sign of bait shyness.

Four of the five stoats that ate the egg/flax-oil bait returned to eat more or to lick the plate after first eating the bait. In contrast, none of the five stoats that ate the brain bait did this, because they all ate all of the bait during their first feeding event.

Table 2. Comparison between acceptance (number of encounters before voluntarily taking a lethal dose) of two formulations of bait, each offered as 1-g doses, containing 0.1% sodium monofluoroacetate (1080), to 10 stoats.

	Egg/flax-oil bait		Brain bait	
	Sex/No.	Encounters	Sex/No.	Encounters
	M3	23	F8	21
	M4	9	M10	10
	M5	2	F11	6
	M6	0	M12	21
	M9	5	M13	18
Mean		7.8		15.2
SEM		4.09		3.06

M = male; F = female; SEM = standard error of the mean

Behavioural observations

The full details of the 14 experimental animals used, toxic baits offered, number of encounters and times from first encounter to acceptance and from acceptance to death are presented in Table 1. In all cases, the mouse offered in the morning was carried back to the nesting box and eaten several hours before the bait was offered and explored in the evening.

All stoats that took a lethal dose died between 1 h 15 min and 4 h 7 min (mean 2 h 38 min) after eating the bait. The behaviour of the stoats following ingestion of the 1080 bait followed a similar pattern for the two formulations of bait. At first (range 29 min – 2 h 7 min, mean 1 h 1 min), their behaviour appeared to be normal. During this period, the stoats either returned to their nesting box, groomed and slept, or walked or climbed in an exploratory way around the cage. Next, the stoats became obviously ataxic, showing progressive loss of coordination coupled with hyperactivity. They repeatedly collapsed or fell over. One stoat had two bouts of rapid head-shaking for 1 and 5 min during this phase. On average, this set of behaviours lasted 26 min (range 2 min – 1 h 40 min). One stoat (M2) was observed directly during this period. It responded by racing rapidly around its cage as we entered the room and turned the light on.

All intoxicated stoats eventually failed to get up, and remained lying on their sides. While recumbent, they exhibited limb movements, spasms, twisting of the body, and rapid breathing. These behaviours lasted 58 min on average (range 16 min – 2 h). Three stoats (M2, M10 and M12) were observed directly while recumbent. All were non-responsive to a light being turned on, or to touch.

All 10 stoats that consumed a lethal dose of 1080 released anal-gland scent and convulsed occasionally during this period, and individual convulsions lasted up to 1 min 14 sec. Convulsions took the form of dorsoflexion with limbs extended, head bent backwards, fore- and hind-limb paddling and running movements, and tail-flailing with fur erect. The convulsions often propelled the animal across the floor. Neither retching nor vomiting was observed, but two stoats must have vomited a little during this phase because small quantities of regurgitated bait were later observed smeared on the walls or floor of the cage some distance from the plate on which it had been presented. Finally, the stoats remained prostrate, and showed little physical activity other than breathing movements that became progressively more shallow and infrequent during the final 33 (range 1–51) min immediately preceding death.

Toxic residues

The results of the analyses of the toxic residues in muscle are given in Table 1. Residues were found in every stoat that took the toxic bait, at concentrations ranging from 0.075 µg/g in a 287-g male that died 4h 7 min after eating only 0.74 g of bait, to 2.5 µg/g in a 254-g female that died 2 h 42 min after taking a whole 1-g bait. There was no correlation between the level of residues found and the time from eating bait to death.

Discussion

These trials demonstrated that most stoats would eat baits containing a concentration of 1080 as high as 0.1%, and that 1 g of these baits provided a lethal dose. This is equivalent to the 100% lethal dose of 2 mg/kg for a 500-g stoat reported by Spurr and Hough (1997), but the present concentration was 167 times greater than in previous trials (Spurr 2000).

Whether the bait was an egg/flax-oil mixture or homogenised bovine brain made little difference to the number of encounters or the time between first encountering bait and eating it. One stoat (M6) licked the plate clean on the first encounter, but the others did not. Their delay in taking the bait was probably not a reaction to the dishes, from which they had been feeding for weeks, nor to a dislike of the baits, which they eventually ate well. It was more likely to have been either a neophobic reaction to an unfamiliar formulation presented without a visual cue as to its nature, such as an artificial egg, or resistance to being made to eat in the open. Tame stoats are reluctant to eat unfamiliar foods under observation, even when offered by a familiar handler (CM King, unpubl. obs.). These individuals had been trained to take their normal food, usually whole mice, from the dishes, but they always picked up each carcass and carried it to the nesting box before eating. When presented with the semi-fluid experimental baits, several tried to grasp them to carry them away but once they realised they could not they started to eat the bait *in situ*, and most did so eagerly. Field trails have confirmed that wild stoats were quick to take non-toxic semi-liquid egg/oil baits presented inside the tunnel of a Scentinel[1] (Purdey et al 2003; CM King, unpubl. obs.).

Our observations strongly suggested that none of the 14 stoats tested in the pen could detect the presence of 0.1% 1080 in either bait. A concentration of between 0.08% and 0.15% 1080 is common in commercial baits for possums (*Trichosurus vulpecula*), rabbits and cats (Green 2003). Several stoats took the lethal dose over several feeding events without reluctance; one returned four times over 20 min, finally licking the plate clean. Ten of the 12 stoats that voluntarily took a lethal dose licked the plate clean, five on their first encounter. The baits could have been offered in more enclosed conditions, but then we would not have been able to obtain such clear video records of their behaviours.

The analyses of the carcasses detected 1080 residues in all 13 stoats that took it (Table 1), and mostly at much higher levels than the 0.03–0.48 mg/kg reported by Murphy et al (1999). Neither those authors' analysis nor ours revealed any correlation between the concentration of residues and the time since the toxin was made available, but in the study by Murphy et al (1999) the poisoning was secondary and the stoats died 2–18 days after a poison drop, whereas in our trial the poisoning was primary and all the stoats died within hours of taking the bait.

The experimental protocol specified that another cohort of six stoats would be tested with a lower dose (0.03% 1080) if any refused the 0.1% dose. Two of 14 animals did refuse the 0.1% dose, although one stoat later licked bait off itself, but from these data we cannot distinguish between two alternative interpretations of their refusal. Firstly, there may be a natural variability in response to the taste of the baits themselves; or secondly, there could be variation in the ability to taste the 1080. If the first is the true explanation, it would be better tested with non-toxic formulations, preferably presented under cover instead of in dishes. If the second is true, we might predict fewer refusals of a lower-dose version of the egg/flax-oil bait, but if 0.03% is closer to or below the threshold for a lethal dose there would also be a greatly increased probability of sublethal effects and possibly prolonged dying for the experimental animals. The radio-collared stoats recovered by Dilks and Lawrence (2000) after eating eggs injected with 1080 all survived at least one day, some several days, after taking a dose of about 0.003%. Our use of animals for toxic tests was minimised by animal welfare constraints, and we did not consider there were sufficient grounds to test this explanation.

Sublethal dosing by acute-acting poisons such as 1080 induces bait shyness, a serious problem that greatly reduces kill rates in second and subsequent applications of both the same and other toxins (Hickling et al 1999). We intended to test whether it might be possible to prevent this by adding an experimental memory-blocker to the bait offered to the stoats in our trial, but discontinued this approach after the first two stoats rejected baits containing the additive. Testing the memory-blocker was a secondary aim of the study, and we did not want it to interfere with the main aim, which was to assess whether stoats could detect 1080 in the baits. The ability of stoats to detect the presence of the memory-blocker should be investigated further in a non-toxic bait trial.

We chose to test a 1-g semi-fluid bait because that is the type and most cost-effective amount of bait dispensed by an automatic bait dispenser (the Scentinel) which we are developing in a series of related programmes (CM King, unpubl. obs.). In two field trials, we have recorded stoats readily taking non-toxic baits of an egg/flax-oil mixture from the dispensers (Purdey et al 2003; King et al 2003; CM King, unpubl. obs.). In another study, one unmarked wild stoat took the same egg/flax-oil bait, but with 0.1% 1080 added, from a dispenser in the field (E Gould[2] and CM King, unpubl. obs). Non-toxic bait was not offered in conjunction with toxic bait because some animals would, by chance alone, have tried the non-toxic bait first, and thereby effectively been pre-baited in a way that would not happen in the field.

Humaneness of vertebrate pesticides has been raised as an ethical and animal welfare concern by the public and several authors, including members of non-governmental organisations (see Littin et al 2004). Our study is the first to report the behavioural responses of stoats that have consumed a lethal dose of 1080 and how long it takes to kill them. The behavioural responses of stoats that ate 1080 were broadly similar to those reported for other mammals (McIlroy 1981; Sherley 2004). The latent period of 29 min to 2 h 7 min from ingestion of the bait to onset of initial signs of poisoning observed here is similar to the 30 min to 3 h reported for dogs (Sharp and Saunders 2004a) but shorter than the 4 h reported for foxes (*Vulpes vulpes*) (Marks et al 2000; Sharp and Saunders 2004b). The 1 h 15 min to 4 h 7 min the stoats took to die in our study after eating 1080 is shorter than the times reported for dogs of 2 h 30 min to 5 h (Sharp and Saunders 2004a), 4.8–14.6 h for dingos (*Canis lupus*) (McIlroy 1981), about 6 h for foxes (Sharp and Saunders 2004b), and for 11 other eutherian

[1] The Scentinel® research was conducted by scientists in the BioEngineering group of HortResearch based at Ruakura Research Centre. The two principal researchers involved were Mr Rod McDonald, of HortResearch, and Dr Carolyn King, who at the time of the research had a 50:50 HortResearch:University of Waikato appointment. By agreement with HortResearch, the Scentinel will be further developed, manufactured and made available to conservation groups, farmers and other potential users, by Technology Transfer Ltd (TTL), an entity established for this purpose. For further information on TTL, contact Mr Tony Brenton-Rule, at 0064-4-5627895, mobile 0064-21-774745, or by email at tony@technologia.co.nz

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and marsupial carnivores (fat-tailed dunnart, *Sminthopsis crassicaudata*, 2.8–46.5 h; stripe-faced dunnart, *Sminthopsis macroura*, 3.4–13.1 h; brown antechinus, *Antechinus stuartii*, 2.1–146.6 h; dusky antechinus, *Antechinus swainsonii*, 1.6–62.1 h; kowari, *Dasyuroides byrnei*, 6.4–13.5 h; northern native cat, *Dasyurus hallucatus*, 10.9–450.7 h; eastern native cat, *Dasyurus viverrinus*, <2.0–63.2 h; tiger cat, *Dasyurus maculates*, 1.5–11.8 h; Tasmanian devil, *Sarcophilus harrisii*, 2.6–<22.3 h; long-nosed bandicoot, *Perameles nasuta*, 3.9–56.3 h; cat, *Felis catus*, 20.7–21.0 h) (McIlroy 1981). It is also short compared with the 6–18 h reported for possums (Eason et al 1997). The only comparative data available for stoats fed other toxins are for p-aminopropiophenone, which killed stoats within 1 h (Fisher et al 2005).

The sudden onset of ataxia and hyperactivity seen in the stoats following consumption of 1080 was consistent with the early symptoms of 1080 poisoning reported for many other mammalian carnivores (McIlroy 1981; Eason et al 1997; Sherley 2004), but the stoats were much less likely than those other species to vomit. It is difficult to adequately assess the impact of 1080 in terms of pain and distress to poisoned animals, as the severe disruptions to the central nervous system induced by the toxin alter behavioural indicators of pain (Anonymous 1989). The lack of any behavioural symptoms of poisoning during the initial latent period, during which fluoroacetate is metabolised to fluorocitrate (Peters 1952), suggests that pain or distress were probably minimal during this stage, which on average occupied about one-third of the period from consumption of the bait to death. A similar asymptomatic latent period is reported for cases of humans poisoned with 1080 (Chi et al 1996). Following this latent period, 74% of patients suffered from nausea and vomiting, 29% reported feelings of agitation, 21% complained of respiratory distress, and 26% complained of abdominal pain in the early stages of poisoning.

Our direct observations during the period of recumbency showed that the stoats were not responsive to light, our presence, or prodding, but this lack of response should not be interpreted as indicating a state of unconsciousness. Conversely, Sharp and Saunders (2004ab) stated that both dogs and foxes were thought to be unconscious and unlikely to suffer following collapse and during the period of convulsions and tetanic spasms that followed. Marks et al (2000) also considered that following collapse, when foxes convulsed and had tetanic spasms but were not ambulatory, they probably experienced severe disruptions to the central nervous system during which pain or distress was unlikely to be experienced. Those authors considered that foxes were most likely to experience suffering from 1080 toxicosis during the initial symptoms of running and retching. This is the early symptomatic stage when humans poisoned with 1080 sometimes report abdominal pain (Chi et al 1996). If this pattern holds true for stoats, then the period of greatest distress for them, and possibly pain, would be limited to the period of ataxia and hyperactivity, which ended with sustained recumbency. This period averaged 45 min out of the average time to death of 2 h 38 min, which is short compared with the equivalent period of 11 h 30 min for possums that consumed a lethal dose of 1080 (KE Littin[3], pers. comm.).

We conclude that the 0.1% 1080 in the 1-g baits used here was lethal to stoats, and induced death comparatively rapidly.

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Acknowledgements

We thank Rod McDonald, HortResearch Bioengineering, for making up the baits; Bill Simmons, Animal Control Products, for supplying the 1080 and adding it to the baits; Paul Chambers, Massey University, for anaesthetising the stoats for pre-trial inspection; Kevanne McGlade, for invaluable assistance throughout the study; Kate McArthur, for help with processing videotapes; and Tracy Harris and Kiryn Weaver, for assistance with feeding and monitoring the stoats. The manuscript benefitted greatly from the input of three anonymous referees. We thank The Department of Conservation for financial support.

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Submitted 19 December 2005

Accepted for publication 01 August 2006