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The development of a toxic 1080 bait, Pro-bait, for fox (*Vulpes vulpes*) control in Western Australia

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ABSTRACT

The *Western Shield* fauna recovery program delivers fox (*Vulpes vulpes*) baits containing 1080 (sodium fluoroacetate) to approximately 3.4 million ha at least four times each year. Originally dried meat baits (DMB) produced by the Department of Agriculture and Food Western Australia (DAFWA) were used but in 1998 the Department of Parks and Wildlife (then Conservation and Land Management [CALM]) developed a new fox bait, Pro-bait, to reduce baiting costs. Pro-baits needed to have similar uptake by foxes and field longevity to DMBs if they were to achieve comparable levels of control. These characteristics were tested between 1999 and 2004 in an experiment that had four phases. In the first phase, uptake of Pro-baits and DMBs by foxes was compared in a field trial and foxes were observed to be 11% less likely to ingest Pro-baits than DMBs (n = 178). This was postulated to be due either to bait damage by invertebrates or to lower Pro-bait acceptability. In Phase 2, invertebrate damage to six bait types (standard Pro-baits, a Pro-bait with added invertebrate repellent Coopex®, a hard Pro-bait, a hard Pro-bait with added Coopex®, DMBs and Foxoff baits) was compared at four sites, and DMBs suffered the most damage. To increase the acceptability of Pro-baits, fox uptake of six flavour enhancers (hexylamine, ethyl caproate, monosodium glutamate or commercial beef, chicken and honey flavours) was examined during Phase 3, and the chicken flavour was most favoured. Accordingly, in Phase 4, the chicken flavour was added to the Pro-bait recipe and field uptake by foxes of DMBs and reformulated Pro-baits was compared. The uptake of both bait types was 87% (n = 104). Collectively, these trials demonstrated that Pro-baits are as efficacious as DMBs in controlling foxes in Western Australia. Pro-baits were registered for use in Western Australia by the Australian Pesticides and Veterinary Medicines Authority (APVMA) in 2002. In late 2005, the Department's Corporate Executive officially endorsed the use of Pro-baits for use in *Western Shield* fox control operations.

Keywords: bait development, fox, introduced predator control, *Vulpes vulpes,* 1080

INTRODUCTION

The rate of mammalian extinction and decline in Australia is higher than that of any other country (Short & Smith 1994). Many of these faunal declines occurred after European foxes (*Vulpes vulpes*) were introduced into Victoria in the mid–late 19th century and as they colonised much of southern half of the continent (Abbott 2011). There is considerable anecdotal and circumstantial evidence to suggest that fox predation was a major factor in the declines and this has been recognised nationally as a key threatening process (Department of Environment, Water, Heritage and the Arts 2008). Foxes can be controlled through the regular delivery of meat baits containing the poison 1080 (sodium fluoroacetate; Saunders & McLeod 2007). The use of this poison is very appropriate because introduced predators such as foxes and cats are highly sensitive to it, whereas many species of native fauna have a natural tolerance to it, especially in south-west Western Australia (King et al. 1981). 1080 baiting is currently used in several large-scale and numerous smaller-scale fox-control programs throughout Australia for both conservation and agricultural purposes (Saunders & McLeod 2007; Robley et al. 2014).

Fox control commenced in several small Wheatbelt reserves in Western Australia in the 1980s (Kinnear et al. 2002) and this resulted in the recovery of a number of species of mammals including numbats (*Myrmecobius fasciatus*; Friend 1990) and rock wallabies (*Petrogale*

lateralis; Kinnear et al. 1988, 1998). In 1996 the area in which fox control was undertaken was expanded to approximately 3.5 million ha when the Department of Parks and Wildlife (then the Department of Conservation and Land Management [CALM]) initiated its *Western Shield* fauna recovery program (Possingham et al. 2004). This program relies on the repeated delivery of 1080 meat baits at least four times (Armstrong 2004), and ideally six times (de Tores & Marlow 2012), per year to be effective. Baiting to control foxes in Western Australia has been so successful that three species, the woylie (*Bettongia penicillata*), the tammar wallaby (*Macropus eugenii*) and the quenda (or southern brown bandicoot, *Isoodon obesulus*), were removed from the state's threatened species list (Mawson 2004).

The fox bait used in Western Australia during these fauna recoveries was the dried meat bait (DMB), manufactured by Department of Agriculture and Food Western Australia (DAFWA). DMBs are made from a single piece of kangaroo meat and are highly attractive and palatable to foxes (Thomson & Algar 2000). Given the quantity of baits used each year in the *Western Shield* fauna recovery programme, replacing the relatively expensive DMB with a more economical alternative was thought likely to yield significant savings in delivering the program (Armstrong 2004). In 1998, CALM decided to reduce the program's baiting costs by developing a new sausage-style fox bait, Pro-bait, based on a salami manufacturing process (Armstrong 2004). The advantages of this development were an automated process, large economically effective production runs, minimal wastage and improved shelf-life of baits. The uniform shape and size of the new bait type also improved packaging efficiency and reduced transport and storage costs (Armstrong 2004).

Before the highly successful DMB could be replaced operationally with Pro-baits, the new bait type had to be shown to be as effective at controlling foxes. It was essential that Pro-baits were equally attractive to foxes in the field so that they would be found and ingested, and similar levels of control attained. Pro-baits needed to be highly palatable so that foxes would consume them readily and not cache them (van Polanen Petel et al. 2001). Pro-baits also needed to have similar field longevity characteristics to those of DMBs. In the field, baits may deteriorate if they are damaged by invertebrates or if they are exposed to soil moisture or rain (McIlroy et al. 1988; Twigg et al. 2000; Twigg & Socha 2001). DMBs are able to withstand some invertebrate damage and weathering because they are partially dried during manufacture and develop a protective outer skin or crust (Thomson1986; Kinnear et al. 2010). Pro-baits required a similar or greater capacity to withstand damage because if they deteriorated more rapidly than DMBs foxes may not have time to find them, and thus their efficacy in controlling foxes would be reduced.

Before Pro-baits could be used operationally their risk to non-target species had to be assessed to ensure that baits delivered to control foxes did not detrimentally impact the populations of threatened species they were intended to protect. Although many non-target species are tolerant to 1080 (King et al. 1981), smaller animals may be susceptible to poisoning if they consume a bait containing sufficient 1080 to kill a 5–8 kg fox. The hard crust on DMBs decreases the ability of smaller, non-target species to chew on the bait, thus reducing the ingestion of bait material and 1080 (Calver et al. 1989). Pro-baits would need to be similarly resistant if they were to withstand chewing by non-target species.

METHODS

Bait manufacture

Pro-baits are sausage baits that contain 70% minced kangaroo meat, 20% animal fat (pork or chicken) and 10% canine 'digest' (a commercial flavour enhancer for dog food). A salami-style binder is added to this mixture to promote hardening of the final product so that weathering and the risk of non-target consumption of the bait is reduced. When manufactured, individual Pro-baits weigh approximately 80–85 g and they are then heated to between 30–40 °C to promote uniform shrinkage during the drying process. Baits are dried to approximately 40 g before delivery to the field (Armstrong 2004). Pro-baits are manufactured in a purpose-built factory that was constructed at Harvey WA (Armstrong 2004).

Phase 1: An initial comparison of the field uptake of Pro-bait and DMB by foxes

The acceptability of Pro-baits to foxes was examined by comparing the relative uptake of Pro-baits and DMBs at two sites in the semi-arid zone of WA. The study sites were Wagga Wagga Station, a pastoral lease in the Yalgoo region, and Burnabinmah Station, a former pastoral lease that is now conservation estate in the Paynes Find region (Fig. 1).

The two bait types were labelled with different biomarkers so that foxes ingesting either bait could be identified. The biomarkers iophenoxic acid (IPA; Sigma-Aldrich, Castle Hill NSW) and tetracycline HCl (Sigma-Aldrich, Castle Hill NSW) were used. IPA raises blood iodine levels and its ingestion can be detected by analysing a blood sample (Saunders et al. 1993). If the blood iodine level present in a fox was above a prescribed background level it was assumed that an individual had ingested a bait. IPA was added to baits as a solution prepared by dissolving IPA crystals in 100% alcohol. A 0.6 ml aliquot of the solution contained 20 mg of IPA, and this volume was added to each bait using a standard dosing gun. After dosing, the baits were kept upright as they dried and the IPA remained in the baits as they cured. Tetracycline produces a characteristic fluorescent ring in the canine teeth of foxes that ingest it (Johnston et al. 1987). Tetracycline was added to baits as a powder using a modified syringe to insert 150 mg of tetracycline powder into a 2 mm diameter hole that had been drilled into the side of each bait with an electric drill. To ensure that

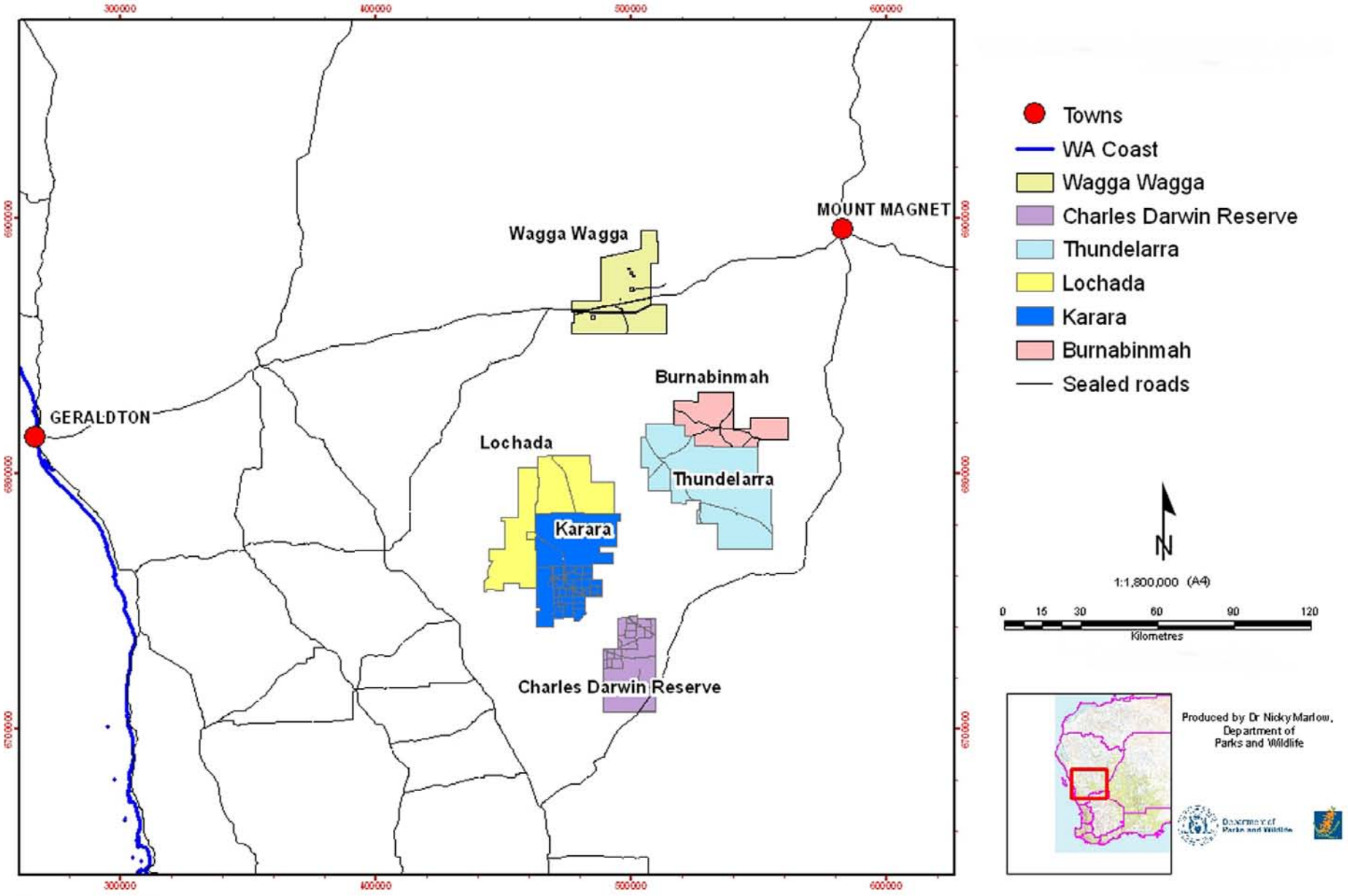

Figure 1. Map of the bait development study sites.

tetracycline was an effective biomarker, a sample of seven captive foxes were fed non-toxic tetracycline labelled baits. These foxes were euthanased with cyanide 16 days after they had ingested a bait. Very thin sections of each of the fox's canine teeth were produced using an Isomet saw. These sections were examined under a microscope using ultraviolet light (450 nm) to reveal the presence of fluorescent rings that indicated bait consumption. Examination of the teeth of all foxes detected tetracycline rings.

Non-toxic Pro-baits and DMBs labelled with biomarkers were aerially delivered to both study sites at the standard baiting rate of 5 baits km^{-2} (i.e. a combined total of 10 baits km^{-2} were laid) with the expectation that 80–95% of foxes would ingest baits (Thomson & Algar 2000; Thomson et al. 2000). On Burnabinmah Station, DMBs were labelled with IPA and Pro-baits were labelled with tetracycline. To avoid any potential influence of the biomarker on bait uptake, the biomarkers were interchanged for the subsequent trial on Wagga Wagga station (i.e. Pro-baits were labelled with IPA and DMBs were labelled with tetracycline). The non-toxic baits were delivered to both sites on 15 October 1999. An area of approximately 200 km^{-2} was baited on each station and the position of the plane on the baiting transects when the baits were dropped was recorded using a GPS (model GPS76; Garmin Corporation, Kansas USA). Transects were approximately 1 km apart.

Foxes were given sufficient time to find and ingest baits (Dexter & Meek 1998; Thomson et al. 2000) and were then killed six to seven weeks after bait delivery using cyanide (Algar & Kinnear 1990). Cyanide baiting involved the placement of two wax capsules containing 1 g sodium cyanide at 200 m intervals along transects within the study site. Capsules were covered with a condensed milk/icing sugar lure. Foxes died at, or very close to, the site at which they had bitten a cyanide capsule and it was relatively easy to collect the carcasses. Cyanide transects of up to 20 km in length were positioned each night. Fox carcasses were retrieved early the following day and a blood sample and all canine teeth were collected from each fox. Blood samples were not centrifuged because they had been obtained from foxes that had been dead for up to 12 hours. Samples were stored frozen. The iodine concentration of the whole blood sample was obtained using the method described by Saunders et al. (1993). Hot perchloric acid was used to release the protein-bound iodine and in that process the iodine was oxidised to iodide, which catalysed a caesium-arsenic redox reaction. The change in absorbance (measured at 420 nm) was proportional to the iodide and consequently the total iodine concentration. Samples with concentrations higher than the standard ranges were diluted with deionised water and re-run. The background level iodine concentration of foxes for the study area was estimated from four foxes that were killed with cyanide just prior to bait delivery on 15 October 1999. An iodine concentration of more than three standard deviations above the mean value for the 'control' foxes was concluded to indicate that a fox had ingested a bait. The uptake of the two biomarkers, and hence the ingestion of the two bait types, was compared using chi-squared contingency tests.

Phase 2: The comparative testing of the field longevity of Pro-bait and DMB

A trial to compare the field longevity of standard Pro-baits and DMBs was conducted to assess whether decreased Pro-bait durability had resulted in the lower uptake of this bait type by foxes during the initial comparison in Phase 1. The longevity of four other bait types was also investigated: a Pro-bait with added invertebrate deterrent Coopex®; a Pro-bait dried to a hard consistency (drying continued until daily weight loss did not exceed 1% of bait weight); a hard Pro-bait with added Coopex®; and a commercially available fox bait (Foxoff; Staples et al. 1995). Non-toxic samples of each bait type were placed in exclosures to prevent non-target removal and were monitored at four sites with different mean annual rainfalls: Collie (200 km south-east of Perth, rainfall 940 mm), Kalgoorlie (600 km east-north-east of Perth, rainfall 265 mm), Manjimup (300 km south of Perth, rainfall 1010 mm) and Narrogin (190 km south-east of Perth, rainfall 500 mm). Baits were weighed to the nearest 0.1 g before being placed in exclosures on 14 February 2003. A random sample of four baits of each of the six types was collected after 1 day, 4 days, 7 days, and then weekly for 10 weeks. Baits were reweighed after collection and the proportion of each bait removed by invertebrates was calculated. The amount of each bait type removed by invertebrates in all sites for each time frame was averaged. A more detailed investigation of the site-related removal of DMBs during each time frame was undertaken using a two-way ANOVA. This analysis was repeated for the standard Pro-bait. The extent of invertebrate damage to Pro-baits within each time-frame was then compared with that of each of the other bait types using a series of two-way ANOVAS.

Phase 3: A field comparison of the uptake by foxes of six flavour enhancers

A variety of flavour enhancers was tested to determine if foxes showed any preferences. The preferred flavour could then be incorporated into Pro-baits to increase uptake. Six flavour enhancers were trialled: hexylamine (which smells like rotting meat), ethyl caproate (which smells like matured cheese), monosodium glutamate, a commercial beef flavour (Springarom beef juice #220, Magnum Essence Pty Ltd, Osborne Park WA), a commercial chicken flavour (50% Springarom chicken #221, Magnum Essence Pty Ltd, Osborne Park WA and 50% Chicken booster #9502 New Foods Coatings Pty. Ltd, Wetherill Park NSW), and a commercial honey flavour (Honey #576, Magnum Essence Pty Ltd, Osborne Park WA). Fox preferences for the flavours were compared by incorporating them into a lure placed on cyanide capsules. The lure was made from a puree of Pro-bait ingredients, minus any binder, plus the flavour enhancer (10 g kg^{-1}). Two capsules were placed at each cyanide station, one with

a test lure and the other with a standard condensed milk and icing sugar lure. The lure on the cyanide capsule which killed the fox was assumed to be more appealing. If no fox was killed a preference was assumed if only one lure was removed. If both lures were removed no preference could be assigned. These trials were undertaken between 25 August to 5 September 2003 at Karara and Thundelarra stations in the pastoral area of WA where no recent fox control had been undertaken (Fig. 1). Standard cyanide transects were run each night with 100 bait stations per 20 km of transect. On each night only one test lure was compared with the standard lure. The order of lure testing was assigned randomly.

Phase 4: A field trial to compare the uptake of DMB and reformulated Pro-bait by foxes

After the preferred flavour enhancer had been identified in Phase 3 it was then added to Pro-baits (10 g kg^{-1}) in an attempt to increase their uptake to equal that of DMBs. The relative field uptake by foxes of the reformulated Pro-bait was then compared with that of DMBs at two sites in the semi-arid zone of WA: Lochada Station and Charles Darwin Reserve (CDR; Fig.1). Both bait types were aerially delivered to both study sites on 26 February 2004 at the standard baiting rate of 5 baits km^{-2} (i.e. a combined total of 10 baits km^{-2} were laid). An area of approximately 400 km^{-2} was baited at each site using the same methods as described above. Foxes were baited with cyanide at both sites six weeks later (13–23 March 2004) and their carcasses retrieved. On CDR, DMBs were labelled with IPA and Pro-baits with tetracycline. On Lochada Station, Pro-baits were labelled with IPA and DMBs with tetracycline. No recent fox control had been undertaken at either site.

To determine uptake of IPA-labelled baits, a further calculation of the mean background iodine concentration in the blood of foxes was made. Four foxes were killed with cyanide on CDR on 26 February 2004, just before the labelled baits were delivered. The IPA results obtained from these individuals were combined with those obtained during the 1999 trial.

RESULTS

Phase 1: An initial comparison of the field uptake of Pro-bait and DMB by foxes

Fifty-eight foxes were obtained from Burnabinmah Station and 78 from Wagga Wagga Station. The four foxes sampled for background iodine concentration in the study site before the baiting trials commenced had a mean blood iodine concentration of 13.1 ug L^{-1} (SD = 10.2). Foxes in the treatment samples that had a blood iodine concentration of more than 43.7 ug L^{-1} (i.e. mean + 3 SD) were determined to have ingested a bait. Three standard deviations greater than the mean (instead of two) were used because there were very few samples, and it was concluded that a Type II error was preferable to a Type I error (i.e. it was preferable to assume that too few foxes had ingested baits than to assume too many had). The concentration of iodine in the blood samples ranged from 0.36 to 24,959 ug L^{-1}.

The proportion of foxes that consumed each bait type within the study sites was not significantly different. At Burnabinmah, 81% of foxes ingested Pro-baits and 88% ingested DMBs, whereas at Wagga Wagga, 64% of foxes ingested Pro-baits and 78% ingested DMBs. However, when data were pooled across sites, the uptake of DMBs was significantly greater (82% compared with 71% for Pro-baits; $X^2 = 4.65$; $p < 0.05$).

Phase 2: The comparative testing of the field longevity of Pro-bait and DMB

Of all the bait types tested, DMBs suffered most from invertebrate damage (Fig. 2) and this increased at sites with higher rainfall ($F_{3,191} = 55.0$, $p < 0.001$). In contrast, there were no significant differences in invertebrate damage to the standard Pro-baits between sites. Also, Pro-baits were consumed significantly less by invertebrates than DMBs ($F_{1, 383} = 59.8$, $p < 0.001$). The addition of Coopex® to Pro-baits significantly decreased invertebrate damage, and both the standard Pro-bait with Coopex® ($F_{1, 383} = 19.9$, $p < 0.001$) and the hard Pro-bait with Coopex® ($F_{1, 383} = 20.4$, $p < 0.001$) withstood invertebrate damage significantly more than the standard Pro-bait. However, increasing bait hardness did not increase longevity and there was no significant difference in invertebrate damage between the standard Pro-bait and the hard Pro-bait. Foxoff baits sustained less invertebrate damage when compared with the standard Pro-bait during the first 11 monitoring periods ($F_{1, 351} = 9.9$, $p < 0.01$) but most Foxoff baits had either completely disintegrated or had deteriorated into an amorphous mass by the final monitoring period.

The invertebrate species responsible for the damage to baits varied between the four sites. At Collie and Manjimup most damage was done by beetle larvae (*Dermestes* spp.) and there were also dipteran eggs within the baits. The removal of bait material at Kalgoorlie and Narrogin was primarily caused by meat ants (*Iridomyrmex purpureus* and *I. chasei* respectively).

Phase 3: A field comparison of the uptake by foxes of six flavour enhancers

The carcasses of 38 foxes were recovered from Karara Station and 37 from Thundelarra Station. Whether the lure on the capsule these foxes had bitten contained the flavour enhancer or was the control was recorded (Table 1). When foxes removed only one lure from a pair of cyanide capsules, their preference for the flavoured or the control lure was assigned. This occurred on 110 occasions on Karara station and on 49 occasions on Thundelarra station. The only enhancer for which foxes had any significant preference was the chicken flavour (Table 1). In contrast, the flavours ethyl caproate and hexylamine were significantly avoided.

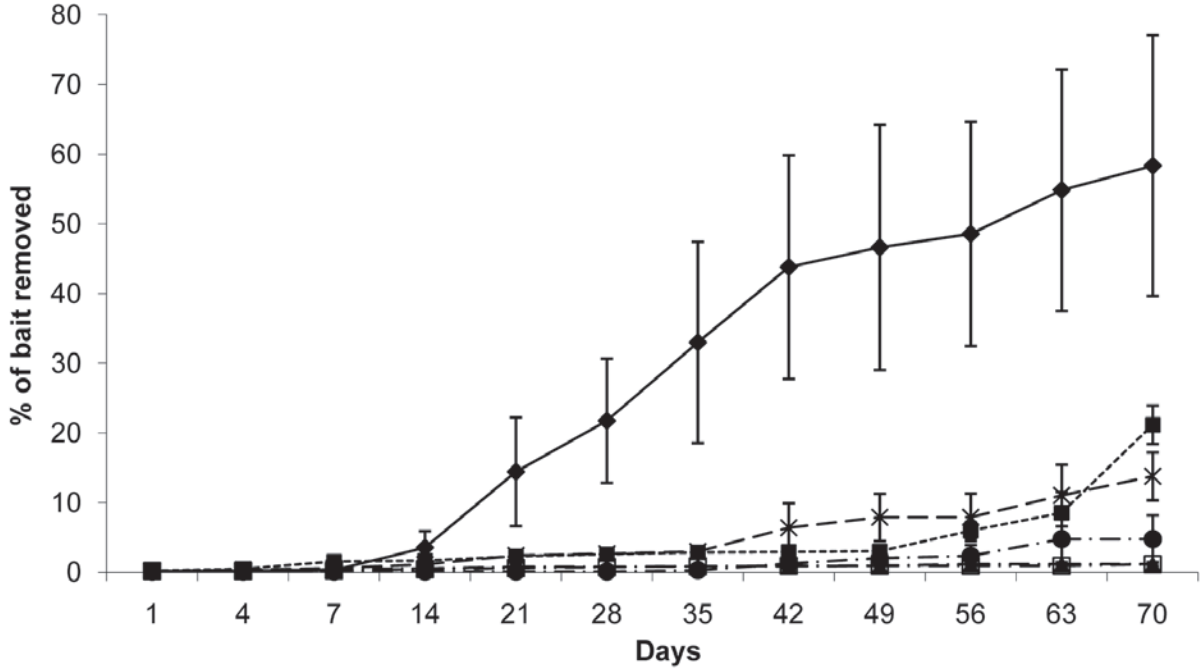

Figure 2. Mean (± SE) proportion (%) of six bait types removed by invertebrates at four sites: Collie, Kalgoorlie, Manjimup and Narrogin. Diamond = DMB; filled square = standard Pro-bait; triangle = Pro-bait with added Coopex; cross = hard Pro-bait; open square = hard Pro-bait with added Coopex; circle = Foxoff bait.

Table 1

Preferences shown by foxes for six flavoured versus control lures at Karara station (KS) and Thundelarra station (TS). Fox = the lure type on the cyanide capsule that killed a fox; Single = the lure type removed from one of a pair of cyanide capsules (if both lures were removed no preference could be assigned); n. s. = not significant.

			Beef	Chicken	Ethyl caproate	Hexylamine	Honey	MSG
KS	Fox	Flavour	1	7	2	0	2	6
		Control	1	1	6	5	0	7
	Single	Flavour	5	12	6	5	3	10
		Control	12	2	17	24	5	9
	Total	Flavour	6/19	19/22	8/31	5/34	5/10	16/32
		Control	13/19	3/22	23/31	29/34	5/10	16/32
TS	Fox	Flavour	1	2	0	0	2	1
		Control	3	2	5	17	2	2
	Single	Flavour	0	3	4	2	2	0
		Control	0	0	6	27	4	1
	Total	Flavour	1/4	5/7	4/15	2/46	4/10	1/4
		Control	3/4	2/7	11/15	44/46	6/10	3/4
Total		Flavour	7/23	24/29	12/46	7/80	9/20	17/36
		Control	16/23	5/29	34/46	73/80	11/20	19/36
χ^2			1.83	6.97	5.58	32.81	0.1	0.06
p			n. s.	$p<0.01$	$p<0.05$	$p<0.001$	n. s.	n. s.

Phase 4: A field trial to compare the uptake of DMB and reformulated Pro-bait by foxes

When the background IPA results obtained from the four foxes sampled at CDR were combined with those obtained during the 1999 trial, a mean background iodine level for the eight foxes was 23.7 ug L^{-1} (SD = 24.4). Therefore, any fox with a blood iodine level above 72.5 ug L^{-1} (i.e. mean + 2 SD) was concluded to have ingested an IPA-labelled bait. This value is slightly lower than that used by Fleming (1997; 168–1717 ug L^{-1}).

Fifty fox carcasses were collected from Lochada station and 54 from CDR. A blood sample was not obtained from two foxes recovered from Lochada station and one fox from CDR because their blood had coagulated

overnight. The teeth of one fox from CDR were either missing or rotten and so no sample could be collected.

At CDR, 46 of the 53 foxes ingested a DMB and 48 foxes ingested a Pro-bait ($X^2 = 0.38$). At Lochada, 44 of the 50 foxes recovered ingested a DMB and 40 of 48 foxes ingested a Pro-bait ($X^2 = 0.44$). There were no significant differences between uptake of the different baits at either site or when the data from both sites were pooled. Foxes ingested 87% of both bait types.

DISCUSSION

The uptake of Pro-baits was significantly lower than that of DMBs in Phase 1 of the experiment and this was attributed to a possible difference in field longevity between the two bait types. Pro-baits, which are made of minced meat (Armstrong 2004), were suggested to be more prone to invertebrate damage or weathering than DMBs, which are made from a single piece of kangaroo meat (Thomson & Algar 2000). During Phase 1, Pro-baits at Wagga Wagga station had the lower rate of uptake and this was postulated to have been caused by the higher rainfall at this site during the experiment. However, the results of the bait longevity trial in Phase 2 showed that Pro-baits were able to withstand invertebrate damage significantly better than DMBs, irrespective of the amount of rainfall at four study sites.

DMBs suffered significantly more invertebrate damage than any of the other bait types tested and were very susceptible to damage by *Demestes* beetle larvae and meat ants (*Iridomyrmex* spp.). Similar invertebrate damage to baits, especially that caused by meat ants, maggots and beetles, has been observed in other bait uptake trials (McIlroy et al. 1988; Fleming & Parker 1991; Saunders et al. 2000). McIlroy et al. (1988) stated that the amount of damage sustained by baits was related to the geographical and seasonal distribution of invertebrates, their abundance, the weather conditions, and the shape and condition of the baits. They also observed that invertebrate damage was responsible for more bait deterioration than rainfall and this is consistent with observations made during the current study. However, in contrast, Twigg et al. (2000) found very little evidence of insect damage to DMBs tested in central Australia, but this may have resulted because their trial was undertaken in an arid site and their baits became desiccated and developed an especially dry, tough outer skin that may have prevented invertebrate damage.

In comparison with DMBs, standard Pro-baits sustained very little invertebrate damage and this was significantly reduced through the addition of an invertebrate deterrent, though increasing the hardness of Pro-baits did not affect their durability. These results reveal that the observed difference in uptake between Pro-baits and DMBs by foxes in Phase 1 was not explained by a difference in bait longevity.

The lesser uptake of Pro-baits was therefore concluded to be due to lower acceptability of the manufactured bait. In an attempt to increase the acceptability of Pro-baits, a flavour that was attractive to foxes was sought for inclusion in the bait's recipe. Foxes showed a significant preference for chicken flavour but were indifferent to beef or honey flavours and to monosodium glutamate. These results are in contrast with observations by Saunders & Harris (2000) who found that captive foxes preferred beef and honey flavours. Their result may have occurred because they used a bran-based control bait that contained no meat whereas in this study all lures contained meat and consequently any preference for a beef flavour would have been diminished. Saunders & Harris (2000) also observed that ethyl caproate and hexylamine were not attractive to captive foxes and this is consistent with the avoidance of these chemicals by foxes in the current study.

The uptake of Pro-baits that had been reformulated to include the chicken flavour enhancer was compared with that of DMBs in a second trial (Phase 4). There was no difference in the ingestion rate of the two bait types and both had an uptake of 87%. This level of uptake exceeds that of some other bait types developed for fox control (e.g. 23% D-K9 bait uptake [Fleming et al. 1992] and fresh meat baits 69.5% [Thompson & Fleming 1994]) but is similar to the uptake of Foxoff baits (90%; Applied Biotechnologies 1994) and to DMBs tested in other field trials (mean 79.5%; Thomson & Algar [2000]; >95%, Thomson et al. [2000]). The 87% uptake of Pro-baits occurred irrespective of any potential for caching (Kay et al. 1999; Thomson & Kok 2002; Gentle et al. 2007) that may have resulted if its palatability had been low (van Polanen Petel et al. 2001). This level of Pro-bait uptake is sufficient to achieve the 75–80% fox reduction necessary for the prevention of rabies (Trewhella et al. 1991) and, because it equals that of the DMB (Thomson et al. 2000), it is sufficient to promote fauna recovery.

Before the operational use of re-formulated Pro-baits could be approved, CALM needed to ensure there was no increased non-target risk of using Pro-baits rather than DMBs. Martin et al. (2003) had investigated the rate of ingestion of Pro-baits and DMBs by a range of endemic species in captivity and found brush-tailed phascogales (*Phascogale tapoatafa*) and chuditch (*Dasyurus geoffroii*) to potentially be at risk from the ingestion of Pro-baits. All other species investigated consumed too little Pro-bait material (or DMBs) to ingest a lethal dose of 1080. The response of phascogale and chuditch populations to an operational fox baiting programme was examined and the results of these two studies demonstrated that baiting with Pro-baits did not detrimentally impact either species (Morris et al. 2005; Marlow et al. 2015).

Once Pro-baits had been shown to be as efficacious as DMBs without increased non-target risk they could be registered for operational use. Initially an application was made to register Pro-baits with the invertebrate repellent 'Coopex®' included in their formulation. However, due to potential synergistic actions of this chemical and 1080, which precluded registration without exhaustive testing, it was decided to exclude this agent. Pro-baits were registered by the Australian Pesticides and Veterinary Medicines Authority (APVMA) for use in Western Australia in 2002. In future this registration of Pro-baits

may possibly be expanded so that they can be used to deliver substances other than 1080, which may include cabergoline for the reproductive control of foxes (Marks et al. 2001), a potential immunocontraceptive vaccine (Bradley et al. 1996), or alternative toxins such as PAPP (Fleming et al. 2006). In late 2005, Parks and Wildlife officially endorsed the use of Pro-baits for use in *Western Shield* fox control operations. Subsequently, the Harvey bait manufacturing facility was expanded to produce sufficient baits for the entire *Western Shield* fauna recovery programme and the operational use of Pro-baits commenced.

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