Feratox and Feracol as alternatives to brodifacoum for possum control

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ABSTRACT

The Department of Conservation (DOC) has recently restricted the use of baits that contain the toxicant brodifacoum for control of possums (*Trichosurus vulpecula*). Possible alternatives are Feratox®, which is an encapsulated cyanide pellet, and Feracol®, which contains 0.8% wt/wt cholecalciferol. Comparisons were made of the advantages and disadvantages of these toxicants, and field trials were undertaken to examine efficacy. Additional alternatives to brodifacoum were also identified. Feeding trials indicated that the bait formulations used with Feratox® and Feracol® are below the DOC standards for palatability which could lead to sub-lethal poisoning and an increase in bait shyness. Feratox® used in bait bags and bait stations achieved similar possum kills to those achieved using leg-hold traps. Possum populations were reduced by > 75% by using Feracol® with pre-feeding. Baiting grids using bait stations and bait bags containing Feratox® and Feracol® were unlikely to attract all possums, but pre-feeding and the use of visual lures could increase the numbers of possums targeted. Pindone was identified as the best alternative toxicant to brodifacoum, having its advantages with a low risk of secondary poisoning but requiring more to be eaten to be effective. A combination of pindone or diphacinone with a low concentration of cholecalciferol could enhance the efficacy of these toxicants.

Keywords: possum, pest control, toxic baits, cyanide, Feratox, Feracol, cholecalciferol, New Zealand

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1. Introduction

Feratox® and Feracol® are two possum control products manufactured by Connovation Ltd (East Tamaki, Auckland). Both products have potential as alternatives to baits containing brodifacoum. Limited information on Feratox® and Feracol® is currently available. These products and associated delivery systems were investigated, and recommendations were made on ways to improve manufacture and use.

1.1 BACKGROUND

Baits containing the second-generation anticoagulant brodifacoum are currently (in 2004) registered to contain 0.002% brodifacoum wt/wt (registration numbers P004991, P005136, and P003443 (see www.nzfsa.govt.nz/acvm/registers-lists/pesticides/index.htm). Brodifacoum baiting has been one of the mainstays of DOC's possum control programme and has been shown to be effective for reducing persistent infestations of possums (Brown 1993; Henderson et al. 1994; Thomas et al. 1995).

However, concerns have been raised over the persistence of brodifacoum in New Zealand's natural ecosystems (Eason et al. 2001). Of particular concern is the contamination of wild game, such as feral pig (*Sus scrofa*), which eat the baits and also poisoned possum carcasses that might be contaminated with brodifacoum residues (Eason et al. 1996). Contaminated pigs could be a threat to human health if they were hunted and eaten (Eason et al. 2001). Therefore the Department of Conservation (DOC) has undertaken to reduce and restrict the use of brodifacoum on the mainland (DOC 2000). Because brodifacoum has played a major role in the reduction of possum populations, it is important that alternative baits and baiting strategies are identified as replacements. These alternatives need to reduce possum populations to similar levels without the long-term persistence problems associated with the use of brodifacoum. Feratox® and Feracol® are two baits that could provide alternatives, and their suitability is examined in this study along with other potential alternatives.

1.1.1 Feratox

Feratox® was developed in 1995, principally to overcome cyanide shyness that can occur after cyanide paste baits are used (Warburton & Drew 1994; Morgan et al. 2001). Feratox® consists of a 5 mm sphere of compressed cyanide coated with an impervious layer that prevents the release of hydrogen cyanide gas (HCN). HCN has a distinctive smell that is thought to cause cyanide shyness (Warburton & Drew 1994), and Feratox® is not effective unless it is embedded in a non-toxic feed paste. Its effectiveness relies on the possum crushing the sphere between its molars when eating the non-toxic paste. Cyanide humanely kills possums within an average of 18 min (Gregory et al. 1998). Feral IP Ltd holds registrations for this product (registration number P004713, www.nzfsa.govt.nz/acvm/registers-lists/pesticides/index.htm), and it is registered to contain 800g/kg (80% wt/wt) of potassium cyanide.

Warburton et al. (1996) conducted a study using Feratox® for possum control shortly after the bait was registered in 1995. They showed that cyanide paste baits such as Trappers Cyanide Paste (R. Bushby, Christchurch) killed more possums than Feratox® when placed on the ground. However, when bait stations were used, Feratox® appeared to be the more effective. Morriss et al. (1997) conducted field trials to measure percentage kills at two study sites using Feratox® in bait stations and achieved kills of 69% and 70% compared with a 60% kill when cyanide paste was used.

1.1.2 Feracol

Feracol® was developed in 2000 and consists of a paste bait containing the rodenticide cholecalciferol or vitamin D3. Feral IP Ltd holds registrations for this product (registration number P005263, www.nzfsa.govt.nz/acvm/registers-lists/pesticides/index.htm). Feracol® contains 8g/kg (0.8% wt/wt) of cholecalciferol. Cholecalciferol has been shown to be effective for possum control, killing possums in an average of 7 days (Wickstrom et al. 1997).

Only one study has been undertaken to investigate the use of Feracol® (Morgan & Rhodes 2000a). This cage study found that 18 of 20 captive possums (90%) were killed when fed Feracol® paste containing a nominal 0.4% wt/wt cholecalciferol. However, the concentration of cholecalciferol stated as tested was not the 0.8% wt/wt registered concentration. Previous studies using concentrations less than this indicate that it is ineffective for possum control (Henderson & Morriss 1996).

Possums appear to be less susceptible to cholecalciferol poisoning than to toxicants such as cyanide and sodium monofluoroacetate (1080). An approximate LD_{95} for cholecalciferol in cereal bait (i.e. the amount of poison required to kill 95% of test animals) is 55.0 mg/kg (range 38.2–93.5 mg/kg, Henderson et al. 1999a). Therefore, a 3 kg possum would need to eat approximately 20 g of bait containing 0.8% wt/wt cholecalciferol for the bait to be fatal. In comparison, the LD_{95} for 1080 is 4.3 mg/kg (Henderson et al. 1999b) and to kill a 3 kg possum approximately 10 g of 0.15% wt/wt 1080 bait would need to be eaten. This highlights the need for baits containing cholecalciferol to be highly palatable, to ensure that adequate quantities of bait are eaten for it to be lethal.

Possums can also become bait shy after eating sub-lethal amounts of baits containing cholecalciferol (Morgan & Milne 2002).

1.1.3 Ferafeed

Connovation Ltd has developed a non-toxic paste bait called Ferafeed® (Morgan & Rhodes 2000b) to be used with Feratox®. This bait consists of a mixture of oils, vegetable fat, and cereals, and it contains, as placebos, hard lumps of cereal of a similar size and dimension to Feratox®. The addition of the placebos is to condition possums to eat lumps in the paste, and this reduces the likelihood of the Feratox® being rejected. However, no research results are available to determine whether this is effective. Also there has been no research undertaken to evaluate the palatability of Ferafeed® or to determine its efficacy when containing Feratox®. Ferafeed® is also the bait matrix used to deliver the toxicant cholecalciferol, which is marketed as Feracol® (see above).

1.1.4 Importance of bait palatability

Bait palatability influences the amount of bait eaten and hence the amount of toxicant ingested. This directly determines the number of possums killed (Henderson & Morriss 1996; Henderson & Frampton 1999). Palatability depends on the composition of the bait material and the availability of natural foods. It is important that new baits undergo palatability tests, using both captive and wild possums, to ensure they are suitable. Palatability tests are a requirement for the registration of vertebrate pesticides (MAF 2000).

The standard method for measuring bait palatability in New Zealand is a 2-choice test, where possums are offered a test bait and a standard bait. The relative consumption of the two baits are compared (Grote & Brown 1971) and a palatability score is recorded as the amount of test bait eaten (expressed as a proportion of total bait eaten). A figure of 50% indicates that the palatability of the test bait is equivalent to the standard bait. The accepted standard for comparison is a compressed cereal pellet consisting of the RS5 formulation manufactured by Animal Control Products Ltd (Private Bag 3018, Wanganui). A palatability figure of < 40% is considered to be below standard for pest control operations undertaken by DOC (Eason & Wickstrom 2001).

1.1.5 Bait delivery methods

Feratox® and Feracol® are commonly applied using two bait delivery methods: bait stations, and bait bags. Connovation Ltd have recently developed two additional bait delivery methods called Blocks and Sentinels.

Bait stations

Bait stations are plastic containers that can be attached to trees. They reduce bait interference by non-target species and protect the baits from rain. Bait stations placed at regular intervals are a proven method for killing possums in native forest (Thomas 1994; Thomas et al. 1996). Research using non-toxic rhodamine-dyed baits fed for 3 weeks showed that 87% and 81% of possums used the bait stations when they were spaced in 100 m × 100 m and 150 m × 150 m grids, respectively (Thomas & Fitzgerald 1995).

Figure 1. Bait bag used to deliver Feratox®. Space is provided on the bag for the address of the possum control operator.

Bait bags

Bait bags are small bags approximately 80 × 140 mm in size that are stapled to trees approximately 200 mm above the ground (Fig. 1). No research results are available to compare the effectiveness of bait bags with other bait delivery methods.

Blocks and Sentinels

Blocks and Sentinels (Fig. 2) are new bait delivery methods developed by Connovation Ltd and both are manufactured using the same bait formulation. It consists of a mix of vegetable fat, sugar and ground cereal and

has waterproof qualities making it long-lasting in the field. Manufacture of these baits is undertaken by melting the mix and pouring it into moulds. The Blocks consists of a 40 × 40 × 20 mm, 20 g square and the Sentinel consists of a 150 × 50 mm, 300 g cylinder. The Block is designed to fit inside bait stations or bags, and the Sentinel is encased in a cardboard cylinder that can be stapled directly to trees. Both Blocks and Sentinels can contain either Feratox® or cholecalciferol. No research results are available to evaluate the relative efficacy of these products.

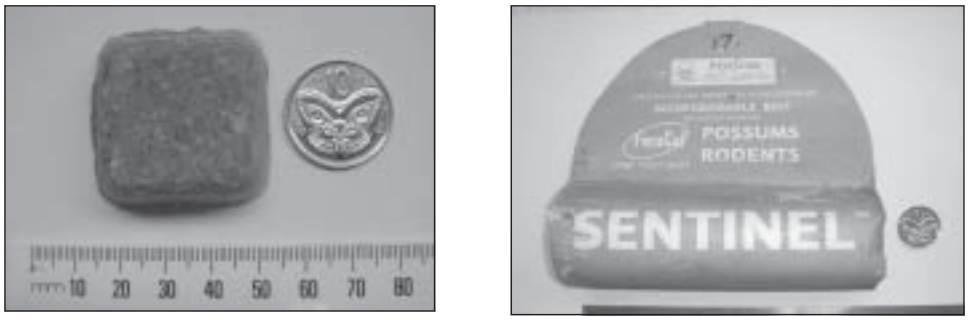

Figure 2. A Feracol® Block bait (left) and a Feracol® Sentinel bait (right), each containing 0.8% wt/wt cholecalciferol.

1.2 OBJECTIVES

The objectives of this study were to assess the suitability of Feratox® and Feracol® as alternatives to brodifacoum by:

- Comparing the relative advantages and disadvantages of the toxicants cyanide, cholecalciferol, and brodifacoum for possum control.
- Assessing the palatability of Ferafeed® non-toxic bait compared with the Block and Sentinel bait formulations.
- Assessing the suitability of bait bags and bait stations as bait delivery methods.
- Comparing the relative efficacy of four different delivery methods for Feratox®.
- Measuring efficacy of Block and Sentinel baits when they contain 0.8% wt/wt cholecalciferol.
- Identifying additional baiting methods that could provide alternatives to brodifacoum.

2. Methods

2.1 COMPARISONS OF CYANIDE, CHOLECALCIFEROL, AND BRODIFACOUM

A comparison of the relative advantages and disadvantages of the toxicants cyanide, cholecalciferol, and brodifacoum was made using the available literature and industry knowledge. Topics examined were comparisons of possum kills, ability of the toxicants to provide pre-feeding (pre-baiting), tendency to cause or mitigate bait shyness, and their ability to provide multi-species control.

2.2 PALATABILITY OF FERAFEED, BLOCK, AND SENTINEL FORMULATIONS

2.2.1 Cage studies

The palatability of Ferafeed® and the Block and Sentinel formulations were assessed using 15 individually caged acclimatised possums of approximately equal sex ratio. Each possum was presented with approximately 200 g of one of two bait formulations over a single night. The formulations were all non-toxic. Possums were also offered, simultaneously, approximately 200 g of a standard bait (RS5 cereal pellets), so they had a choice between the test bait and the standard bait. Palatability of the test baits was expressed as a proportion of the total bait eaten. A figure of > 40% indicated that the test bait was suitable for possum control on conservation land (Eason & Wickstrom 2001). Significant differences between the amounts of test and standard bait eaten were determined using *t*-tests.

2.2.2 Field trials

Bait acceptance of the Block and Sentinel baits to wild possums was assessed using paired bait stations (Ogilvie et al. 2000). The study was conducted in mature pine forest (*Pinus radiata*) at Eyrewell Forest, Canterbury. Fifty bait station pairs were used. Twenty-five of these pairs contained the Block bait in one of the bait stations and RS5 cereal pellets in the other bait station (Fig. 3). The remaining 25 pairs consisted of a Sentinel bait and a Sentry bait station containing the RS5 control baits (Fig. 3). Both types of pairs were located on stakes approximately 20 cm above ground and were sited alternately along lines at 100 m intervals along forest edges.

Each pair was considered to be an independent sample, giving a sample size of 25 for each bait type. The pairs were weighed daily for 2 days, and comparisons were made between the amounts of test baits consumed and the amounts of standard bait consumed. As before, a figure of > 40% of the total bait eaten was the criterion of suitability (Eason & Wickstrom 2001). Significant differences between the test and standard baits were determined using paired *t*-tests.

Figure 3. Paired Sentry bait stations (left) that offered wild possums the choice of a test bait (non-toxic Feracol® Block bait) and a standard bait (non-toxic RS5 pellets), and paired Sentinel and Sentry bait stations (right) that offered wild possums the choice of a test bait (non-toxic Feracol® Sentinel bait) and a standard bait (non-toxic RS5 pellets).

2.3 SUITABILITY OF BAIT STATION AND BAIT BAG GRIDS FOR BAIT DELIVERY

2.3.1 Study site

A field trial was conducted in the Hollyford Valley (Fiordland) in May 2001 to determine the suitability of bait stations and bait bags for delivering Ferafeed®. Four 25 ha study sites were established in mixed beech/podocarp forest containing possum densities of approximately 15% residual trap catch index (RTCI, NPCA 2004). This density was chosen because possum control is commonly undertaken when populations are below 15% RTCI.

2.3.2 Spacing of bait stations and bait bags

At two of the study sites, Sentry bait stations (Pest Management Services, 5b Hicks Crescent, Waikanae) were located in a 100 m × 100 m grid (30 bait stations) and a 100 m × 50 m grid (60 bait stations). At the remaining two study sites, paper bait bags (Fig. 1) were attached to trees 20 cm above the ground in a 100 m × 10 m and a 50 m × 10 m grid.

The bait stations and bags were filled with 200 g and 20 g of Ferafeed® paste, respectively. Total amounts of bait used were 6 kg for the 100 m × 100 m bait station grid and 100 m × 10 m paper bag grid but 12 kg for the 100 m × 50 m bait station grid and 50 m × 10 m paper bag grid. These spacings and quantities were chosen as those that would be practical for DOC staff when using bait stations and bait bags in native forest situations.

2.3.3 Identifying possums using bait stations and bags

The Ferafeed® paste used at all sites contained 0.5% wt/wt rhodamine dye which stained the paws, mouth, and gut contents of the possums eating the bait (Morgan 1981). This enabled possums eating bait from the bait stations and bait bags to be identified. Possums were allowed to feed at the stations and bags for a total of 6 nights at all sites before the stations and bags were removed. This was considered to be an adequate time for all possums to find and feed at the baiting sites. Immediately after baiting, leg-hold trapping was undertaken across the grids for a 2-night period. Captured possums were examined externally and internally for signs of rhodamine dye. In addition, stomach and intestinal samples were collected from the possums that did not show obvious traces of rhodamine dye. These samples were later checked in the laboratory by exposing them to UV light which causes rhodamine particles to fluoresce.

2.4 COMPARISON OF FERATOX PRESENTATION METHODS

2.4.1 Study sites and presentation methods

Field trials were conducted to compare four commonly used Feratox® presentation methods: plastic bait bags on wires; paper bags stapled to trees; bait stations with pre-feeding; and bait stations without pre-feeding. Four sites throughout New Zealand were used to evaluate the methods, but not all methods were tested at every site (Table 1).

TABLE 1. EXPERIMENTAL DESIGN FOR EACH FERATOX® TREATMENT AT EACH FIELD SITE.

TREATMENT	SITE	LINES	DEVICES/ LINE	SPACING (m)	FERATOX® PELLETS/ SITE	FLOUR BLAZE
1. Plastic bags	Northland	20	40	5	1	No
2. Plastic bags	Kaingaroa	20	40	5	1	No
3. Paper bags	Catlins	20	10	20	3	Yes
4. Paper bags	Rahu	10	10	20	3	Yes
5. Bait stations (pre-fed)	Rahu	10	5	50	6	No
6. Bait stations (not pre-fed)	Rahu	10	5	50	6	No

Plastic bags (75 × 100 mm) were used in pine plantations near Kaitaia, Northland, in July 2000, and at Kaingaroa Forest, Bay of Plenty, in February 2001. The bags were placed on wires at 5 m spacings along twenty 200 m lines (800 bags) at each site (Table 1). Wires were used to help deter rats, which may eat or remove Feratox® pellets (McGlinchy & Warburton 2000). In addition, the bags were coated with a white paste containing a repellent to further deter rats (Morgan & Rhodes 2000b). Each bag contained 20 g Ferafeed® and one Feratox® pellet, i.e. 40 pellets per line.

Three paper bags (76 × 146 mm) each containing 20 g Ferafeed® and one Feratox® pellet (i.e. 30 pellets per line) were stapled to trees at 20 m intervals on twenty 200 m lines in beech/podocarp forest in the Catlins Forest, Otago, in January 2001, and on ten 200 m lines near Rahu Saddle, North Canterbury, in April 2002 (Table 1). Beside each bag, a 'blaze', or white stripe, of 5:1 flour and icing sugar mixture was made on the tree from ground level to about 50 cm high, using the method specified for leg-hold trapping by the NPCA (2004).

Bait stations containing 200 g Ferafeed® and six pellets of Feratox® (i.e. 30 pellets per line) were located in beech (*Nothofagus* sp.) forest near Rahu Saddle, North Canterbury, in April 2002. The bait stations were placed at 50 m intervals along twenty 200 m lines (i.e. a total of 200 bait stations with 5 bait stations per line; Table 1). Ten of the lines were pre-fed (Thomas et al. 1996) with 200 g Ferafeed® that did not contain Feratox®. The pre-feed bait was available to possums for 6 days and then stations were refilled with 200 g Ferafeed® containing six pellets of Feratox®. Bait stations on the remaining 10 lines were filled with 200 g of Ferafeed® and six pellets of Feratox®.

2.4.2 Possum kills

For each method, lines were paired with a leg-hold trap line that was run parallel to the bait lines at least 200 m away. Leg-hold traps are recognised as an effective means of capturing possums (Warburton 1992). This allowed a comparison of the numbers of possums killed using Feratox® pellets with the number of possums captured in leg-hold traps. The trap lines were laid out according to a standard trap-catch protocol used throughout New Zealand to monitor possum numbers (NPCA 2004). Briefly, this protocol specifies that 10 leg-hold traps be spaced at 20 m intervals along 200 m lines. The traps are attached to trees and a flour and icing sugar blaze is used on the trees to attract possums to the trap. Both trapping and baiting lines were conducted on three consecutive fine nights simultaneously at all study sites.

The numbers of Feratox® pellets used per presentation device were chosen to ensure a potential kill of 30 to 40 possums per line (i.e. 40, 30, and 30 Feratox® pellets per line for the plastic bags, paper bags, and bait stations, respectively). The trap lines also had a potential kill of 30 possums per line. Mean kills per line obtained from each Feratox® presentation method were compared with mean kills per line obtained from the accompanying trap lines, using paired *t*-tests. Data were log-transformed to stabilise the variances, and differences were considered significant at $P < 0.05$.

2.5 EFFICACY OF BLOCKS AND SENTINELS CONTAINING CHOLECALCIFEROL

2.5.1 Study sites

Two 25 ha study sites were chosen in mature pine forest (*Pinus radiata*) at Eyrewell Forest, Canterbury, to evaluate the efficacy of possum baiting using the Block and Sentinel baits containing 0.8% wt/wt cholecalciferol. The sites were surrounded by roads or firebreaks to maximise isolation and limit reinvasion by possums from adjacent forest.

2.5.2 Possum baiting

Grids of 100 m × 100 m were located throughout each study site using a compass and hip-chain. A total of 25 baiting sites (i.e. one per ha) were systematically located at 100 m intervals on the grid. Baiting sites consisted of either two Sentry bait stations containing Blocks (in the Block study site) or two Sentinels (in the Sentinel study site). Both bait stations and Sentinels were located either side of trees to maximise the chance of possums finding the devices.

At the Block site, the Sentry bait stations were each filled with sixteen 20 g Blocks to provide a total of approximately 640 g of bait at each baiting site. Similarly, two 300 g Sentinels provided approximately 600 g of bait at each Sentinel baiting site. The total amount of bait available at both sites was, therefore, approximately 15–16 kg. Possums were pre-fed with the same amount (15 kg) of non-toxic bait at both sites for 2 weeks prior to poisoning. This was followed with toxic bait containing a nominal 0.8% wt/wt of cholecalciferol. The bait was left at the study sites for a further 2 weeks. Actual concentration of cholecalciferol was assayed from four samples of bait collected at the sites by the CENTOX Toxicology Laboratory, Lincoln.

2.5.3 Measuring possum kills

Possum kills were measured by systematically locating 5 leg-hold trap lines within each block, so that the lines were at least 200 m apart and with an end-to-end distance of at least 100 m. This spacing ensured that each line was an independent sampling unit (NPCA 2004). Each line contained 10 traps that were spaced along the lines at 20 m intervals. Trapping was undertaken for 1 fine night during the week before (pre-poison) and 2 weeks after (post-poison) the application of the poison bait.

All animals captured in the pre-poisoning trapping were ear-tagged using Monel self-piercing ear tags (National Band & Tag Co.) and released so that possums that survived the poisoning could be identified. Possum kill was calculated using the following formula as described in the trap-catch protocol (NPCA 2004):

$$\%kill = \left[1 - \left(\frac{Mean_{post}}{Mean_{pre}}\right)\right] * 100$$

Possums captured in the post-poisoning trapping operation were checked for ear tags and autopsied and examined for signs of calcification of the major heart vessels (a symptom of cholecalciferol poisoning).

2.6 ADDITIONAL ALTERNATIVES TO BRODIFACOUM

Toxicants and baiting strategies that were considered to be additional potential alternatives to brodifacoum baiting were identified by conducting a literature search of reports and papers and using existing knowledge of toxicants and bait development in the possum control industry.

3. Results and discussion

3.1 COMPARISONS OF CYANIDE, CHOLECALCIFEROL, AND BRODIFACOUM

3.1.1 Possum kills

A review of the current literature indicates that possum kills achieved when baiting with cyanide, cholecalciferol, and brodifacoum are similar and can be in excess of 80%. Highest kills were achieved with baits containing brodifacoum (Table 2).

3.1.2 Pre-feeding

Pre-feeding or pre-baiting is a process whereby non-toxic baits are fed to vertebrate pests prior to feeding toxic baits. Research indicates that more toxic baits are eaten by possums after pre-feeding (Thomas 1994), and higher possum kills can be achieved if pre-feeding is undertaken (Thomas et al. 1996). Because brodifacoum poisoning is slow and occurs over a period of several weeks (Morgan & Ross 2001), possums continue to eat baits on a nightly basis. Therefore a combination of pre-feeding and poisoning occurs when baiting with brodifacoum. In contrast, baits containing cyanide and cholecalciferol are fast-acting, and possums generally feed on them only once (O'Connor & Mathews 1995; Morgan & Milne 2002), so they do not have this 'built-in' pre-feeding ability.

3.1.3 Bait shyness

Bait shyness occurs when possums eat sub-lethal amounts of toxic bait and become ill. This illness is associated with consumption of bait, so possums are reluctant to eat baits on following nights. Bait shyness only occurs when possums eat fast-acting toxicants such as cyanide and cholecalciferol (Warburton & Drew 1994; Morgan & Milne 2002), and does not occur with slow-acting toxicants such as brodifacoum (Morgan & Ross 2001). In addition, possums that are bait-shy can be killed with baits

TABLE 2. REDUCTIONS IN POSSUM POPULATIONS (%) RECORDED FOR POSSUM BAITS CONTAINING BRODIFACOUM, CHOLECALCIFEROL, AND CYANIDE.

BRODIFACOUM	CHOLECALCIFEROL	CYANIDE
52–100% 0.002% brodifacoum Henderson et al. (1994)	45–97%, test baits 0.8% cholecalciferol Henderson et al. (1994)	60–84%, paste 60% sodium cyanide Henderson et al. (1997a)
60–88% 0.002% brodifacoum Henderson et al. (1997b)	82 (n = 5) 0.8% cholecalciferol Henderson et al. (1997b)	31–70% 80% potassium cyanide Morriss et al. (1997)
86% & 92% 0.002% brodifacoum Morriss & Henderson (1997)	51% & 22% 0.8% cholecalciferol Morriss & Henderson (1997)	70% (n = 6) 60% sodium cyanide Henderson et al. (1997b)

containing brodifacoum (Morgan & Ross 2001). These advantages cannot be achieved to the same extent using baits containing cyanide or cholecalciferol (Ross et al. 1997).

3.1.4 Multi-species control

Brodifacoum baiting is a multi-species control tool that can control possums and rodents simultaneously. However, although brodifacoum is registered as a rodent bait in New Zealand, it is not in the same formulation used for possum baits. Baits containing cholecalciferol also have multi-species potential, but currently there are no baits containing cholecalciferol registered in New Zealand for rodent control. Baits containing cyanide are unlikely to kill rodents, and cyanide is only registered for possum control; any use of these toxicants in possum baits to control rodents is currently illegal until re-registration specifies otherwise. There are no research results available that examine the ability of possum baits containing these toxicants to control rodents.

Brodifacoum baiting may also give secondary control of predators such as stoats (*Mustela erminea*), ferrets (*Mustela furo*), and feral house cats (*Felis catus*) that have consumed dead or dying rodents or possums poisoned by eating baits containing brodifacoum (Alterio 1996; Brown et al. 1998). This occurs because brodifacoum residues in tissue, especially liver, are high enough to cause poisoning of animals that eat them. Secondary poisoning of predators is unlikely to occur when baiting with cyanide or cholecalciferol (Eason et al 2000; Eason & Wickstrom 2001).

3.2 PALATABILITY OF FERAFEED AND THE BLOCK AND SENTINEL FORMULATION

3.2.1 Cage studies

Significantly less Ferafeed® paste was eaten by captive possums compared with RS5 cereal pellets ($P < 0.05$). Mean (± SE) bait consumption was 19.6 ± 5.4 g for the Ferafeed® paste and 50.2 ± 7.9 g for the RS5 cereal pellets (n = 15). This produced a palatability rating of 28% for the Ferafeed® paste.

Significantly less Block and Sentinel formulation was eaten by captive possums compared to RS5 cereal pellets ($P < 0.001$). Mean (± SE) bait consumption was 7 ± 2.6 g for the Block and Sentinel formulation and 58.3 ± 7.4 g for the RS5 cereal pellets ($n = 15$). This produced a palatability rating of 11% for the Block and Sentinel formulation.

3.2.2 Field trials

Similar amounts of Block and Sentinel baits were eaten over the 2-day period (864 g and 868 g for the Block and Sentinel baits, respectively) indicating that the delivery methods were equally effective. There were no significant differences in the weights of Block or Sentinel baits eaten compared with RS5 cereal pellets on day 1. However, day 2 and the total for days 1 and 2 combined indicated that significantly more RS5 cereal pellets were eaten (Table 3). The field-based palatability rating for the Block and Sentinel baits over the 2-day period was 36% and 37%, respectively (Tables 4, 5).

The higher palatability for the Block and Sentinel bait formulation achieved for wild possums compared with captive possums could reflect differences in feeding habits and food availability. However, both results indicate that the Block and Sentinel formulation is below the standard specified for possum control on conservation land (Eason & Wickstrom 2001).

3.3 SUITABILITY OF GRID AREA FOR BAIT STATIONS AND BAGS

Of the total of 141 possums captured at the four grid baiting sites located in the Hollyford Valley (Fiordland), 100 (71%) were marked with rhodamine dye (range 62–79%, Table 6), indicating they had fed on bait. These results suggest that bait bags and bait stations located in practically sized grids are unlikely to target all possums when baits containing cyanide or cholecalciferol are used.

These results were obtained without pre-feeding and it is likely that a pre-feeding component would increase the numbers of possums at risk of poisoning when using these grids (Thomas 1994). Also, the study was undertaken without the use of visual lures such as a flour blaze (Warburton & Yockney 2000) or photo-luminescent strips (Thomas & Maddigan 2004), which may help increase the numbers of possums targeted.

3.4 POSSUM KILLS USING DIFFERENT FERATOX PRESENTATION METHODS

Feratox® presented in plastic bags attached to wires killed a mean of 0.5 and 3.0 possums per line compared to a mean of 1.5 and 5.3 possums per line for leg-hold traps at the Northland and Kaiangaroa sites, respectively (Fig. 4). These differences were statistically significant ($P < 0.05$).

When paper bags were attached to trees and accompanied with a flour blaze, no significant difference was recorded compared with possum captures in leg-hold traps ($P = 0.25$); means were 3.7 and 2.2 for paper bags and 3.3 and 1.6 for leg-hold traps for the Catlins and Rahu sites, respectively (Fig. 4).

TABLE 3. ANALYSIS OF AMOUNTS OF BLOCK AND SENTINEL BAITS v. RS5 CEREAL PELLETS EATEN.

n.s. = no significant difference; s. = significantly less.

	BLOCKS		SENTINELS	
Day 1	t =1.7; P = 0.09; d.f. = 24	n.s.	t = 1.3; P = 0.2; d.f. = 24	n.s.
Day 2	t = 2.1; P = 0.04; d.f. = 24	s.	t = 2.2; P = 0.04; d.f. = 24	s.
Days combined	t = 2.7; P = 0.008; d.f. = 49	s.	t = 2.5; P = 0.01; d.f. = 49	s.

TABLE 4. AMOUNTS OF BLOCK AND RS5 CEREAL PELLETS EATEN FROM PAIRED BAIT STATIONS.

n = 25, percentages are in parenthesis.

	BLOCK EATEN (g)	RS5 EATEN (g)	TOTAL (g)
Day 1	299 (33)	606 (67)	906
Day 2	564 (37)	962 (63)	1526
Days combined	864 (36)	1568 (64)	2432

TABLE 5. AMOUNTS OF SENTINEL AND RS5 CEREAL PELLETS EATEN FROM PAIRED BAIT STATIONS.

n = 25, percentages are in parenthesis.

DAY	SENTINEL EATEN (g)	RS5 EATEN (g)	TOTAL (g)
Day 1	205 (34)	399 (66)	604
Day 2	663 (38)	1097 (62)	1760
Days combined	868 (37)	1496 (63)	2364

TABLE 6. POSSUMS CAPTURED IN LEG-HOLD TRAPS IN THE FERAFEED BAIT STATION AND BAIT BAG GRIDS, AND NUMBERS OF THEM MARKED WITH RHODAMINE DYE.

LAYOUT	NUMBER CAPTURED	NUMBER MARKED	PROPORTION MARKED (%)
100 m × 100 m bait stations	26	16	62
100 m × 50 m bait stations	42	33	79
100 m × 10 m bait bags	40	29	72
50 m × 10 m bait bags	33	22	67

When bait stations were used, mean possum kills of 0.9 and 1.4 possums per line were recorded for the pre-fed possums and those not pre-fed, respectively. Kills were not significantly different to captures in leg-hold traps (1.5 and 1.5 for the pre-fed and non-pre-fed sites, respectively: P = 0.33, Fig. 4). There was no significant difference between possum kills achieved in the pre-fed and non-pre-fed sites although more possums were killed when pre-fed (14 compared to 9 for pre-fed and non-pre-fed, respectively: P = 0.66, Fig. 4).

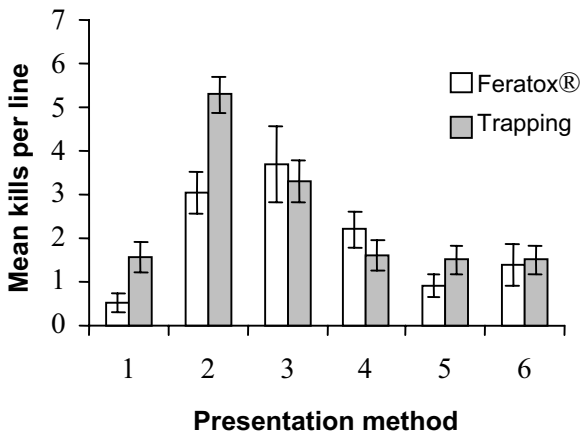

Figure 4. Mean (± SEM) possum kills per line using different methods of presenting Feratox® compared with control using leg-hold traps. 1, 2 = plastic bags on wires, 3, 4 = paper bags stapled to trees with flour blaze, 5 = bait stations without pre-feeding, 6 = bait stations with pre-feeding.

These results indicate that Feratox® baiting with paper bags attached to trees accompanied with a flour blaze can achieve similar possum kills to baiting using bait stations. Plastic bags on wires achieved lower kills, suggesting they are unsuitable as a delivery method for Feratox®. Reasons may be that plastic bags on wires are less visually attractive than bait bags or bait stations. Also possums may have had difficulty in accessing the bait through the plastic bags.

3.5 EFFICACY OF BLOCKS AND SENTINELS CONTAINING CHOLECALCIFEROL

3.5.1 Amount of bait eaten

A mean concentration of 0.76% wt/wt cholecalciferol was recorded for the bait used in the trial (CENTOX report numbers T1954, T1955, T1956, and T1957). All non-toxic pre-feed bait in both the Block and Sentinel study sites was eaten over the 2-week pre-feeding period. Following 2 weeks of toxic baiting, significantly more Block bait was eaten than Sentinel bait (mean 311 g and 177 g for the Block and Sentinel baiting sites, respectively; $P = 0.002$, $t = 3.52$, d.f. = 24). The total amount of bait eaten at each study site was 7.8 kg in the Feracol® Block study site and 4.4 kg in the Feracol® Sentinel study site. These differences are likely to reflect different numbers of possums present at the study sites rather than a preference for the Block delivery method (see palatability trial, Section 3.2).

3.5.2 Possum kills

Numbers of possums captured before poisoning were 12 in the Block site and 16 in the Sentinel site. After poisoning, these numbers reduced to 4 possums in the Block site and 3 possums in the Sentinel site. No possums captured after poisoning had ear tags, and autopsies did not show calcification of major heart vessels. Percentage kills are summarised in Table 7.

These results suggest that these bait delivery methods have the potential to achieve high possum kills, although higher kills might be obtained if the palatability of the baits was improved (see Section 3.2).

TABLE 7. POSSUM DENSITIES, EXPRESSED AS POSSUMS CAPTURED PER 100 TRAP NIGHTS (%) PRE- AND POST-POISONING USING BLOCK AND SENTINEL BAIT DELIVERY METHODS.

BAIT	PRE-POISON CATCH (%)	POST-POISON CATCH (%)	POSSUM KILL (%)	SE (%)
Block	33	8	75	20
Sentinel	33	6	83	12

3.6 ADDITIONAL ALTERNATIVES TO BRODIFACOUM

Three baiting methods were identified as having potential to provide additional alternatives to brodifacoum baits.

Pindone

Pindone is the only first-generation anticoagulant registered for possum control in New Zealand. The bait is registered to contain 0.05% pindone wt/wt and the registration is held by Pest Management Services Ltd (Waikanae, registration no. P004396 www.nzfsa.govt.nz/acvm/registers-lists/pesticides/index.htm).

Pindone has a very low persistence in rat liver compared with brodifacoum (a half-life of 2 days compared with 113.5 days for brodifacoum, Fisher et al. 2003). Therefore baiting with pindone is likely to pose a lower secondary poisoning risk to non-target species such as native birds and wild pigs (*Sus scrofa*) than baiting with brodifacoum. However, because of this low persistence, control of predators such as stoats and ferrets is unlikely to occur.

Baits containing pindone are considered to be less effective for possum control than baits containing brodifacoum (Eason et al. 1993). Jolly et al. (1994) showed that 9 of 14 possums died when dosed with 320 mg of pindone—an equivalent of approximately 600 g of bait at the current 0.05% wt/wt concentration. This is compared with approximately 120 g of bait containing 0.002% brodifacoum that is required to kill a possum (Eason et al. 1994b).

A field trial conducted to measure the efficacy of continuous feeding of baits containing 0.05% pindone over a period of 85 days achieved a mean (± SE) possum kill of 89% ± 17% (Wickstrom et al. 1997). Commins (2000) located 37 bait stations in a 80 ha study site and continuously filled them with a new formulation of pindone possum bait (S. Nelson pers. comm.) over a period of 33 days. This achieved a mean possum kill of 92% (95% CI of 15%) with a total of 229 kg of bait or 2.9 kg/ha eaten. Conclusions from this study were that the bait was effective in reducing a low-density possum population to a low level and the product was an economical alternative to brodifacoum.

Diphacinone

Currently diphacinone is only registered in New Zealand for rodent and ferret control (www.nzfsa.govt.nz/acvm/registers-lists/pesticides/index.htm) and there has been no research undertaken to examine the susceptibility of possums to diphacinone or to measure the efficacy of baits containing diphacinone for possum control. However, research examining the persistence of diphacinone in rat livers indicated that it has a

half-life of 3 days compared with 113.5 days for brodifacoum (Fisher et al. 2003). These results suggest that, like pindone, possum baiting with diphacinone is likely to pose a lower secondary poisoning risk to non-target species than baiting with brodifacoum.

A combination anticoagulant and cholecalciferol

First-generation anticoagulants such as pindone, diphacinone, and coumatetralyl are less effective for possum control compared with second-generation antcoagulants such as brodifacoum (Eason & Wickstrom 2001). However, the ability of first-generation anticoagulants to kill possums could be enhanced with the addition of cholecalciferol. The combination of 0.04% wt/wt coumatetralyl and a low concentration of cholecalciferol (0.025% wt/wt) significantly increased the ability of coumatetralyl to kill rats (Pospischil & Schnorbach 1994). A combination of low concentrations of brodifacoum and cholecalciferol enhanced the effect of both toxins when administered to possums in corn oil using gastric intubation (Eason et al. 1994a; Wickstrom et al. 1997).

Coumatetralyl may pose a higher risk of secondary poisoning of non-target species than pindone or diphacinone because it is more persistent in rat tissue (half-life of 55 days: Parmar et al. 1987). Therefore combinations of cholecalciferol with either pindone or diphacinone are likely to be safer options for use on conservation land.

4. Conclusions and recommendations

Advantages of brodifacoum baiting include: the ability to achieve high possum kills, 'built-in' pre-feeding, prevention and mitigation of bait shyness, and ability to control other species such as rodents and predators. Baiting with Feratox® and Feracol® are unlikely to achieve all of these advantages. Possum baiting using Feracol® should not be undertaken until a more palatable bait matrix is developed.

Cage trials in this study indicate that the palatability of Ferafeed® paste is below the standard specified by DOC. This could potentially reduce possum kills when using Ferafeed® with Feratox® and could increase the likelihood of bait shyness occurring. A more palatable version needs to be developed.

The Block and Sentinel formulation containing 0.8% wt/wt cholecalciferol can achieve possum kills in excess of 75% provided that possums are pre-fed. However, cage and field trials indicate that the palatability of the Block and Sentinel formulation is below the standard specified by DOC. Consequently these baits are unsuitable for possum control on conservation land, especially when they contain the toxicant cholecalciferol. Use of this bait could also increase the likelihood of sub-lethal poisoning and bait shyness in possum populations. More palatable versions of these formulations should be developed.

Bait stations and bait bags containing Ferafeed® located in grids that are practical to establish and service by DOC staff are unlikely to target all possums present. The use

of pre-feeding and lures such as a flour blaze or photo-luminescent strips could increase the numbers of possums that these delivery methods target. Bait stations and bait bags containing Feratox® used with Ferafeed® with a flour blaze can achieve similar kills to leg-hold trapping. It is recommended that all baiting using bait bags and bait stations for possum control should include a pre-feeding component and be accompanied with a visual lure such as a flour blaze and/or photo-luminescent strip.

Of all alternatives, possum baiting with a new formulation of pindone could provide a cost-effective alternative to brodifacoum baiting and retain all the inherent advantages of brodifacoum baiting except secondary poisoning of predators. However, more pindone bait is likely to be needed to achieve a similar result. Pindone baiting is likely to pose a lower risk to non-target species compared to baiting with brodifacoum. Moreover, pindone baits have the advantage of being the only first-generation anticoagulant bait registered for possum control in New Zealand, so re-registration of a new formulation will only require a 'variation to a trade name product' rather than a full registration. It is recommended that trials to evaluate the efficacy and cost-effectiveness of a new formulation of pindone bait should be undertaken, including research on its persistence in possums and non-target species to provide information on the comparative risks to non-target species.

Baits containing diphacinone could offer an alternative to baits containing brodifacoum but no information is available on either the susceptibility of possums to diphacinone or the efficacy of diphacinone baits used in the field to control possum populations. Combinations of anticoagulants such as pindone or diphacinone with low levels of cholecalciferol could improve their ability to control possums, and it is recommended that diphacinone and these combinations be investigated.

The ability of possum baits containing brodifacoum, cholecalciferol, and pindone to simultaneously control rodents should be investigated.

It is recommended that a quality control system to regularly evaluate all baits (especially those containing cholecalciferol) be undertaken, following the guidelines outlined in Eason & Wickstrom (2001). Particular emphasis should be placed on bait palatability and toxicant concentration.

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