Breakdown of cyanide and cholecalciferol in Feratox and Feracol possum baits

Malcolm Thomas and Philip Ross

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ABSTRACT

Feratox®, which contains potassium cyanide, and Feracol®, which contains cholecalciferol (vitamin D3), are two baits commonly used for possum (*Trichosurus vulpecula*) control. This study aimed to determine the persistence of the toxins in these two baits, which are often left in the field for several months. In this study, monthly samples of weathered baits were collected from two sites (wet and dry) over 1 year. These were assayed to measure the concentration of cyanide and cholecalciferol to determine decay rates. Decay of cyanide (in Feratox) depended on how long the surface coating on the Feratox capsule remained intact: once the coating ruptured, the cyanide decayed rapidly. Results indicated that the coating could remain intact for 8 months retaining 100% of the cyanide toxicity. Cholecalciferol (in Feracol) decayed at a steady rate, retaining 50% of its toxicity after 8 months and 30% after 11 months. We conclude that both target and non-target animals will be at risk from poisoning for at least 8 months from the cyanide in Feratox baits and for at least 12 months from the cholecalciferol in Feracol baits. Therefore, we recommend that Feratox and Feracol baits be removed from the field after 1 month to reduce risks of sub-lethal and non-target poisoning.

Keywords: possum, pest control, baits, cyanide, Feratox®, Feracol®, cholecalciferol, environmental fate, New Zealand

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1. Introduction

Feratox® and Feracol® are two possum baits manufactured by Connovation Ltd (East Tamaki, Auckland). These baits are commonly used to control possums (*Trichosurus vulpecula*) by the Department of Conservation (DOC) (Thomas 2005). However, there is limited information on the breakdown rates of these baits in the field. This study was undertaken to investigate breakdown rates and to use this information to calculate potential risks to target and non-target species.

2. Background

2.1 PERSISTENCE OF TOXINS

Materials exposed to ambient conditions in the environment may be affected by physical, chemical and biological action that is capable of causing significant alterations to the material. Physical attack on materials involves the direct action of heat, light, wind, water and physical abrasion. Chemical attacks on materials may involve a variety of reactants: oxidisers, reducing agents, and other substances that promote solubility or otherwise react with the material in question. Finally, biological attack involves the action of fungi, bacteria, plants and animals.

These agents may act alone or together to bring about the complex changes that are collectively described as deterioration or breakdown of a material. Where specific factors interact (such as light, moisture, UV radiation, bacterial action and the action of oxygen), the breakdown rate will be the result of a complex suite of conditions. It is possible that a relatively small change in one factor could result in a large change in the apparent breakdown rate.

Toxins that resist physical, chemical and biological breakdown can persist in the environment for long periods of time. However, even toxins that readily break down can be made more stable by using coatings that can reduce the action of moisture, UV radiation, oxygen and bacteria, and thus slow breakdown rates. For example, the encapsulation of cholecalciferol in a gel, or wax coating of cereal baits that contain the anticoagulant brodifacoum, can reduce the breakdown of these toxins (Morgan 2004).

Persistence can arise from the nature of the compound (e.g. being stable and relatively unreactive) or from the conditions to which the compound is exposed. It is important to differentiate between persistence that is an inherent property of the material as opposed to the circumstances in which the chemical is present. For example, a material may degrade rapidly in warm, aerobic conditions but persist indefinitely under cool, anaerobic conditions.

In Feratox, cyanide is encapsulated within a hard coating, and in Feracol, cholecalciferol is covered with an oil and fat coating. These coatings are likely to extend the baits' field lives. However, little is known about how long these baits remain toxic. This study was designed to measure their field lives and to use this information to evaluate risks to target and non-target mammals and birds.

2.2 FERATOX

Feratox was developed in 1996 principally to overcome cyanide shyness, which can occur following the use of cyanide paste baits (Warburton & Drew 1994; Morgan et al. 2001). In Feratox baits, a 5-mm-diameter pellet of >50% potassium cyanide (KCN) is encapsulated within a hard coating that protects the cyanide from air and moisture. As long as the coating remains intact, the potassium cyanide can be expected to remain relatively stable. To be effective against possums, the Feratox pellet needs to be crushed by their teeth when the non-toxic paste or block formulation that encloses the pellet is eaten (see section 2.4). Cyanide kills possums within an average time of 18 min (Gregory et al. 1998). Feral IP Ltd owns the registration for this product (registration number P004713), which is registered to contain 475 g/kg (47.5% wt/wt) of potassium cyanide.

2.2.1 Toxicity of cyanide

Cyanide is a small molecule (molecular weight = 65.12) that can rapidly cross membranes and directly interact with cellular metabolism. The cytochrome C oxidase enzyme system can be blocked by cyanide during lethal exposure; death follows rapidly due to failure of the respiratory and central nervous systems.

2.2.2 Environmental fate of cyanide

The behaviour of cyanide in the environment has been extensively studied in association with its use as an industrial chemical, mainly in the gold mining industry. Cyanide is quite mobile due to its high solubility in water and moderate rates of volatilisation. In natural water and soil solutions, cyanide occurs in equilibrium primarily in two forms: molecular hydrogen cyanide (HCN) and the dissociated cyanide ion (CN^-). The ion can form simple cyanide salts as well as oxidised cyanate (OCN^-) and thiosulphate (SCN^-) compounds. The form of cyanide is largely dictated by the solution's pH. At neutral and acidic pH, cyanide is present as molecular HCN. At alkaline pH (e.g. >8), cyanide is present as CN^-. The molecular form is prone to volatilisation through gaseous release, while the ionic form is more likely to react with metals and organic matter, and precipitate out of solutions (Moran 1998).

Environmental conversions of cyanide can occur rapidly and be significantly affected by temperature and radiation (particularly UV wavelengths). Several of the metallocyanide complexes (ferricyanides, cuprocyanides and cobalocyanides) may be degraded solely by photolysis (Moran 1998).

Cyanides can also be degraded by microbial action. A wide range of bacterial genera can metabolise cyanide and some can use it as their sole carbon source, although these processes may be impaired at higher cyanide concentrations, when the toxicity of cyanide affects bacterial metabolism (Akcil & Mudder 2003). Cyanide metabolism can convert cyanide to carbon dioxide, nitrogen ammonia and a range of organic nitrogen compounds.

2.3 FERACOL

Feracol is a paste and block bait (see section 2.4) that was developed in 2000. It contains cholecalciferol (or vitamin D3) at a concentration of 8 g/kg (0.8% wt/wt). Feral IP Ltd owns the registration for this product (registration number P005263). Cholecalciferol was developed as a rodenticide in the USA and Europe in the early 1980s (Marshall 1984), and was subsequently shown to be effective for possum control in the early 1990s (Eason 1992). It kills possums in an average of 7 days (Wickstrom et al. 1997; Morgan & Rhodes 2000a).

2.3.1 Toxicity of cholecalciferol

Cholecalciferol is a large organic molecule (molecular weight = 384.62) that is fat soluble and collects in adipose tissue. Low levels are required to prevent deficiency disease, but high doses are toxic. Toxic amounts of cholecalciferol promote mobilisation of calcium from bones, leading to high blood calcium concentrations and calcification of other tissues. This appears to cause hypercalcaemia, tissue calcification and renal or cardiac failure leading to death in the possum (Jolly et al. 1993).

2.3.2 Environmental fate of cholecalciferol

Unlike cyanide, there are no published data on the fate of cholecalciferol in soil and water (Eason & Wickstrom 2001). However, some studies have been undertaken to examine the fate of cholecalciferol in possum baits. Booth et al. (1999) exposed cereal pellets containing cholecalciferol to 400 mm of simulated rainfall and found that the cholecalciferol concentration remained at the same level as unexposed baits even though the pellets had been reduced to a water-saturated paste. They also found that soil under the exposed baits contained very small quantities of cholecalciferol (2% of the concentration in the baits), even after the baits had been exposed to 500 mm of simulated rainfall. Morgan (2004) measured the natural breakdown of cholecalciferol in paste baits (Feracol) that had been protected from the weather using plastic bottles and in gel baits (Kiwicare, 'No Possums Cholecalciferol Gel Bait') that were used in purpose-designed bait stations in Westland, New Zealand. He found that there was no decline in cholecalciferol levels in the paste bait after 12 months and no decline in gel baits after 25 months.

2.4 FERAFEED PASTE AND BLOCK FORMULATIONS

In order to use Feratox, Connovation Ltd developed a non-toxic paste bait called Ferafeed® paste (Morgan & Rhodes 2000b), which acts as a carrier for the Feratox pellets. This bait consists of a mixture of oils, vegetable fat and cereals, and contains hard lumps of cereal of a similar size and dimension to Feratox pellets. These lumps act as placebos to condition possums to eating hard pellets so they are more likely to crush the Feratox pellets. Feracol consists of Ferafeed without the Feratox and placebos but with 0.8% wt/wt cholecalciferol.

Connovation Ltd also developed a 20-g Ferafeed® block formulation that also contains either Feratox or cholecalciferol. The size of the blocks is 40 × 40 × 20 mm and they are made from a mixture of vegetable fat, sugar and ground cereal. The block formulation was developed so that Feratox and Feracol could be handled more easily in the field. It was also intended as a more water-resistant option to the paste formulation, to provide a long-life bait formulation.

2.5 USING FERATOX AND FERACOL

Figure 1. Paper bait bag commonly used to deploy Feratox and Feracol in the field. The bags are attached to trees or fence posts and are ripped open by possums (*Trichosurus vulpecula*) to gain access to the bait.

Feratox and Feracol can be used in standard, commercially available bait stations such as the Philproof, Kilmore and Sentry bait stations (Thomas et al. 1996). However, a more cost-effective method is the use of small paper bait bags (Fig. 1). Since the baits and bait bags are lightweight, many can be carried, allowing large areas to be treated quickly. The bait bags are stapled to trees or fence posts, approximately 100–400 mm above the ground and are often accompanied with a blaze of flour to attract possums (Thomas et al. 2003). Cost-effectiveness is commonly increased by not undertaking any bait retrieval, instead relying on the baits and bait bags being broken down by the various environmental conditions present at the baiting site. Because bait bags are a commonly used bait delivery method for Feratox and Feracol, the degredation of baits enclosed in bait bags was measured in this study.

3. Objectives

The objectives of this study were to:

- Measure the decline in cholecalciferol (Feracol) and cyanide (Feratox) concentrations when used in bait bags exposed to natural weathering.
- Compare cholecalciferol and cyanide concentrations (calculated from the measured rates of decline) with known LD_{50} figures for birds and mammals to calculate the period when target and non-target species are likely to be at risk from poisoning.

4. Methods

4.1 MEASURING THE DECLINE IN TOXIN CONCENTRATION

Two study sites that had rainfall and sunlight extremes were selected, so that the effects of minimum and maximum weathering conditions (i.e. the longest and shortest periods that baits are likely to remain toxic) could be studied. The 'dry' site was a grassland area (0.1 ha) located at Twizel in the Mackenzie Basin (44°15′S, 170°5′E). The 'wet' site was a small, broadleaf podocarp forest (5 ha) located at Paroa near Greymouth on the West Coast of the South Island (42°30′S, 171°10′E).

Bait bags containing 20 g of Ferafeed paste or block baits containing either one pellet of Feratox or 0.8% wt/wt cholecalciferol were deployed in the field at the Mackenzie Basin and West Coast sites from August 2004 to July 2005. For each treatment variant (see below), 24 bait bags (i.e. two for each monthly sample) were placed within wire cages to prevent baits being eaten by birds, rodents or possums (Fig. 2). Bait bags were either elevated above the ground to simulate bait bags attached to trees or located on the ground to simulate bait bags that had fallen to the ground.

The four treatments were:

- Ferafeed paste containing Feratox (Feratox paste) elevated or on the ground
- Ferafeed block containing Feratox (Feratox block) elevated or on the ground
- Ferafeed paste containing cholecalciferol (Feracol paste) elevated or on the ground
- Ferafeed block containing cholecalciferol (Feracol block) elevated or on the ground

For each treatment type (i.e. cyanide or cholecalciferol, paste or block, elevated or ground, West Coast or Mackenzie Basin), one bait bag was

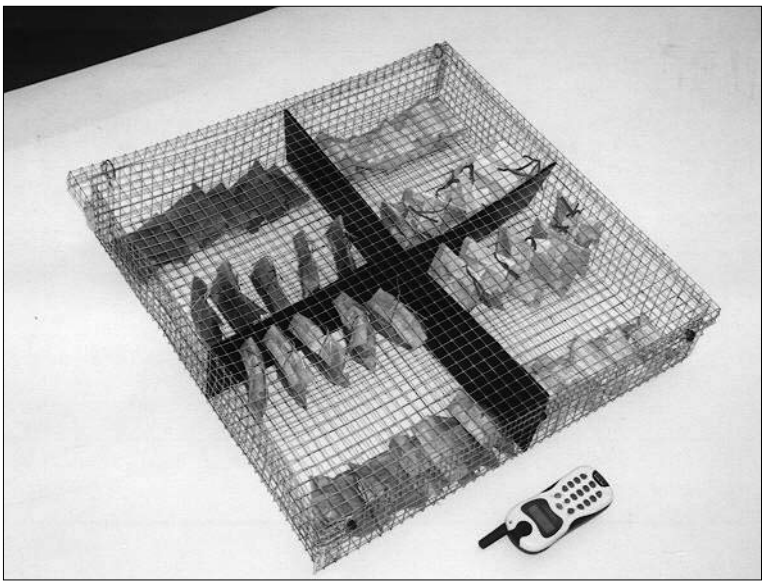

Figure 2. Example of the wire cage used to protect the baits from animals and birds when the bait bags were deployed in the field.

collected each month and then frozen. These samples (48 for paste containing cholecalciferol, 48 for blocks containing cholecalciferol, 48 for paste containing Feratox pellets and 48 for blocks containing Feratox pellets) were sent to Hill Laboratories (Hamilton) for analysis to determine cholecalciferol content (g/kg) and cyanide content (mg/Feratox pellet). Graphs were plotted for each treatment type and regression analyses undertaken to record the reduction of toxin concentration for the treatment types at the two study sites.

4.2 MEASURING RISK TO TARGET AND NON-TARGET ANIMALS

The risk of target and non-target poisoning from degraded baits was determined using published acute oral toxicity LD_{50} data (mg/kg) for cyanide and cholecalciferol for the possum, Norway rat (*Rattus norvegicus*), mouse *(Mus musculus*), mallard duck (*Anas patyrhyncos*), rabbit (*Oryctolagus cuniculus*) and goat (*Capra hircus*), taken from Eason & Wickstrom (2001); values for cholecalciferol in the domestic dog (*Canis familiaris*) were taken from Eason & Wickstom (2001) and those for cyanide in the dog from Sterner (1979). In toxicology, the median lethal dose or LD_{50} (abbreviation for 'Lethal Dose, 50%') of a toxic substance is the dose required to kill half the members of a test population. LD_{50} figures are frequently used as a general indicator of a substance's acute (i.e. lethal) toxicity.

The threshold dose required to kill 50% of a test sample for these animals was then estimated as the published acute oral $LD_{50} \times$ the mean weight of each species (Table 1). Mean weights for the possum, rat, mouse, rabbit and goat were sourced from King (1990), while the mean weight for the mallard duck was sourced from the website http://animals.nationalgeographic.com/animals/birds/mallard-duck.html (viewed 15 September 2007). Because of the diverse size differences of different breeds of dog, this species was divided

TABLE 1. PUBLISHED ORAL LD_{50} VALUES (mg/kg) FOR CYANIDE AND CHOLECALCIFEROL, AND MEAN WEIGHTS FOR A RANGE OF SPECIES. THE AMOUNT OF EACH TOXIN (mg) TO KILL 50% OF THE INDIVIDUALS IN A POPULATION, BASED ON THESE VALUES, IS ALSO ESTIMATED. SEE APPENDIX 1 FOR DOG SIZE CATEGORIES.

ANIMAL	ORAL LD_{50} (mg/kg)		MEAN WEIGHT OF	AMOUNT TO REACH LD_{50} (mg)	
	CYANIDE	CHOLECALCIFEROL	INDIVIDUAL (kg)	CYANIDE	CHOLECALCIFEROL
Possum	8.7	16.8	2.8	24.4	47
Rabbit	4	9	1.4	5.6	12.6
Mouse	6.4	43.6	0.02	0.16	0.9
Rat	6.4	42.5	0.2	1.3	12.7
Duck	1.4	2000	1.2	1.7	2400
Goat	4	Unknown	36	144	Unknown
Dog (miniature)	5.4	80	3	16.2	240
Dog (small)	5.4	80	8	43.2	640
Dog (medium)	5.4	80	19	102.6	1520
Dog (large)	5.4	80	31	167.4	2480
Dog (very large)	5.4	80	50	270	4000

into five weight categories based on information sourced from the website www.pgaa.com/canine/general/size.html (viewed 16 September 2007). These categories were: miniature (2–5 kg), small (5–11 kg), medium (11–27 kg), large (27–36 kg) and very large (36–70 kg). Representative breeds for these weight classes are shown in Appendix 1.

The total amount of toxin in a fresh bait was calculated by taking the mean concentration of toxin recorded in fresh bait in this study (8 mg/g for Feracol and 47.5 mg/g for Feratox pellets) and multiplying it by the mean weight of the bait (20 g for Feracol and 1 g for Feratox). These thresholds were graphed along with the decline in concentration of cyanide and cholecalciferol in bait as determined from this study.

The risk of poisoning target and non-target animals was calculated as the period from bait deployment (i.e. August 2004) to the time when the amount of toxin remaining in the bait was less than the published LD_{50} value. The rate at which the toxin in the bait declined was calculated from the regression relationships derived from the results of this study using the following formula:

$$\text{Toxin}_t = \text{Toxin}_1 + (\Phi t)$$

Where Toxin_t = the toxin remaining at time t after deployment; Toxin_1 = the initial toxin concentration at bait deployment; Φ = mg of toxin lost per month calculated from the toxin breakdown data determined from this study; and t = the time for which the toxin was exposed in the field (months).

Our calculations assumed that the full amount of bait (i.e. one Feratox pellet or 20 g of Feracol) was consumed. For smaller animals such as mice, this is unlikely to occur; therefore, the risk to these smaller animals is likely to be lower than estimated. For larger animals, no attempt was made to evaluate toxicity associated with the animal eating more than one bait, although that would increase the risk.

5. Results and discussion

5.1 DECLINE IN TOXICITY

5.1.1 Decline in cyanide concentration

The cyanide content (mg/Feratox pellet) of both the block and paste baits showed a significant decline over the 12-month sampling period at both sites (Figs 3 & 4, Table 2) with one exception, the block bait on the ground at the West Coast site. This exception occurred because cyanide in this sample was only recorded as present at the start of the study and was absent from all other sampling periods (Fig. 3, Table 2). There was a rapid reduction in the average cyanide concentration within 3 months at the West Coast site and an intermittent reduction for up to 8 months at the Mackenzie Basin site. However, there was no significant difference in the overall breakdown rates

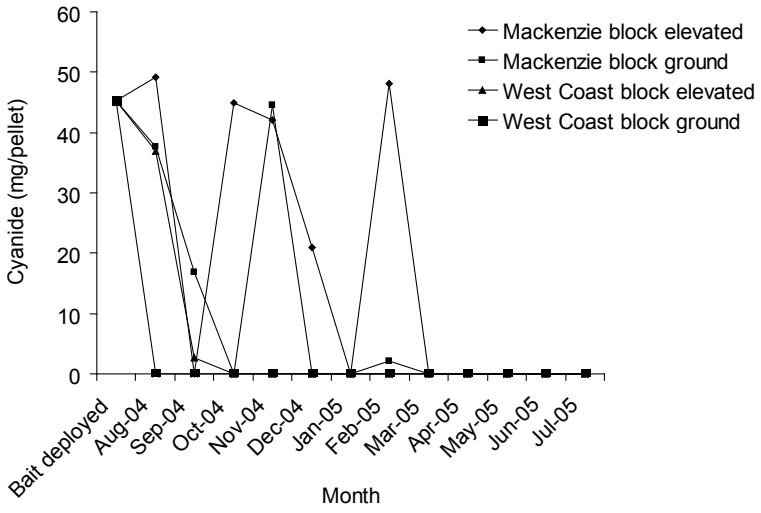

Figure 3. Changes in monthly cyanide concentrations (mg/pellet) in elevated or ground-level Feratox pellets embedded in block baits exposed to natural weathering at sites in the Mackenzie Basin and West Coast.

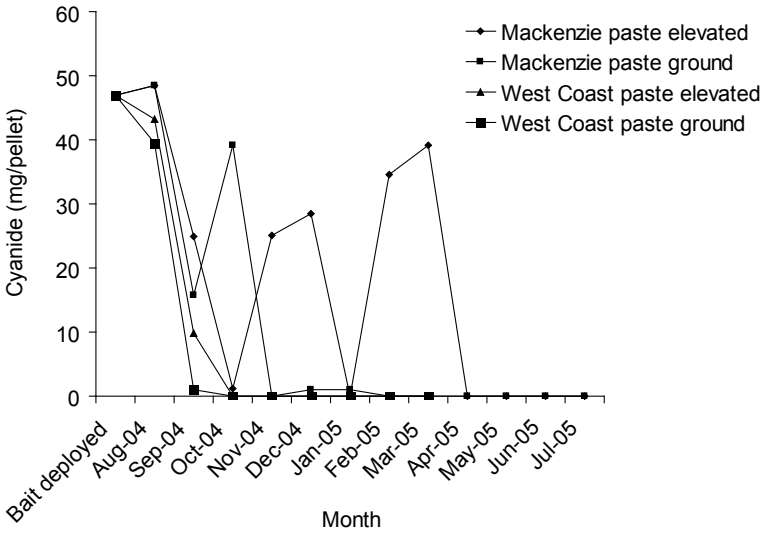

Figure 4. Changes in monthly cyanide concentrations (mg/pellet) in elevated or ground-level Feratox pellets embedded in paste baits exposed to natural weathering at sites in the Mackenzie Basin and West Coast.

TABLE 2. REGRESSION COEFFICIENTS AND LEVELS OF SIGNIFICANCE FOR CYANIDE SAMPLES (n = 12) EXPOSED TO WEATHERING FOR 12 MONTHS AT MACKENZIE BASIN AND WEST COAST SITES IN EITHER PASTE OR BLOCK BAIT FORMULATIONS LOCATED ON THE GROUND OR ELEVATED.

SITE	BAIT TYPE	POSITION	P	REGRESSION COEFFICIENT
Mackenzie	Cyanide block	Elevated	<0.05	–3.85
Mackenzie	Cyanide block	Ground	<0.01	–3.37
Mackenzie	Cyanide paste	Elevated	<0.05	–3.26.
Mackenzie	Cyanide paste	Ground	<0.01	–3.87
West Coast	Cyanide block	Elevated	<0.05	–2.57
West Coast	Cyanide block	Ground	>0.05 n.s.	–1.49
West Coast	Cyanide paste	Elevated	<0.05	–2.95
West Coast	Cyanide paste	Ground	<0.05	–2.66

between study sites ($F = 2.2$, df = 1, 24, $P = 0.14$). This may have been due to the highly variable cyanide concentrations that were collected (see below). Individual decay graphs for cyanide are shown in Appendix 2.

The cyanide samples were commonly found to contain either high cyanide levels or no cyanide. This 'all or nothing' nature of the cyanide samples made statistical analysis difficult because of the variability in the data that it caused. It seems that the breakdown of the Feratox coating occurred inconsistently, but once the pellet coating was ruptured there appeared to be rapid decay of the cyanide contents. Therefore, very few samples had intermediate levels of cyanide recorded. Rupturing times of the coating appeared highly variable regardless of the site, bait formulation or bait placement. Although there were no statistically significant differences in cyanide levels between sites, the graphs suggest that rupturing of the coating (followed by rapid decay of cyanide) is more likely to occur at a faster rate at wet sites.

Wright & Manning (2003) found that exposure to water plays a major role in the breakdown rates of Feratox pellets. They showed that Feratox pellets immersed in water release about 90% of their cyanide after 34 days compared to Feratox pellets immersed in moist soil, which release only about 50% of their cyanide over the same period.

While collecting the samples, rupturing of the Feratox coating could be observed visually in the form of a brown stain on the surface of the Feratox pellet. This staining occurs following the ingress of moisture through the pellet coating and its resulting reaction with the cyanide. Initially, the stain appeared as a small spot; however, it increased in size as the pellet swelled and more moisture entered the pellet. Because laboratory analysis tended to indicate an all or nothing cyanide content, the monthly sampling period appeared to be inadequate to measure the decline once the coating was ruptured. Therefore, in retrospect, we consider that a visual assessment of the pellets rather than a laboratory assessment of the cyanide content would be a cheaper and more practical method of assessing the breakdown of cyanide in Feratox pellets.

We propose that in future studies, a sample of approximately 20 pellets be visually examined for each monthly sampling period instead of undertaking

a laboratory assay of the cyanide content. This will provide larger sample sizes and less variability than the current laboratory method, where the sample size was restricted because of the cost of the chemical analyses. Prior to undertaking such sampling, it would be necessary to conduct a study to determine how quickly the cyanide in the Feratox pellets breaks down once the coating has ruptured when surrounded with media containing different moisture contents. The study should record the percentage of the coating that has a brown stain and calibrate this with an assay of cyanide concentration (mg/pellet).

Overall, it appears that the cyanide in Feratox used in dry sites in New Zealand, such as Central Otago, Mackenzie Basin and parts of Canterbury, is more likely to persist for longer periods than that in Feratox used at wet sites, such as the West Coast, although this was not proven statistically in this study. Also, although we were unable to detect a statistically significant difference in the breakdown rates of Feratox in the paste and block formulations, we consider that Feratox pellets that are enclosed in more water-resistant baits, such as the block formulation, will persist for longer periods than pellets enclosed in paste. Additional studies should be conducted to further test this prediction.

The combined breakdown rates of cyanide calculated using data from both sites, both elevations and both bait types indicated that more than 50% of the cyanide had disappeared after 2 months and more than 80% had disappeared after 8 months (Fig. 5). These results suggest that the Feratox in these bait formulations could reliably provide effective possum control for at least 1 month. However, the inconsistent rate of breakdown of the Feratox coating after 1 month indicates that many baits become ineffective. Also, remnants of cyanide remaining in the pellets could increase the risk of sub-lethal poisoning causing cyanide shyness (Morgan et al. 2001).

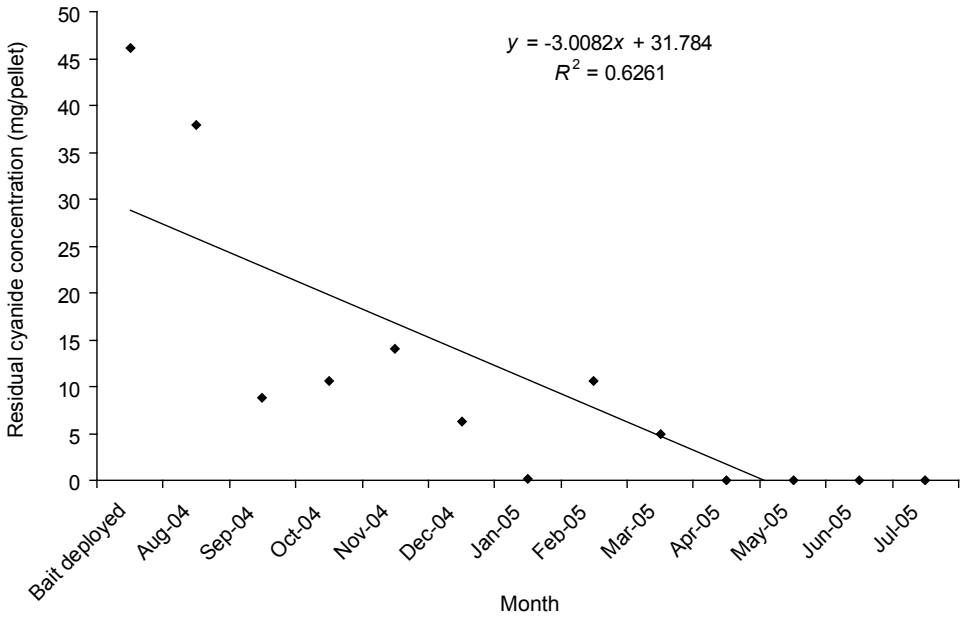

Figure 5. Mean monthly cyanide concentration (mg/pellet) and regression of Feratox pellets (elevated and ground level, embedded in block and paste baits in bait bags at sites in the Mackenzie Basin and West Coast, all combined).

5.1.2 Decline in cholecalciferol concentration

Unlike cyanide, cholecalciferol in the block and paste baits declined in a consistent manner over the 12-month sampling period (Figs 6 & 7, Table 3). The decline of cholecalciferol was significantly greater at the wetter West Coast site than at the drier Mackenzie Basin site ($F = 16.13$, df = 1, 24, $P < 0.005$). Inspection of Figs 6 and 7 indicates what appears to be an anomaly in the data collected for the West Coast site in February 2005, with an uncharacteristically high cholecalciferol content being recorded. The reasons for this anomaly could not be determined.

Analysis of breakdown rates at the individual sites indicated that there was no statistically significant difference at the West Coast site regardless of whether the bait matrices were block or paste, or elevated or on the ground ($F = 2.64$, df = 3, 48, $P = 0.06$). However, at the Mackenzie Basin site, cholecalciferol declined at a significantly faster rate in the paste formulation, regardless of whether it was on the ground ($F = 10.59$, df = 1, 24, $P < 0.005$) or elevated

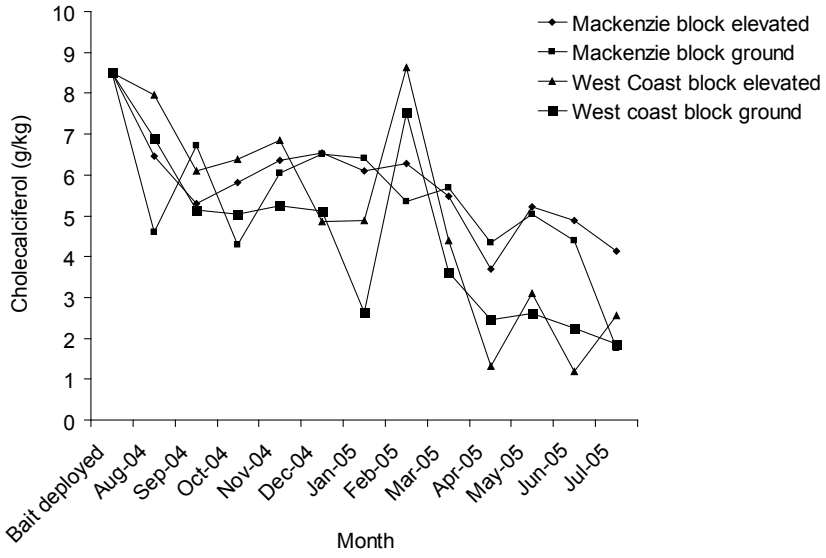

Figure 6. Changes in monthly cholecalciferol concentrations (g/kg) in elevated and ground-level Feracol block baits exposed to natural weathering at sites in the Mackenzie Basin and West Coast.

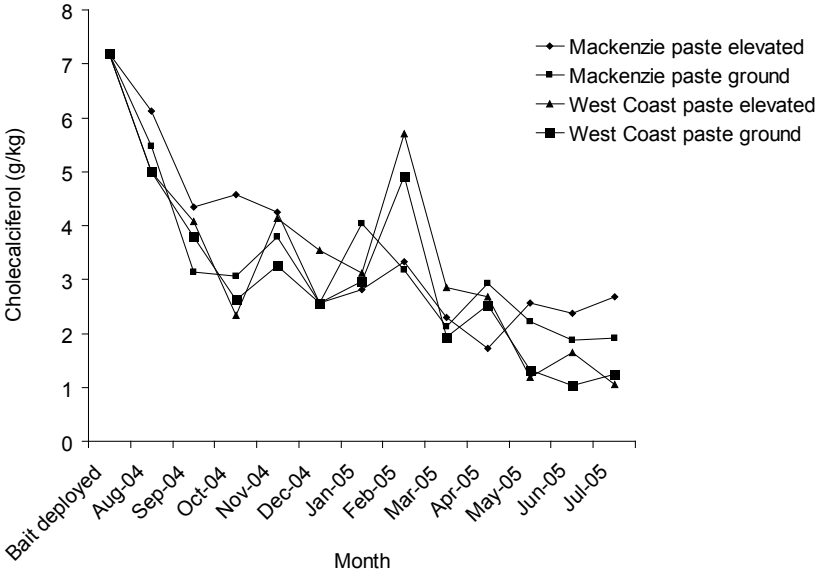

Figure 7. Changes in monthly cholecalciferol concentrations (g/kg) in elevated and ground-level Feracol paste baits exposed to natural weathering at sites in the Mackenzie Basin and West Coast.

TABLE 3. REGRESSION COEFFICIENTS AND LEVELS OF SIGNIFICANCE FOR CHOLECALCIFEROL SAMPLES (n = 12) EXPOSED TO WEATHERING FOR 12 MONTHS AT MACKENZIE BASIN AND WEST COAST SITES IN EITHER PASTE OR BLOCK BAIT FORMULATIONS LOCATED ON THE GROUND OR ELEVATED.

SITE	BAIT TYPE	POSITION	P	REGRESSION COEFFICIENT
Mackenzie	Cholecalciferol block	Elevated	<0.01	–0.23
Mackenzie	Cholecalciferol block	Ground	<0.05	–0.27
Mackenzie	Cholecalciferol paste	Elevated	<0.01	–0.36
Mackenzie	Cholecalciferol paste	Ground	<0.01	–0.31
West Coast	Cholecalciferol block	Elevated	<0.01	–0.54
West Coast	Cholecalciferol block	Ground	<0.01	–0.45
West Coast	Cholecalciferol paste	Elevated	<0.01	–0.35
West Coast	Cholecalciferol paste	Ground	<0.01	–0.36

(F = 14.59, df = 1, 24, P < 0.005). Individual decay graphs for cholecalciferol are shown in Appendix 3.

These results indicate that cholecalciferol concentration is likely to decline more slowly at drier than at wetter sites. Block baits at these drier sites will retain their cholecalciferol content for a longer period than paste baits. The mean breakdown rates of cholecalciferol calculated from data from both sites and both bait types indicate that, overall, the baits retained approximately 50% of their cholecalciferol content after 8 months and about 30% after 11 months (Fig. 8). After 1 month, the cholecalciferol content declined to approximately 6 g/kg or 0.6% wt/wt. Henderson & Morriss (1996) showed that baits containing 0.6% wt/wt of cholecalciferol only achieved a 64% kill of captive possums compared to a 95% kill when using baits containing the registered 0.8% wt/wt concentration. These results suggest that Feracol baits as used in this study are only likely to be effective for possum control in the first month of deployment. Also, the reduction in toxin content could cause bait shyness, as demonstrated by Morgan & Milne (2002), if the baits are used for > 1 month.

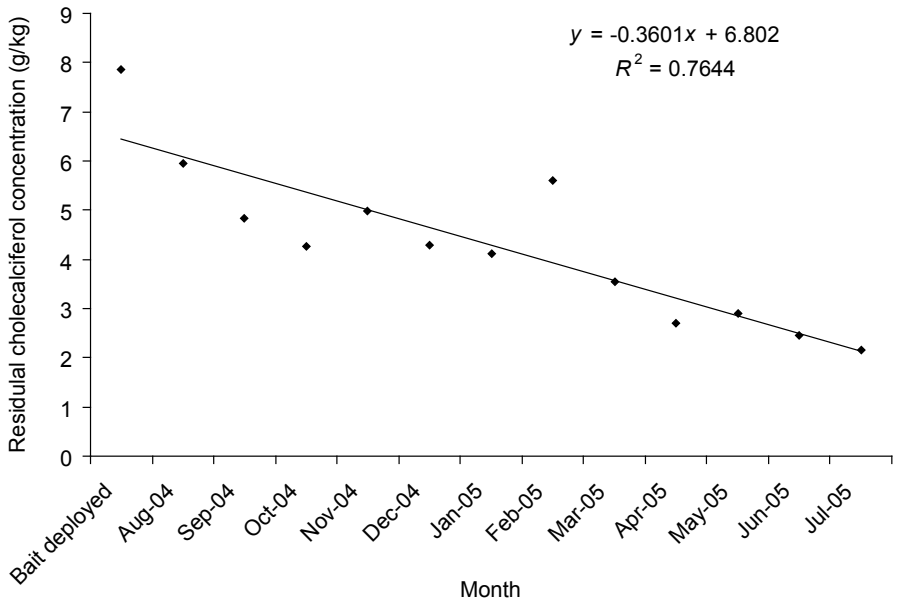

Figure 8. Mean monthly cholecalciferol concentrations and regression in elevated and ground-level Feracol block and paste baits in bait bags at sites in the Mackenzie Basin and West Coast.

5.2 RISKS TO NON-TARGET SPECIES

5.2.1 Feratox

Graphs of residual toxicity and the susceptibility of target and non-target animals from cyanide poisoning with Feratox showed that there is a risk of poisoning non-target species for up to approximately 12–16 months (Fig. 9).

Rats and mice are unlikely to be able to break the Feratox coating; therefore, they would be at low risk of being killed by Feratox baits. However, it is feasible that rats and mice could be killed once the coating has ruptured exposing the cyanide. Mice would require only 0.3% of the cyanide in a Feratox pellet and rats 3% to receive an LD_{50} dose.

Goats and rabbits are about twice as susceptible as possums to cyanide poisoning (Table 1). However, a 36-kg goat would need to eat approximately three Feratox pellets to be at risk of accidental death (Table 1). Domestic livestock are unlikely to be killed by Feratox baits unless they move along a Feratox baiting line and eat a series of baits. Miniature and small dogs could be at risk of accidental death if they eat one Feratox pellet. However, medium-sized dogs and larger are unlikely to die unless they eat more than one Feratox pellet (Table 1, Appendix 1).

Birds, such as the mallard duck, are six times more susceptible than possums to cyanide poisoning (LD_{50} = 1.4 mg/kg c.f. 8.7 mg/kg for the duck and possum respectively). A 1.2-kg duck would need to eat only 1.7 mg (about 3% of a Feratox pellet) of cyanide to exceed the estimated LD_{50}. However, Wiemeyer et al. (1986) recorded considerable variation in the susceptibility of birds to cyanide poisoning, ranging from 4 mg/kg for the American kestrel (*Falco sparverius*) to 21 mg/kg for the domestic chicken (*Gallus domesticus*). They also found that the three flesh-eating birds they examined (American kestrel, black vulture (*Coragyps atratus*; 4.8 mg/kg) and eastern screech-owl (*Otus asio*; 8.6 mg/kg)) were more susceptible to cyanide poisoning than the birds that fed predominantly on plant material (domestic chicken, Japanese quail (*Coturnix japonica*; 9.4 mg/kg) and European starling (*Sturnus vulgaris*; 17 mg/kg)). Despite the differences in susceptibility of these birds to cyanide, all would be at risk of dying if they ate one or more Feratox pellets.

It is likely that New Zealand native birds will fall within the LD_{50} range identified by Wiemeyer et al. (1986), i.e. 4–21 mg/kg. If we assume that the toxicity of cyanide to New Zealand native birds is the same as the bird that he found least susceptible to cyanide poisoning (i.e. 21 mg/kg for the domestic chicken), then all native birds weighing under 2 kg would receive a lethal dose of cyanide if they ate one Feratox pellet. Information from the website www.nzbirds.com/birds/gallery.html (viewed 20 September 2007) indicates that few native birds weigh more than 2 kg, with the exception of the great spotted kiwi (*Apteryx haasti*) and the North Island brown kiwi (*Apteryx australis*). Small native birds, such as an 11-g tomtit (*Petroica macrocephala*), would only need to ingest 0.23 mg of cyanide (< 1% of a Feratox pellet) to exceed an LD_{50} of 21 mg/kg.

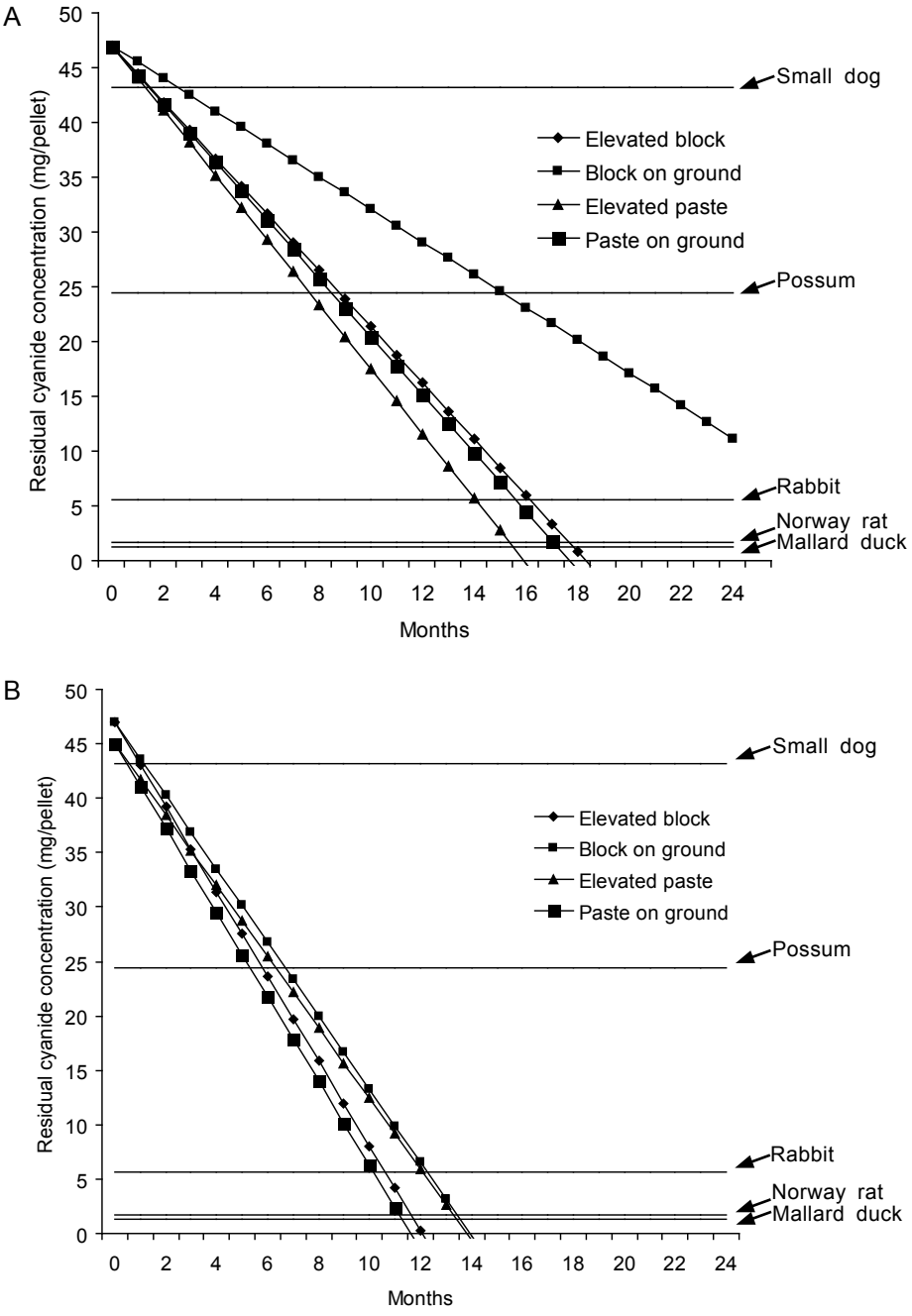

Figure 9. Rates of decline of cyanide content (mg/pellet) in Feratox pellets embedded in paste and block baits, calculated from regression coefficients determined from recorded decay rates. A. West Coast; B. Mackenzie Basin. The amounts of cyanide (mg) required to kill a range of species (calculated from LD_{50} values in Table 1) are plotted as horizontal lines. The period of time (months after application) where cyanide would still constitute an LD_{50} dose for these species is the time to the left of where the horizontal lines intersect the rates of cyanide decline lines.

Since intact coatings on Feratox pellets would be difficult to break, especially for small birds, the risk to small birds is low provided the Feratox coating remains intact. However, this study has shown that the coating will decay, exposing the cyanide to small birds. Larger birds that are capable of swallowing whole Feratox pellets, such as weka (*Gallirallus australis*), probably have only limited ability to break the pellet coating—but swallowed pellets could rupture internally, killing the bird.

Based on the limited information obtained in this study, we conclude that there is a risk of poisoning from Feratox baits for dogs of < 10 kg in weight and native birds (with the exception of those over 2 kg) for up to 1 year after the baits have been deployed in the field. There is likely to be no risk to larger animals, such as sheep, cattle and deer, unless they move along bait lines and eat several baits.

5.2.2 Feracol

The lower variability of the Feracol data allowed more precise estimates of residual and non-target poisoning risks than could be calculated for the Feratox data. Graphs of residual toxicity and the susceptibility of target and non-target animals from cholecalciferol poisoning from Feracol showed that the risk of poisoning non-target species stretched to 14 months for the Mackenzie data and more than 22 months for the Westland data (Fig. 10).

Rats (LD_{50} = 42.5 mg/kg) and mice (LD_{50} = 43.6 mg/kg) are more than 50% less susceptible to cholecalciferol poisoning than possums (LD_{50} = 16.8 mg/kg). Feracol will become even less effective for killing these animals once it has begun to decay because of the reduction in cholecaciferol content. Our estimates indicate that to kill 50% of a test population of possums (with a mean individual weight of 2.8 kg), individual possums would need to eat 6 g of Feracol. This would need to increase to 12 g after 6 months of bait weathering. Similarly, to kill 50% of a test population of rats (mean

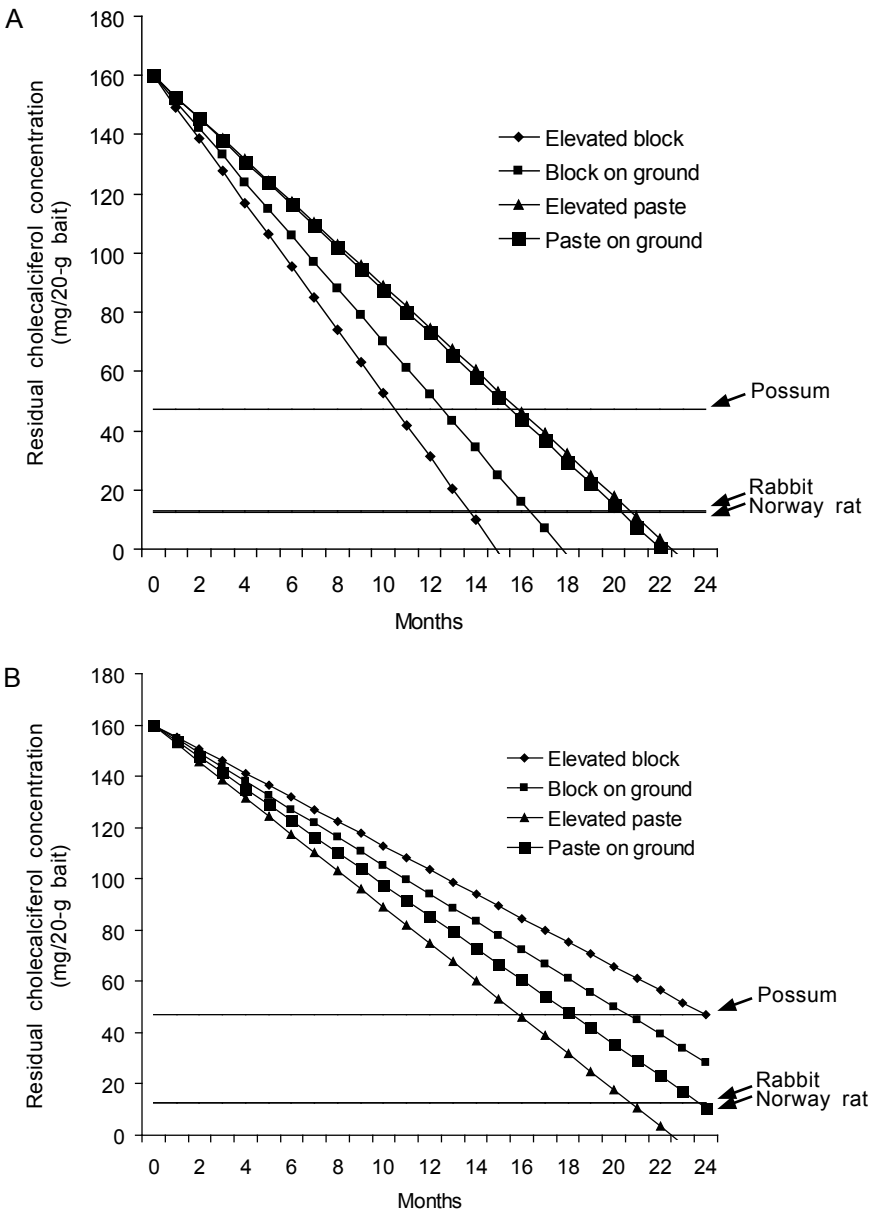

Figure 10. Rates of decline of cholecalciferol content (mg/20-g bait) in 20-g paste and block baits calculated from regression coefficients determined from recorded decay rates. The amounts of cholecalciferol (mg in a 20-g bait) required to kill a range of species (calculated from LD_{50} values in Table 1) are plotted as horizontal lines. The period of time (months after application) where cholecalciferol would still constitute an LD_{50} dose for these species is the time to the left of where the horizontal lines intersect the rates of cholecalciferol decline lines. A. West Coast; B. Mackenzie Basin.

individual weight 200 g), individual rats would need to eat 1.6 g of Feracol or 3.2 g after 6 months of bait weathering.

Dogs are approximately half as susceptible to cholecalciferol poisoning as rats (Table 1). Therefore, to kill 50% of a test population of small (8 kg) dogs (Appendix 1), individuals would need to eat 80 g (four baits) of fresh Feracol bait or 160 g (eight baits) after 6 months of bait weathering. A medium-sized dog of 19 kg (Appendix 1) would need to eat almost ten 20-g baits to receive an LD_{50} dose. However, managers undertaking possum control using baits containing cholecalciferol need to be aware that dogs that are sub-lethally poisoned with cholecalciferol will suffer debilitating effects that are difficult to remedy, such as metastatic mineralisation throughout the body (Talcott et al. 1991).

For birds, a mallard duck weighing 1.2 kg would need to eat 300 g of fresh Feracol bait or 15 20-g baits (about 25% of its body weight). This is unlikely to occur. If we assume that smaller native birds are as susceptible to cholecalciferol poisoning as ducks, then a 10-g bird such as a tomtit or a 20-g robin (*Petroica australis*) would require 2.5 g and 5 g, respectively, of fresh bait to exceed the estimated LD_{50} dose—or up to about 25% of their body weight. However, as various bird species may display different levels of vulnerability to cholecalciferol (Eason & Wickstrom 2001), these estimates need to be treated with caution.

6. Conclusions

The cyanide in Feratox can break down to undetectable levels within 1 month but can also persist for more than 8 months when used in bait bags that are exposed to the weather. The breakdown rate of Feratox is governed by the longevity of its encapsulating coating, which appears to be highly variable. The life of the coating appears to be governed by the amount of moisture present, with faster breakdown rates occurring at higher levels of moisture. Our study could not determine a difference between breakdown rates when using paste or block baits, but it seems likely that water-resistant baits and/or protection from weather will prolong the life of the Feratox pellets.

The cyanide decay data were too variable to determine whether bait position influenced the decay of cyanide in Feratox pellets. A visual examination of the integrity of the coatings for a large sample (> 20 pellets) of Feratox rather than laboratory analysis of a small sample could provide an alternative method for estimating the breakdown rates of Feratox and reduce the variability in the data observed in this study. However, studies would be required to provide a calibration of the visual method against actual cyanide content using laboratory analyses, to determine whether this method can accurately determine cyanide concentration in Feratox.

Our study indicated that cholecalciferol in Feracol decayed at a less variable rate than that recorded for cyanide decay in Feratox. Approximately 25% of

the cholecalciferol content of Feracol baits was removed after 1 month's exposure and approximately 50% after 8 months' exposure to weathering. Cholecalciferol was removed at a faster rate in wet environments regardless of bait formulation. However, in drier climates, more water-resistant bait formulations, such as the block bait, will slow breakdown rates compared to less water-resistant formulations, such as the paste bait. Bait position, i.e. elevated or on the ground, did not influence the decay rates of cholecalciferol in Feracol.

Feratox bait will still have the potential to kill possums for at least 8 months after deployment in the field. The proportion of pellets capable of doing so could not be determined from the results of this study, but is likely to be small. This study indicated that the capability of all Feratox baits used in possum control operations to remain viable (i.e. all are 100% capable of killing possums) is likely to occur for only 1 month. After a month, the ability of the baits to kill possums will progressively decline to zero after 8 months. This characteristic suggests that Feratox is not suitable as a long-life bait.

Feracol bait could remain capable of killing possums 1 year after deployment provided possums ate enough bait for it to be lethal. However, the toxicity of the baits declined by about 20% after 1 month, which is likely to reduce possum kills. This study indicated that the longer the bait is exposed to the weather, the less likely possums are to be killed (and this may increase the risk of bait shyness developing). The study indicated that maximum possum kills are likely to occur within the first 2 weeks of bait deployment, especially in wet climates. As with Feratox, this suggests that Feracol is unsuitable as a long-life bait and should not remain in the field for more than 1 month.

For non-target animals such as dogs and domestic stock, Feratox and Fercol baiting is unlikely to cause deaths. However, managers need to be aware of the debilitating long-term effects that sub-lethal cholecalciferol poisoning can cause. This could have a major impact on the health of animals that have eaten cholecalciferol baits.

Native birds are highly susceptible to cyanide poisoning, but Feratox offers a safer option than using cyanide paste formulations because the cyanide is enclosed within a hard coating that is difficult for birds to break. However, decayed Feratox pellets could pose a cyanide poisoning risk once their pellet coatings are broken. This could occur after less than 1 month's exposure in the field and continue for at least 8 months. There is some evidence that birds such as weka can swallow whole Feratox pellets, which could rupture internally resulting in death (Mehrtens & Gaze 2002).

There is a perception that long-life baits offer cost-effective and sustained possum control with very little labour input over long time periods. However, this option will substantially increase the risk of poisoning non-target species and is more likely to cause bait shyness compared to short-term (< 1 week) poisoning strategies such as 1080 baits used in bait stations (see Thomas et al. 1996), especially if the toxin degrades as observed in this study. Therefore, we conclude that short-term Feratox and Feracol baiting strategies (< 1 month) where unused bait is retrieved will provide high efficacy, low risk of bait shyness and minimise the length of exposure to non-target species.

7. Recommendations

Based on the results of this study, the authors recommend that:

- Managers using Feratox and Feracol in paper bags should be aware that they can remain toxic to target and non-target species for at least 1 year for Feratox and for at least 2 years for Feracol if baits are left in the field.
- To maximise possum kills and minimise the risk of bait shyness and non-target deaths, both Feratox and Feracol baits should be left in the field for no more than 1 month.
- All unused baits should be removed from the field to minimise non-target deaths and to reduce the likelihood of bait shyness developing.
- A study should be undertaken to determine the accuracy of estimating the cyanide content in Feratox using a visual measure of decay on the Feratox coating as an alternative to the more expensive laboratory assay method used in this study.
- Managers should carefully consider the risks associated with the use of long-life baits for possum control.
- Managers need to be aware that sub-lethal poisoning from baits containing cholecalciferol can cause long-term debilitating effects to dogs and domestic stock that are difficult to cure. Therefore, these animals should be excluded from areas where these baits are present.

8. Acknowledgements

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9. References

Akcil, A.; Mudder, T. 2003: Microbial destruction of cyanide waste in gold mining: process review. *Biotechnology Letters 25(6)*: 445–450.

Booth, L.H.; Ogilvie, S.C.; Eason, C.T. 1999: Persistence of sodium monofluoroacetate (1080), pindone, cholecalciferol, and brodifacoum in possum baits under simulated rainfall. *Journal of Agricultural Science and Research 42*: 107–112.

Eason, C.T. 1992: The evaluation of alternative toxins to sodium monofluoroacetate (1080) for possum control. Pp. 348–350 in Borecco, J.E.; Marsh, R.E. (Eds): Proceedings of the 15th Vertebrate Pest Conference, March 3–5 2002, Newport Beach, California. University of California, Davis.

Eason, C.T.; Wickstrom, M. 2001: Vertebrate pesticide toxicology manual (poisons). *Department of Conservation Technical Series 23*. Department of Conservation, Wellington. 122 p.

Gregory, N.G.; Milne, L.M.; Rhodes, A.T.; Littin, K.E.; Wickstrom, M.; Eason, C.T. 1998: Effect of potassium cyanide on behaviour and time to death in possums. *New Zealand Veterinary Journal 46*: 60–64.

Henderson, R.J.; Morriss G.A. 1996: Sub-lethal poisoning of possums with acute pesticides used in bait stations. *Proceedings of the 46th Plant Protection Conference*: 137–142.

Jolly, S.E.; Eason, C.T.; Frampton, C. 1993: Serum calcium levels in response to cholecalciferol and calcium carbonate in the Australian brushtail possum. *Pesticide Biochemistry and Physiology 47(3)*: 159–164.

King, C.M. (Ed.) 1990: The handbook of New Zealand mammals. Oxford University Press, Auckland. 600 p.

Marshall, E.F. 1984: Cholecalciferol: a unique toxicant for rodent control. Pp. 95–98 in Clark, D.O (Ed.): Proceedings of 11th Vertebrate Pest Conference, March 6–8 1984, Sacramento, California. University of California, Davis.

Mehrtens, B.; Gaze, P. 2002: The impact of Feratox on weka. Unpublished report held by Nelson/Marlborough Conservancy Office, Department of Conservation. 4 p.

Moran, R.E. 1998: Cyanide in mining: some observations on the chemistry, toxicity and analysis of mining-related waters. www.zpok.hu/cyanide/baiamare/docs/MoranCyanidePaper0799.rtf (viewed 20 September 2007).

Morgan, D.R. 2004: Enhancing maintenance control of possum populations using long-life baits. *New Zealand Journal of Zoology 31*: 271–282.

Morgan, D.R.; Milne L. 2002: Cholecalciferol-induced bait shyness in possums (*Trichosurus vulpecula*). *International Journal of Pest Management 48(2)*: 113–119.

Morgan, D.R.; Milne, L.; O'Conner, C.; Ruscoe, W.A. 2001: Bait shyness in possums induced by sub-lethal doses of cyanide paste. *International Journal of Pest Management 47(4)*: 227–284.

Morgan, D.R.; Rhodes, A.T. 2000a: Feracol paste bait for possum control—a cage trial. *New Zealand Plant Protection 53*: 305–309.

Morgan, D.R.; Rhodes, A.T. 2000b: Selectivity of Ferafeed paste bait treated with a rodent repellent—a cage trial. *New Zealand Plant Protection 53*: 316–320.

Sterner, R.T. 1979: Effects of sodium cyanide and diphacinone in coyotes (*Canis latrans*): applications as predacides in livestock toxic collars. *Bulletin of Environmental Contaminants and Toxicology 23*: 211–217.

Talcott, P.A.; Mather, G.G.; Kowitz, E.H. 1991: Accidental ingestion of a cholecalciferol-containing rodent bait in a dog. *Veterinary and Human Toxicology 33(3)*: 252–256.

Thomas, M. 2005: Feratox and Feracol as alternatives to brodifacoum for possum control. *DOC Science Internal Series 200*. Department of Conservation, Wellington. 24 p.

Thomas, M.D.; Henderson, R.J.; Hickling, G.J. 1996: Optimising the use of bait stations for possum control. Pp. 65–69 in Wright, D.E. (Ed.): Proceedings of a workshop on improving conventional control of possums. *Royal Society of New Zealand Miscellaneous Series 33.* Royal Society of New Zealand, Wellington.

Thomas, M.D.; Maddigan, F.W.; Brown J.A.; Trotter M. 2003: Optimising possum control using encapsulated cyanide (Feratox). *New Zealand Plant Protection 56*: 77–80.

Warburton, B.; Drew, K.W. 1994: Extent and nature of cyanide-shyness in some populations of Australian brushtail possums in New Zealand. *Wildlife Research 21*: 599–605.

Wickstrom, M.L.; Henderson, R.J.; Eason, C.T. 1997: Alternatives to 1080 for possums (July 1994–July 1996). Landcare Research Contract Report LC9697/79 (unpublished). 26 p.

Wiemeyer, S.N.; Hill, E.F.; Carpenter, J.W.; Krynitsky, A.J. 1986: Acute oral toxicity of sodium cyanide in birds. *Journal of Wildlife Diseases 22(4)*: 538–546.

Wright, G.; Manning, L.A. 2003: Cyanide residues in soil and water. Landcare Research Contract Report LC0203/38 (unpublished).

Appendix 1

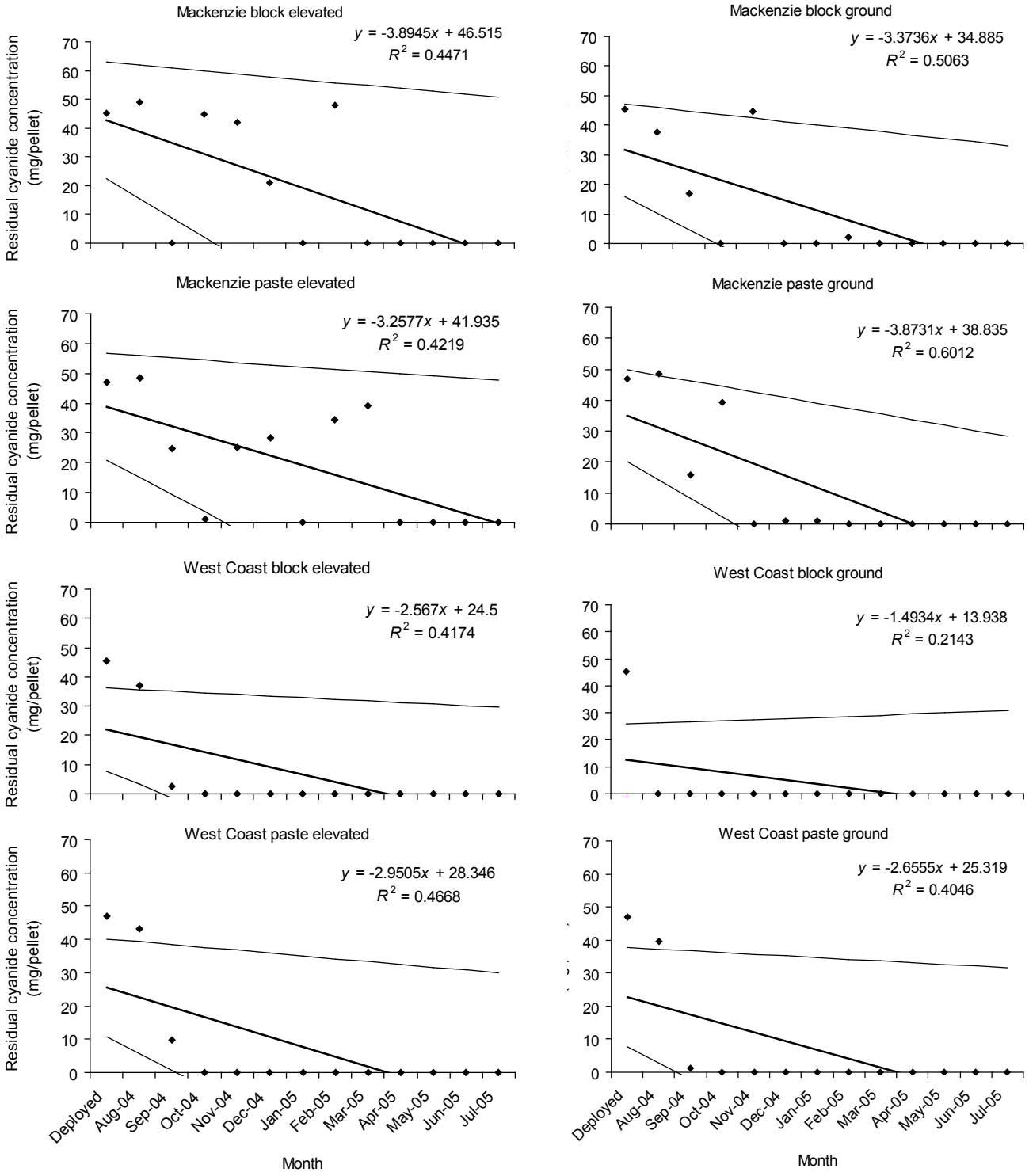
WEIGHT CATEGORIES FOR DOGS AND ASSOCIATED REPRESENTATIVE BREEDS

CATEGORY	WEIGHT (kg)	REPRESENTATIVE BREEDS
Minature	2–5	Chihuahua, Maltese, Pekinese, Poodle (toy), Yorkshire
Small	5–11	Dachshund, Jack Russell Terrier, Pug, Poodle (miniature), Scottish Terrier, Fox Terrier
Medium	11–27	Airedale, Cocker Spaniel, Bassett Hound, Beagle, Border Collie, Whippet, Welsh Corgi, Staffordshire Bull Terrier
Large	27–36	Afgan, Airedale, Boxer, Bull Terrier, Bulldog, Collie, Doberman, English Setter, German Shepherd, Greyhound, Labrador, Irish Setter, English Sheepdog, Weimaraner
Very large	36–70	Bloodhound, Bullmastiff, Great Dane, Rhodesian Ridgeback, Rottweiller, Saint Bernard, Scottish Deerhound

Appendix 2

CYANIDE BREAKDOWN IN FERATOX BAITS

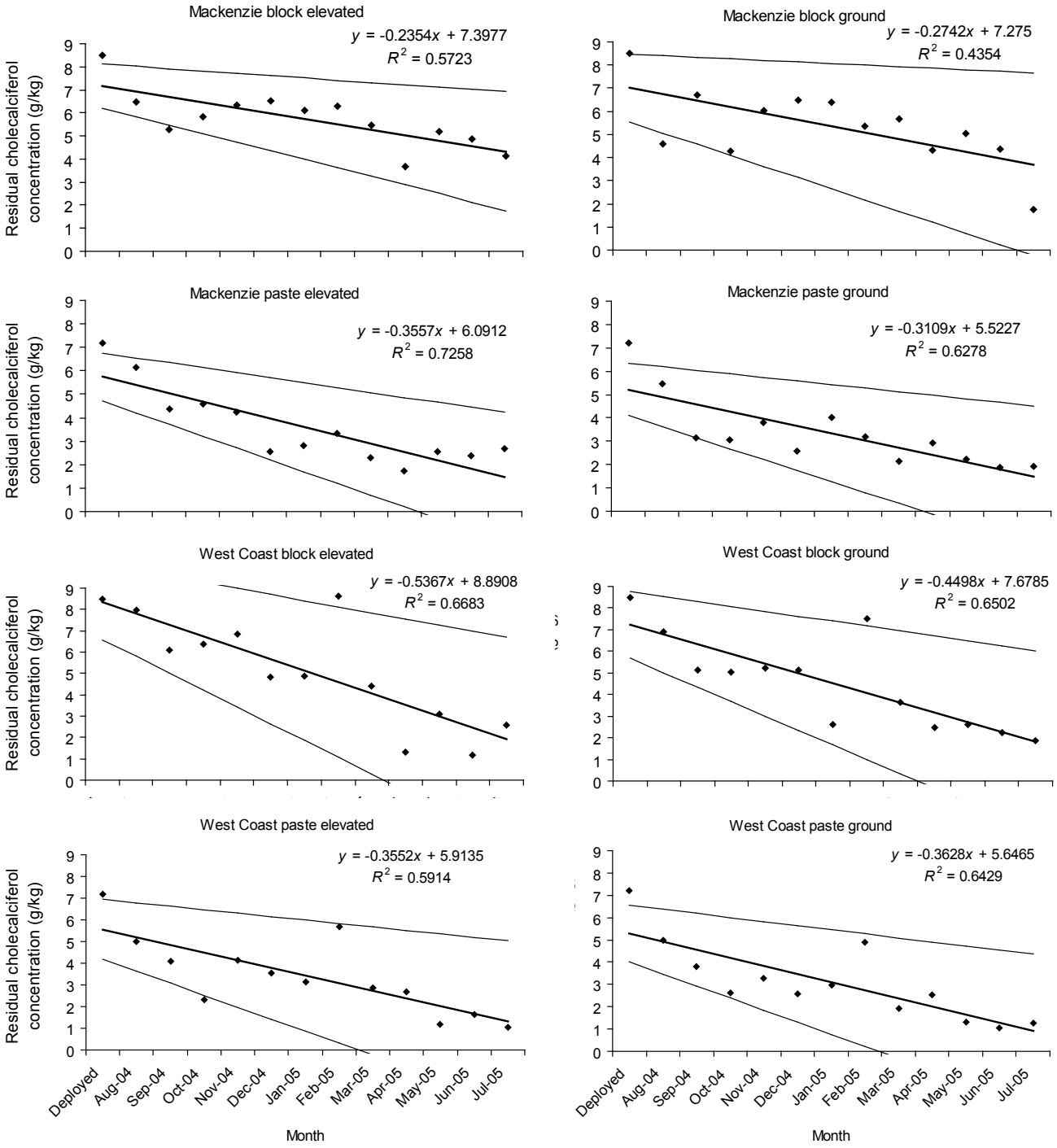
Cyanide breakdown in elevated and ground-level Feratox block and paste baits located at Mackenzie Basin and West Coast study sites. The linear relationship and 95% confidence intervals are also shown.



Appendix 3

CHOLECALCIFEROL BREAKDOWN IN FERACOL BAITS

Cholecalciferol breakdown in elevated and ground-level Feracol block and paste baits at Mackenzie Basin and West Coast study sites. The linear relationship and 95% confidence intervals are also shown.



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