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Assessing the impact of 1080 Pro-baits on wild brush-tailed phascogales (*Phascogale tapoatafa*) during an operational fox baiting campaign

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ABSTRACT

Brush-tailed phascogales were potentially at risk from poisoning from a newly developed fox bait, Pro-bait. Before Pro-baits were used operationally their impact upon a population of phascogales was investigated. Seven radio-collared brush-tailed phascogales (*Phascogale tapoatafa,* undescribed subspecies) were monitored for nine weeks during and after a fox-baiting program using toxic Pro-baits. Each Pro-bait contained 3 mg 1080 (sodium fluoroacetate) and the biomarker dye, Rhodamine B. Baits were aerially delivered to the Catterick Forest Block site on 2 April 2005 at the rate of 5 baits km^{-2}. Additional baits were hand laid near known phascogale locations on 23–24 May 2005. No radio-collared phascogales died, though one collar failed. All other collars were removed on 8 June 2005. No evidence of the biomarker that would indicate bait ingestion was observed in 104 whisker samples taken from the recaptured phascogales. Four scats were collected during trapping in April–May 2005 and another four scats were collected in June 2005. One scat collected on 29 April 2005 had a pink hue suggesting the presence of Rhodamine B, but it did not fluoresce under ultraviolet light. Its colour may have resulted from the ingestion of some other pink-coloured foodstuff. It was concluded that phascogales were unlikely to ingest Pro-baits during operational fox baiting programs and mortality through poisoning would not occur on a scale likely to affect the overall population.

Keywords: bait development, fox, introduced predator control, phascogale, 1080

INTRODUCTION

The *Western Shield* fauna recovery program aims to reduce fox (*Vulpes vulpes*) predation on vulnerable endemic fauna and to maximise the sustainable recovery of wildlife populations (Possingham et al. 2004). This program was launched by the Department of Parks and Wildlife (Parks and Wildlife, then the Department of Conservation and Land Management [CALM]) in 1996 and it relies on the repeated delivery of meat baits containing the poison 1080 (sodium fluoroacetate). 1080 is used in this fox control program because of its high toxicity to canids (McIlroy 1981; McIlroy et al. 1986; McIlroy & King 1990). Many endemic species in south-western Australia have developed a tolerance to fluoroacetate through their co-evolution with fluoroacetate-bearing vegetation (King et al. 1978, 1981; Calver et al. 1989; Twigg & King 1991), and this ensures that 1080 baiting campaigns are particularly target-specific in Western Australia.

Initially the *Western Shield* program obtained its fox baits, dried meat baits (DMBs), from the Department of Agriculture and Food Western Australia. These baits were delivered to approximately 3.4 M ha at least four times each year (Armstrong 2004). The program was so successful that the woylie (*Bettongia penicillata*), the tammar wallaby (*Macropus eugenii*) and the quenda (*Isoodon obesulus*) were removed from the state's threatened species list in 1996 (Mawson 2004). In 1998, CALM decided to develop a sausage-style bait, Pro-bait, to reduce the cost of the *Western Shield* program (Armstrong 2004). The cost of Pro-bait manufacture is lower because they are made from minced kangaroo meat that is cheaper and more readily available than the chunks of meat required for the production of DMBs. Pro-bait production is based on a salami manufacturing process and the advantages of this are automation, large economically effective production runs, minimal wastage

and improved shelf life of baits. The uniform shape and size of this bait type also improves packaging efficiency and reduces transport and storage costs (Armstrong 2004).

Before Pro-baits could be used operationally they had to be shown to be as effective at controlling foxes as DMBs and to pose no more of a risk to non-target wildlife. Various uptake trials, longevity assessments and amendments to the recipe for Pro-baits were undertaken to ensure they were as palatable to foxes as DMBs (Marlow et al. 2015a).

The potential risk of Pro-baits and FOXOFF® baits to non-target species had been investigated in captive trials (Martin et al. 2002). In those trials the ingestion of the two bait types by 15 potentially susceptible non-target species was compared with that of DMBs. The species selected for testing were chosen based upon their diet, their sensitivity to 1080, and their size relative to the probable 1080 loading of baits they may encounter (Martin et al. 2002). The results of these trials indicated that the brush-tailed phascogale (*Phascogale tapoatafa*, undescribed subspecies) was potentially at risk from operational fox-baiting campaigns using Pro-baits. Chuditch (*Dasyurus geoffroii*) were also potentially at risk from Pro-baits but were at more risk from DMBs (Martin et al. 2002). The potential risk to brush-tailed phascogales from the operational use of Pro-baits was of particular concern to the department because there had been anecdotal reports of their abundances decreasing in areas where fox baiting with DMBs occurred and they had been found to be more susceptible to 1080 poisoning than previously recognised (Twigg et al. 2004).

The actual risk of Pro-baits to brush-tailed phascogales was investigated in a trial in which toxic 3 mg 1080 Pro-baits were delivered at the standard baiting rate (5 baits km^{-2}) to a population of brush-tailed phascogales, in which seven animals were radio-collared. The Pro-baits also contained a biomarker dye, Rhodamine B, which would label the whiskers and scats of individuals that ingested it (Fisher 1999). The results of these trials were used to estimate the proportion of brush-tailed phascogales that would consume Pro-baits in the field.

METHODS

Bait characteristics

Pro-baits are a sausage bait that contain 70% minced kangaroo meat, 20% animal fat (pork or chicken), canine 'digest' (a commercial flavour enhancer for dog food) and other flavour enhancers (Armstrong 2004; Marlow et al. 2015a). A salami-style binder is added to this mixture to promote hardening of the final product. This reduces the risk of smaller non-target species being able to bite into the bait (Martin et al. 2002). The toxin 1080 is added as a solution and is automatically injected into each bait as it is formed in the sausage-making machine. Each bait weighs approximately 80–85 g at manufacture and is then heated to between 30–40 °C to promote uniform shrinkage during the drying process. The baits are then dried to approximately 40 g before delivery to the field (Armstrong 2004).

Pro-baits were labelled with the biomarker Rhodamine B. This biomarker produces persistent systemic markings in the hairs and faeces of mammals that ingest the baits and these are detectable under ultraviolet light (Fisher et al. 1999). Pro-baits were labelled with Rhodamine B by inserting 0.5 ml aqueous solution (40 mg ml^{-1}) into a 2 mm diameter hole that had been drilled into the side of each bait with an electric drill. This volume of Rhodamine B was sufficient to deliver the recommended dose for mammals of 15–35 mg kg^{-1} (Spurr 2002). The addition of the biomarker was intended to simulate the addition of 1080 and so was injected into one site.

The study site

The experimental site was at Catterick Forest Block, a 6550 ha area approximately 10 km east of Balingup and 230 km south of Perth, Western Australia (Fig. 1). This forest block is in the southern jarrah forest IBRA region, near the southern edge of the Darling Plateau, and exhibits the Darling Uplands subtype of the Darling Plateau Landscape Character Type. It has winter-dominant rainfall of 800–900 mm per annum. It is in the Darling Botanical District and is characterized by open forest of *Corymbia calophylla – Eucalyptus marginata* with *E. wandoo* and *E. patens* on slopes, woodlands of *E. rudis* and *Melaleuca rhaphiophylla* on lower slopes, and *E. rudis* and *Banksia littoralis* on valley floors. It has moderately fertile grey-brown earths and yellow or red duplex soils with a gravelly sand loam topsoil over clay (Havel & Mattiske 2000).

Baiting

Catterick Forest Block was aerially baited every three months with DMBs at the standard baiting regime (5 baits km^{-2}; Armstrong 2004). Regular baiting at this site commenced in 1998. Pro-baits containing 3 mg 1080 and Rhodamine B were aerially delivered to Catterick Forest Block during the scheduled *Western Shield* baiting event on 2 April 2005. The location of all Pro-baits delivered was recorded using a GPS (model GPS76; Garmin Corporation, Kansas USA). To ensure Pro-baits were available to brush-tailed phascogales, additional Pro-baits were hand laid at Catterick Forest Block on 23–24 May 2005. Five Pro-baits were positioned near the diurnal resting site of each of the six brush-tailed phascogales that were being monitored. One bait was placed at the base of the inhabited tree and another four baits were placed 200 m from this central point; one at each of the four major compass points.

Trapping and monitoring

The primary method of determining if toxic Pro-baits were lethal to brush-tailed phascogales was through monitoring the survival of radio-collared individuals. Phascogales were initially trapped and radio-collared between 15–20 March 2005. One hundred Sheffield cage traps (Sheffield Wire Products, Welshpool, WA) and 17 small Elliott traps

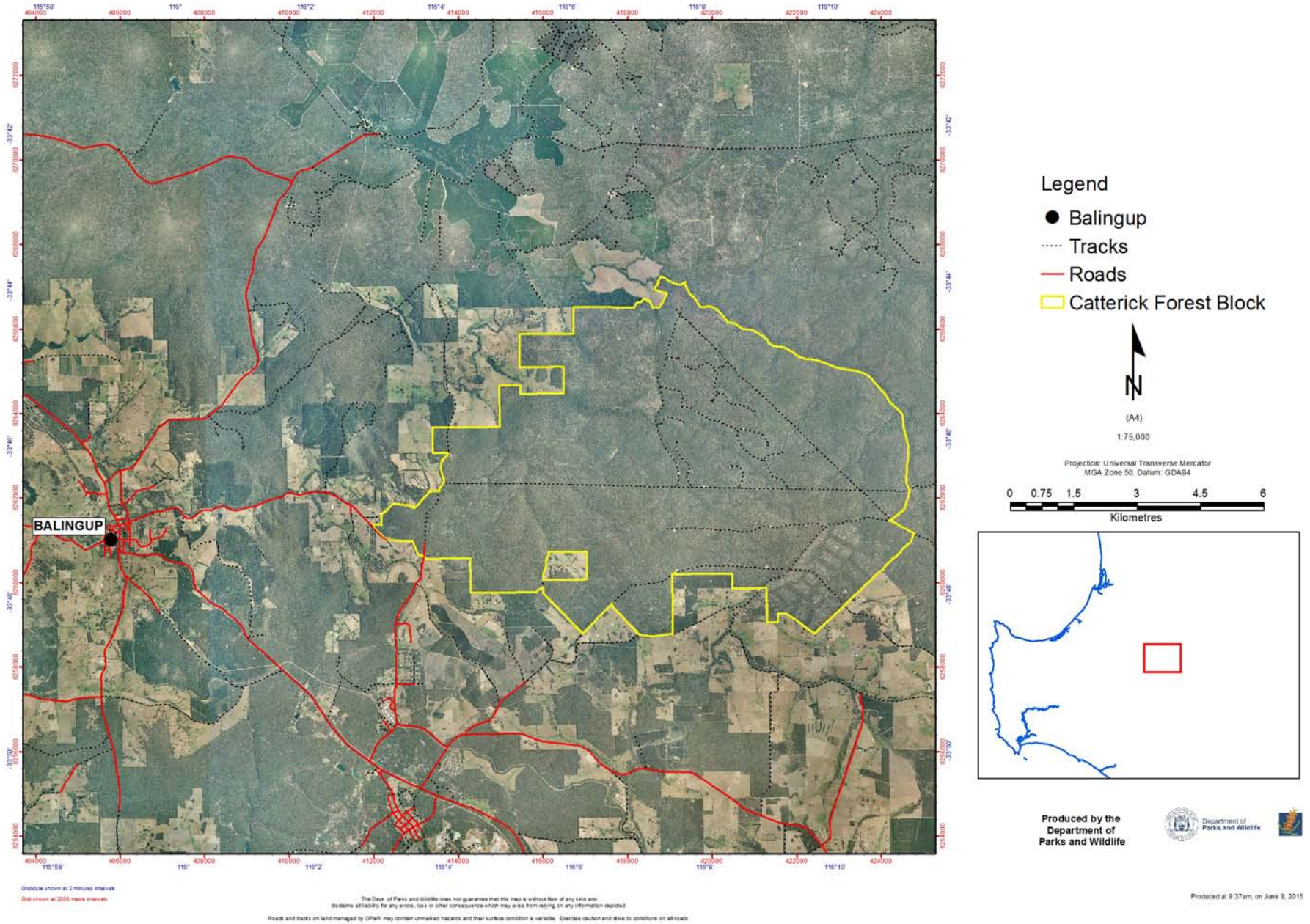

Figure 1. Map of the study site at Catterick Forest Block.

Table 1

Trapping effort for brush-tailed phascogales during 2005.

Date	No. trap nights, cage traps	No. trap nights, Elliott traps	No. individuals captured
15–20 March	500	85	6 new
26–28 April 2–4 May	240	48	6 (1 new, 5 recaptures)
8 June	72	0	6 (all recaptures)

(Elliott Scientific Equipment, Upwey, Victoria), baited with peanut butter, oats and sardines, were set at 200 m intervals along vehicle tracks. Trapped phascogales were fitted with Biotrack P1P2 (Biotrack, UK) radio–collars. Radio-collared individuals were tracked to their diurnal refuge sites at least once per week but more often where possible (Table 2). The survival of these phascogales was monitored during the operational delivery of Pro-baits and after the hand-placement of baits near to their known resting sites. It was anticipated that if phascogales ingested a lethal dose of 1080 their death would occur within approximately four hours (Potter et al. 2006).

Trapping was repeated in April–May and June 2005 but only cage traps were used and these were strategically positioned to recapture collared individuals. All brush-tailed phascogales were weighed at each capture using a 500 g capacity Pesola scale (Prospectors Earth Sciences, Seven Hills, Australia). A qualitative assessment of the condition of phascogales was made at the initial and final captures. A sample of 6–10 whiskers was plucked from each captured individual (as recommended by Spurr 2002) in each of the March–April and June trapping sessions (Table 1). Any scats deposited in traps were collected. Whiskers and scats were later examined for the presence of the biomarker Rhodamine B. Whiskers were examined using a fluorescence microscope as described by Fisher et al. (1999). In small mammals, Rhodamine B is detectable in whiskers from 12 hours to 17 weeks after bait ingestion (Jacob et al. 2002), and in scats the ingestion of the dye can be detected for up to two days after bait consumption (Jacob et al. 2002).

RESULTS

Trapping and monitoring

During the 15–20 March 2005 trapping session, six brush-tailed phascogales (3 males, 3 females) were captured and radio-collared at Catterick Forest Block (Table 1). Trap success was higher with cage traps than Elliott traps (five captures versus one) and so the use of Elliott traps was phased out during the experiment. Radio-collared brush-tailed phascogales were monitored regularly (Table 2). The signal from one male phascogale (M#15) was lost on 5 April 2005 but this individual was later re-trapped and re-collared on 27 April 2005. The signal from another male (M#14) was lost on 27 April 2005 and was not

Table 2

Dates of collaring (C), re-collaring (RC), monitoring (Y = signal present, N = no signal present) and collar removal (CR) of brush-tailed phascogales in relation to aerial and hand delivery of Pro-baits at Catterick Forest Block in 2005.

Date	F#12	M#13	M#14	M#15	F#16	F#17	M#18
15 Mar	C						
16 Mar	Y						
17 Mar	Y	C	C				
18 Mar			Y				
19 Mar	Y	Y	Y	C	C		
20 Mar		Y		Y	Y	C	
22 Mar	Y	Y	Y	Y	Y	Y	
29 Mar	Y	Y	Y	Y	Y	Y	
2 Apr			Aerial Pro-bait delivery				
5 Apr	Y	Y	Y	N	Y	Y	
11 Apr	Y	Y	Y	N	Y	Y	
18 Apr	Y	Y	Y	N	Y	Y	
26 Apr	Y	Y	Y	N	Y	Y	
27 Apr	Y	Y	N	RC	Y	Y	
28 Apr	Y	N	N	Y	Y	Y	
29 Apr					RC		C
2 May	Y	N	N			N	
3 May	Y	RC	N	N	Y	Y	Y
4 May	RC			N		RC	
5 May	Y	Y	N	Y	Y	Y	Y
17 May	Y	N		Y	Y	Y	Y
23 May	Y	Y		Y	Y	Y	Y
23–24 May			Hand Pro-bait delivery				
26 May	Y	Y		N	Y	Y	Y
3 Jun	Y	Y		Y	Y	Y	Y
8 Jun	C	CR	N	CR	CR	CR	CR

Table 3

Duration of monitoring of radio-collared brush-tailed phascogales in Catterick Forest Block in 2005 before and after aerial and hand delivery of Pro-baits, respectively.

ID	Initial weight (g)	Final weight (g)	No. days monitored pre-aerial Pro-bait delivery	No. days monitored post-aerial Pro-bait delivery	No. days monitored pre-hand Pro-bait delivery	No. days monitored post-hand Pro-bait delivery
F#12	130	120	18	67	69	16
M#13	150	149	16	67	67	16
M#14	150	n/a	16	24	n/a	n/a
M#15	155	140	14	67	65	16
F#16	110	112	14	67	65	16
F#17	130	118	13	67	64	16
M#18	155	162	0	40	24	16

relocated. A new male (M#18) was trapped and collared on 29 April 2005. All six brush-tailed phascogales with functional collars were re-trapped on 8 June 2005 and their collars removed. All animals were assessed to be in good condition at each capture and no females had any pouch young.

All phascogales survived and were monitored for an average 57 days (± 17 SD; Table 3) after the aerial delivery of Pro-baits. They also survived for 16 days after hand delivery of Pro-baits (except M#14 whose signal was lost).

Biomarker detection

A total of 104 whisker samples was collected from seven individual phascogales. Of these, 56 were collected at least 24 days after the aerial baiting with toxic Pro-baits (mean 57 days ± 17 SD; Table 3) and 48 were collected 16 days after the strategic placement of baits around diurnal resting sites (i.e. 67 days after initial exposure to toxic baits; Table 3). None contained any evidence of the biomarker.

Four scats were collected during the April–May 2005 trapping session (i.e. at least 24 days after aerial Pro-bait delivery) and one of these (from F#16 on 29 April 2005; 27 days after aerial Pro-bait delivery) had a pink hue. This colouration may have been due to the presence of the Rhodamine B biomarker but this was not conclusive because it did not fluoresce under ultraviolet light. It may have resulted from the individual ingesting a pink-coloured invertebrate or other foodstuff. A further four scats were collected during the June 2005 trapping session, which was undertaken 16 days after the strategic placement of additional Pro-baits near the known locations of radio-collared brush-tailed phascogales, but none of these scats revealed the biomarker.

DISCUSSION

There was no evidence from whisker marking that brush-tailed phascogales removed or ingested 3 mg 1080 Pro-baits delivered at the standard fox-baiting rate of 5 baits km^{-2}. Although one female may have ingested a Pro-bait, as evidenced by pink colouration in a scat, no mortality of collared brush-tailed phascogales occurred. When additional Pro-baits were positioned at known locations of brush-tailed phascogales no further evidence of bait ingestion was detected and all individuals maintained their weight and general body condition.

The concerns raised by Martin et al. (2002) that brush-tailed phascogales may be at risk from toxic Pro-baits during operational fox-baiting programs were not realised. Martin et al. (2002) acknowledged that they used the worst-case scenario, and therefore the conservative approach which follows the 'precautionary principal' (Calver et al. 1999), in their assessments of risk. They defended their stance by stating that it is well recognised that food consumption by free-ranging animals can be more than two-fold greater than that of captive-held animals (McIlroy 1981; Nagy et al. 1988; Calver et al. 1990). This may lead to an underestimate of the amount of 1080 potentially ingested by non-target species based on their consumption of non-toxic baits in the laboratory (McIlroy 1981). Also, once encountered, a predator bait is likely to provide an easy meal for carnivorous non-target species with a reduced need to hunt prey. One reason brush-tailed phascogales may not have ingested Pro-baits may be that they are able to detect 1080 in a similar manner to that described for dunnarts (*Sminthopsis crassicaudata*; Sinclair & Bird 1984). Also, if phascogales vomit after the ingestion of even a small amount of meat containing 1080, as dunnarts do, then they are unlikely to be at risk from operational baiting campaigns (Sinclair & Bird 1984).

Martin et al. (2002) recognised that other species they identified as potentially being at risk from baits were not detrimentally affected when actually exposed to toxic fox baits during a baiting program. They describe how chuditch and northern quolls (*D. hallucatus*) were considered to be theoretically at risk from baiting operations by Calver et al. (1989), Soderquist & Serena (1993), and in their own study (2002), but that those concerns were not realised when the survival of these species was monitored during routine control operations by King (1989) and Morris et al. (1995).

Brush-tailed phascogales have been observed to ingest fox baits in other studies. Fairbridge et al. (2003) reported that 15% of the 40 brush-tailed phascogales they monitored at the Puckapunyal Military Area in central Victoria ingested buried non-toxic 30 g FOXOFF® baits.

The factors that may have affected those bait ingestion rates included the timing of bait lay, the hardness, composition and size of baits, and the density of baits deployed. The timing of bait lay was unlikely to have been responsible for the observed differences in bait uptake between Victoria and the current study. Although Fairbridge et al. (2003) undertook their trial during summer and autumn when juveniles were becoming independent and adult females may have been nutritionally stressed, the current study was also undertaken in autumn, and although no juveniles were present, adults may similarly have been nutritionally stressed.

The hardness and size of the bait types used in the two experiments may account for the observed differences in uptake. FOXOFF® baits are soft and moist (Martin et al. 2002) and are smaller than Pro-baits (30 g versus 40–45 g). Softer and smaller baits are more easily handled and consumed by small non-target mammals that lack the dentition to eat substantial amounts of large, harder baits (Calver et al. 1989; Martin et al. 2002). The hardness of the bait matrix has been observed to influence bait consumption by non-target dasyurid species (Soderquist & Serena 1993; Martin et al. 2002; Fairbridge et al. 2003). FOXOFF® baits are readily accepted by eastern (*D. viverrinus*) and spotted-tailed quolls (*D. maculatus*) from eastern Australia (Belcher 1998) and were also consumed much more readily than Pro-baits or DMBs by spotted-tailed quolls, eastern quolls and northern quolls (*D. hallucatus*) in captivity (Martin et al. 2002). The observed differences in uptake of FOXOFF® and Pro-baits by brush-tailed phascogales may be due to Pro-baits being larger and specifically formulated to include a binder to render baits harder so as to reduce non-target ingestion (Marlow et al. 2015a). The size of baits will also influence the hazard to non-target species (Martin et al. 2002) because the toxin in smaller baits will be relatively more concentrated if they contain the same amount of 1080 as larger baits. Ideally larger baits should be used to reduce risks to non-target species, though this attribute needs to be balanced against the possibility that larger baits are potentially more likely to be cached than smaller baits.

The density of baits available to brush-tailed phascogales may also have influenced the difference in observed bait ingestion rates between Victoria and Western Australia. Fairbridge et al. (2003) wanted to test whether brush-tailed phascogales had the propensity to eat fox baits deployed in buried bait stations. They used parallel transects positioned 100 m apart with bait stations located at 50 m intervals. Their extrapolated bait delivery rate would therefore have been approximately 200 baits km^{-2}, which is about 40 times greater than the standard baiting rate of 5 baits km^{-2} used in Western Australia (Armstrong 2004). In Western Australia there would be one bait delivered every 20 ha but the number of baits actually available to phascogales may be much lower due to a very high ingestion rate of baits by brush-tailed possums, birds and other non-target species (Marlow et al. 2015b). Given the average home range areas used by female and male phascogales in these areas are 20 ha and 25.9 ha respectively (Rhind 1998), it is unlikely that many baits will be detected. The foraging behaviour of brush-tailed phascogales may also reduce bait consumption because this arboreal species was observed to spend little time foraging at ground level, at least in south-western Australia (Scarff et al. 1998). Even when additional baits were laid in the current study the probability of brush-tailed phascogales encountering a bait would be low.

If the use of Pro-baits was to be expanded to eastern Australia, field trials would need to be undertaken to ensure that non-target species that have not had evolutionary exposure to fluoroacetate-bearing vegetation would not be at risk (Mead et al. 1985; Twigg & King 1991). Some mammals from eastern Australia would be placed in a moderate to high theoretical risk category if they ingested 3 mg Pro-baits due to their higher level of sensitivity to 1080 (Martin et al. 2002). The sensitivity to 1080 of brush-tailed phascogales from eastern Australia has not been assessed but they are likely to be more sensitive than the Western Australian conspecific (Twigg & King 1991). Therefore populations of this species in the eastern states should be monitored for potential non-target impacts if baiting with Pro-baits was ever to be introduced (Martin et al. 2002).

Although brush-tailed phascogales have been shown not to be at risk from operational fox-baiting campaigns in Western Australia, there are still some factors that need to be considered when predator baiting campaigns are undertaken (Martin et al. 2002). If the food supply of phascogales is known to be reduced, the potential protection this species may be afforded by predator baiting needs to be weighed against a greater risk to them from Pro-baits (and other predator baits) when no alternative food is available (Martin et al. 2002). Similarly, if juveniles are present, their inclination to consume baits because they are less experienced hunters (Soderquist & Serena 1993) needs to be balanced against the protection they would acquire from predator control. Also, if possible, baiting should not be undertaken immediately preceding and during the breeding season of dasyurids that undergo post-mating male die-off. Although Morris et al. (2005) found that adult and juvenile chuditch were unaffected by toxic Pro-baits in the field, it would be prudent to undertake adequate monitoring of chuditch and phascogale populations in areas where fox baiting programs are routinely undertaken to detect non-target mortality if it occurs.

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