THE USE OF DIFFERENT TYPES OF TOXIC BAIT FOR SUSTAINED CONTROL OF POSSUMS

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ABSTRACT

Assessment of six types of toxic bait in replicated field trials demonstrated that baits containing 0.15% 1080 were the most cost-effective for initial control of possum populations. Possums surviving an initial exposure to either 1080, cyanide, or cholecalciferol baits would not eat lethal amounts of bait containing another fast-acting toxicant during the following 2.5 months. However, 'shyness' to 1080 or cholecalciferol baits in possums surviving initial control was overcome by using a slow-acting anticoagulant poison during maintenance control. Sustained control of possums is currently most cost-effective if baits containing 0.15% 1080 are followed at least 2 months later by baits containing 0.002% brodifacoum. Unlicensed operators can similarly achieve sustained control of possums at very low densities by using brodifacoum baits 2 months after initial control is undertaken with baits containing cholecalciferol.

Keywords: possum, pesticide, pest control, baits, bait-shyness

INTRODUCTION

Over the past four decades possums have been extensively controlled with sodium monofluoroacetate (1080) baits. The proportion of possums surviving such control typically ranges from 5 to 40% (Spurr 1993). Most survival is attributed to either sub-lethal poisoning by baits that are of low palatability or low toxic concentration (Henderson and Morris 1996), or an inadequate distribution of baits (Morgan 1994). Although better quality baits and bait delivery during poison operations should minimise these effects (Morgan *et al.* 1996a), it is likely that a few possums will still survive initial control. As well as possums that survive initial control, reinfestation can be expected depending on the proximity and density of other possum populations (Green and Coleman 1984).

Therefore, to maintain low numbers of possums to eradicate Tb (Barlow 1991), or protect critical ecological values (Cowan 1991), an initial 'knockdown' is routinely followed by 'maintenance' operations undertaken at intervals of 6-24 months. However, possums surviving 1080 poison operations may become 'shy' of baits and not eat lethal quantities of cereal-based 1080 when re-exposed to the same type of toxic bait during the following 2 years (Morgan *et al.* 1996b; O'Connor and Matthews 1996). Therefore, as with other vertebrate pests, effective 'maintenance' control of possums may require the use of different pesticides or different bait types to keep populations at low levels (Oliver *et al.* 1982).

This study evaluated the effectiveness and cost of six types of toxic bait for initial reductions of moderate to high-density populations, and the effectiveness of changing to a different type of toxicant in baits used for maintenance control.

MATERIALS AND METHODS

Baits

Baits evaluated for either 'initial' control or 'maintenance' control of possums are shown in Table 1.

We have classified cholecalciferol, 1080, gliflor and cyanide *as acute* toxicants, since

possums normally ingest a lethal dose during a single feed and the onset of clinical signs of toxicosis occurs within 24 hours (Eason *et al.* 1994). In contrast, brodifacoum is referred to as a *chronic* toxicant since it is ingested in lethal amounts only after several feeds of toxic bait and possums take more than 2 weeks to die (Eason *et al.* 1996).

Before baits were used in field studies, we assessed their palatability to caged possums (Henderson and Morriss 1996), and the concentration of toxicant in each bait type was verified in the laboratory using a gas-liquid chromatography method for determination of 1080 (Okuno *et al.* 1982), or liquid chromatography methods for cholecalciferol (Gehrig and Stringham 1987) and brodifacoum (Felice and Murphy 1989).

Field trials

Field trials were carried out in discrete plantations of exotic forest (10–41 ha) in Canterbury during 1994–97.

The amount of bait required for control, and the related costs are dependent on the number of possums eating bait. Therefore, before the application of toxic bait, the relative abundance of possums at each site was estimated using Victor leg-hold traps that allow possums to be caught and released with minimal injury. At each field site, 100 traps were set at 20–30 m intervals on 'marked' sites along lines that were spaced so there were no more than 7 traps per hectare. An index of possum density was assessed from the percentage of traps that caught possums (Henderson *et al.* 1994). Densities were nominally ranked as low (i.e. <25% of traps catching), moderate (i.e. >25–40% of traps catching), and high (i.e. >40% traps catching).

Cereal baits were presented in each trial in bait stations (Thomas 1994), which were distributed at approximately 1/ha. They were located mainly around the edge of each forest block at approximately 100 m spacings, with some sited within the forest to ensure that bait was readily accessible to all possums. At moderate densities a measured 200 g of bait containing one of the acute toxicants was placed in each station, and 300 g was used if the initial density was high. Irrespective of relative numbers of possums, 1000 g of bait containing 0.002% brodifacoum (Talon) was applied in each station, and the bait eaten was replaced throughout each field trial. Bait consumption was monitored at 1–2 week intervals for 5 weeks (if it contained an acute toxicant), or up to 4 months (if it contained brodifacoum). The amount of bait eaten during each interval, and for the trial as a whole, was calculated.

On completion of each field trial, the sites used for pre-poison estimates of possum abundance were retrapped and the percentage of the population killed estimated as the percentage decline in the proportion of traps that caught possums.

Cost-effectiveness of bait

In field trials (n=17) that assessed the cost-effectiveness of commercial baits for initial control, the baits used were of an assured quality (i.e., palatability and toxicant concentration complied with specifications), and few possums were expected to survive. The cost of baits eaten per hectare was calculated by dividing the total cost of bait eaten by the area of each field site. As the costs of control are dependent on the relative number of possums present, data were pooled for possums at low to moderate densities (<25% traps catching) and moderate to high densities (>25% traps catching).

Maintenance control using acute or chronic pesticides

In field trials (n=15) that tested maintenance control strategies, possums were either intentionally sub-lethally dosed with baits known to be sub-standard, or alternatively they were controlled with cereal pellets containing 0.15% 1080 or paste baits containing 60% sodium cyanide (i.e. the poisons most frequently used for initial control). Sub-standard baits either contained low concentrations of toxicant (0.08% 1080 or 0.6% cholecalciferol), or were made slightly unpalatable so that approximately half of all possums were expected to eat a lethal dose (Henderson and Morriss 1996). Using sub-standard baits for initial control ensured that adequate numbers survived and subsequent kills in the maintenance phase could be precisely measured. When baits containing 1080, cholecalciferol, gliflor and brodifacoum were used for maintenance control, they were applied 3–5 days after initial control with cereal bait (Table 3). However, in two trials cereal pellets containing 0.002% brodifacoum were applied 2 and 3 months after the

completion of initial control with baits that contained cholecalciferol. The percentage kill with brodifacoum baits was log-transformed and regressed against time to test for differences in the rate at which it killed naive possums and those made shy following initial control with 1080 and cholecalciferol.

RESULTS

Toxicant concentration

The measured concentration of acute toxicant in baits was $\pm 10\%$ of the nominal concentration of 1080 and $\pm 7\%$ of the nominal concentration of cholecalciferol (i.e. the concentrations fell within the stated precision of the method of analysis) (Table 1). However, six of ten batches of commercial bait used had concentrations of brodifacoum significantly lower than 20 ppm (viz. measured concentrations ranged from 14.1 to 22.7 ppm). The mean concentration of brodifacoum in bait used in field trials was 17.4 ppm (s.d. = 2.7).

TABLE 1: Commercial and experimental baits assessed for initial and maintenance control of possums.

Bait (matrix)	Toxicant	Nominal conc. (% wt./wt.)	Measured conc. (mean % wt./wt.)	Cost (excl. GST)	Licence required
RS5 (cereal) ¹	1080	0.08	0.085	\$34.25/25 kg	Yes
RS5 (cereal) ¹	1080	0.15	0.154	\$38.25/25 kg	Yes
Campaign (cereal) ²	cholecalciferol	0.8	0.79	\$131.40/2.5 kg	No
Talon (cereal) ³	brodifacoum	0.002	0.0017	\$43.86/10 kg	No
Cyanide (paste) ⁴	sodium cyanide	60	56.6	\$15.11/270 g	Yes
RS5 (cereal) ⁵	gliftor	0.4	— ⁶		N/A
RS5 (cereal) ⁵	cholecalciferol	0.8	0.76		N/A
(low palatability)					
RS5 (cereal) ⁵	cholecalciferol	0.6	0.62		N/A

Bait manufactured by: ¹Animal Control Products Ltd, Waimate; ²Hoechst Schering AgrEvo Pty Ltd, NSW, Australia; ³ICI Crop Care Ltd, Nelson; ⁴Trappers Cyanide Co., Christchurch; ⁵experimental baits made at Landcare Research, Lincoln; ⁶analytical technique unavailable
N/A = not applicable

Cost-effectiveness of bait

Cereal baits containing 0.15% 1080 were the most cost-effective (Table 2) for initial control, although operators using Campaign can also achieve kills of up to 97% in moderate-high density populations and users do not require a licence (Henderson *et al.* 1994). Control with cyanide paste cost less than \$0.90 per hectare, although fewer possums were killed than with cereal baits containing cholecalciferol, brodifacoum or 0.15% 1080. Bait containing brodifacoum is not cost-effective when used for initial control.

Of the four toxicants trialled, only brodifacoum was effective for maintenance control (at an average cost of \$9 per hectare when densities were low). Based on the results of these field trials the mean kill of 87% using 0.15% 1080 followed by a mean kill of 75% of the residual population using brodifacoum baits would result in fewer than 5% of possums surviving control. Using Campaign (82% mean kill) followed by baits containing brodifacoum (75% mean kill) would also result in fewer than 5% of possums remaining.

TABLE 2: The average cost per hectare of commercial possum baits eaten during initial and maintenance control.

Pesticide bait	Cost per ha of bait eaten (low-moderate density)	Cost per ha of bait eaten (moderate-high density)	Average kill (%)
Initial control (naive possums)			
Cyanide paste	\$0.54 ¹ (n=2)	\$0.86 ¹ (n=2)	70 (n=6)
0.08% 1080 in RS5 bait	\$0.06 (n=2)	\$0.10 (n=4)	56 (n=6)
0.15% 1080 in RS5 bait	\$0.06 (n=2)	\$0.08 (n=1)	87 (n=3)
Campaign	\$3.44 (n=2)	\$6.70 (n=2)	82 (n=5)
Talon	\$17.22 (n=2)	— ²	85 (n=2)
Maintenance control (shy possums)			
0.08% 1080 in RS5 bait	\$0.01	— ²	0 (n=1)
Campaign	\$1.85 (n=2)	— ²	0 (n=2)
Talon bait to shy possums	\$9.05 (n=6)	\$26.93 (n=2)	75 (n=8)

¹ costs of bait applied rather than bait eaten

² not assessed in this study

Maintenance control using acute or chronic pesticides

Possums surviving an acute toxicant during initial control would not eat lethal amounts of cereal bait containing an alternative acute toxicant during maintenance control (Table 3). However, baits containing a slow-acting anticoagulant poison (brodifacoum) were effective for maintenance control. The percentage of possums killed by brodifacoum was lower immediately after initial control with 0.15% 1080 than after control with 0.08% 1080 (Fig. 1). By delaying the application of brodifacoum for 2-3 months after initial control with cholecalciferol, a higher percentage of possums were killed at an earlier stage of maintenance control than when brodifacoum followed immediately after cholecalciferol (Fig. 1). The rate at which possums were killed with brodifacoum was dependent on the whether there had been previous control and the type of pesticide used ($F=3.86$, d.f.=4, $P=0.03$). Kills with brodifacoum increased during a prolonged period of 8-20 weeks ($F=23.9$, d.f.=1, $P=0.004$), irrespective of which

FIGURE 1: Percentage of possum populations killed during continuous baiting with brodifacoum. Lines fitted by regression are: n — n naive possums; r r after 0.08% 1080; s s 2-3 months after cholecalciferol; l - - - l immediately after cholecalciferol; m - - - m after 0.15% 1080.

toxicant had been used for initial control (Fig. 1), indicating that the maintenance phase of control must be continued for longer than 2 months.

TABLE 3: The mean kill of previously unpoisoned possums and bait-shy possums with baits of substandard quality (S) (i.e., baits of low palatability or toxicant concentration) or baits of assured quality (A) (i.e., baits containing 0.15% 1080 or 60% sodium cyanide).

Number of trials	Initial control (naive possums)			Maintenance control (shy possums)		
	Toxicant or bait	Quality (A/S)	Mean kill (%)	Toxicant or bait	Mean kill (%)	Overall kill (%)
(a) Maintenance control using an acute toxicant						
1	0.6% Cholecalciferol	S	63	0.08% 1080 ¹	0	63
1	Unpalatable					
	0.8% Cholecalciferol	S	46	Gliflor ¹	0	46
2	0.08% 1080	S	56	Campaign ¹	0	56
1	0.08% 1080	S	75	Gliflor ¹	0	75
2	Cyanide Paste	A	58	Campaign ²	0	0
TOTAL			59 ± 8		0	59
(b) Maintenance control using a chronic toxicant						
2	0.6% Cholecalciferol	S	55	Talon ¹	74	88
2	0.6% Cholecalciferol	S	55	Talon ³	79	91
2	0.08% 1080	S	51	Talon ¹	88	94
2	0.15% 1080	A	75	Talon ¹	60	90
TOTAL			59 ± 13		75 ± 19	91

¹ maintenance control immediately after initial control

² applied 1 month after cyanide paste

³ applied 2-3 months after cholecalciferol

Patterns of bait consumption

Naive possums consumed most acute toxicants in the first week that bait was presented (Fig. 2a-c). In contrast, shy possums (i.e. following initial exposure to sub-lethal doses of cholecalciferol, cyanide, or 1080) ate small amounts of cereal baits containing an acute toxicant during 5 weeks of maintenance control (Fig. 2a-c).

The chronic toxicant (brodifacoum) was eaten by both shy and naive possums over a period of 17–18 weeks (Fig. 3a). Whereas naive possums consumed most brodifacoum bait during the first 3 weeks of poisoning, possums made shy with 1080 ate most brodifacoum 5–7 weeks after baits were first presented (Fig 3a). More brodifacoum bait was eaten by possums that survived 0.08% 1080 than by those surviving 0.15% 1080 (Fig. 3a). When cholecalciferol was used for control, survivors would eat only small amounts of brodifacoum bait immediately after the initial poisoning (Fig 3b). However, when bait containing brodifacoum was applied 3 months after cholecalciferol, it was eaten almost as readily as it was by naive possums (Fig. 3b).

DISCUSSION

For 2.5 months after being sub-lethally poisoned by an acute toxicant, possums would not eat lethal amounts of an alternative acute toxicant in a similar bait matrix. Although possums lose their appetite after they have been poisoned, this probably lasts for only 1–2 days after sub-lethal doses of 1080 and cyanide, and for up to approximately 3 weeks after sub-lethal doses of cholecalciferol (Henderson unpubl. data). Therefore, given the longer duration of these trials, the failure of the acute toxicants in maintenance control is attributed, for most possums, to the development of shyness, not reduced appetite. However, a small proportion of possums that ate bait containing cholecalciferol,

FIGURE 2: Estimates of the bait eaten per week by wild possums in naive and shy populations. Lines fitted by eye indicate trend. (a) 1080; (b) Campaign; (c) gliflor.

FIGURE 3: Estimates of brodifacoum bait eaten by wild possums. Lines fitted by eye indicate trend. (a) Naive and 1080-shy possums; (b) Following cholecalciferol

particularly in the latter phase of initial control, may have refused baits in the maintenance phase due to loss of appetite.

Wild possums made shy in these field trials could only be controlled with brodifacoum (i.e. a slow-acting anticoagulant poison), presumably because shy possums are cautious feeders that progressively eat more bait each day with no ill-effects until they eventually consume a lethal quantity. However, the use of brodifacoum baits is constrained by price and the amount of bait possums eat. Although Campaign was effective (73% kill) following 1080 baits in a recent cage study (Rosset *et al* 1997), no 1080-shy possums were killed with Campaign in our field trials. It is possible that caged possums ate baits because they were continuously exposed to them (Rosset *et al* 1997), whereas possums in the wild encounter baits for only brief periods. Familiarity with baits through prefeeding may therefore be an effective field strategy for overcoming shyness, and studies to investigate this possibility are underway.

Cage studies (Morgan *et al* 1996) and limited field studies (Ogilvie *et al* 1996) have shown that changing the bait matrix partly overcomes shyness to 1080 baits, and that changing both the bait matrix and toxicant was more effective (Ross *et al* 1997). These

strategies should be further field-tested as options for sustained control of possum populations, as most trials reported here used cereal-based baits for both initial and maintenance control.

Possums surviving cyanide paste developed a generalised shyness (described elsewhere as a 'conditional food aversion') (O'Connor and Matthews 1995) and would not eat lethal amounts of cereal-based Campaign bait 4-9 weeks later. Given the extensive use of cyanide by possum hunters in New Zealand, this finding indicates that strategies for sustaining the use of other types of toxic bait (particularly 1080 baits as used by the main possum control agencies) after cyanide should be further examined.

The timing of maintenance control following an initial 'knockdown' of possums with an acute toxicant is very important. These field trials suggest kills will be enhanced if a gap of at least 2 months is left between initial control with cereal baits and maintenance control with brodifacoum in a different type of cereal bait.

Baits of the future may be manufactured from materials other than cereal, or contain toxicants that are chemically coated or micro-encapsulated to slow their rate of delivery: this may result in less shyness, higher bait consumption, and a greater choice of options that could be used for maintenance control. In parallel with attempts to overcome the effects of shyness on control effectiveness, it is essential that continuing efforts are made to improve standards of bait preparation and presentation. This will ensure that only a small proportion of possums survive control, and that the development of shyness is avoided.

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