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Improved bait and trapping techniques for chuditch (*Dasyurus geoffroii*): overcoming reduced trap availability due to increased densities of other native fauna

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ABSTRACT

The populations of several native medium-sized mammals have increased in abundance in response to an extensive fox control program in southwestern Australia. In particular, the woylie (*Bettongia penicillata*), established sufficient densities in some forest areas between 1996 and 2005, that they saturated the traps used in several long-term monitoring studies. As a consequence, less abundant and/or less readily caught species were likely to be excluded from traps and may have been inadequately represented in surveys.

In a series of comparative trials within several Western Australian native jarrah (*Eucalyptus marginata*) forests, this study tested an alternative lure for cage-traps that could be used in the presence of abundant woylies to improve capture rates of chuditch, *Dasyurus geoffroii*, and possibly other native vertebrates.

Compared with 'universal bait' (peanut butter and oat-based), the 'chuditch bait' (meat meal and fish oil-based) increased chuditch capture rates up to 800% by reducing woylie capture rates by about 50% or more: the species diversity and capture rates of several other vertebrates were also greater. Other associated trapping techniques to improve chuditch survey efficiency are also discussed.

INTRODUCTION

The chuditch (*Dasyurus geoffroii*: Family Dasyuridae) is the largest native carnivorous marsupial in Western Australia: adult males weigh 1175–2075 g and adult females weigh 705–1285 g (Serena & Soderquist 1995). As opportunistic nocturnal hunters, chuditch feed largely on small mammals, birds, reptiles and invertebrates but also consume some fruits, food scraps and carrion (Soderquist & Serena 1994). Early records suggest that the chuditch occupied a diverse range of habitats within a former distribution that covered much of the Australian continent, from Western Australia to western areas of Victoria, New South Wales and Queensland (Ride 1970; Serena et al. 1991). Since European settlement its distribution has substantially declined such that since the 1970s it has been largely confined to the southwest corner of Western Australia. By the late 1980s the conservatively-estimated 6000 individuals remaining in the wild were largely confined to the jarrah forests of southwestern Australia (Serena et al. 1991). In 1983 the species was listed under the WA *Wildlife Conservation Act 1950* as threatened and in 1991 it was listed as Endangered under the Commonwealth *Endangered Species Protection Act 1992*. A recovery plan for the species was prepared and implemented in 1992 (Orell & Morris 1994).

The decline of many species of native mammals, including the chuditch, was thought to be attributed in part at least to the introduction of the European red fox (*Vulpes vulpes*) (Burbidge & McKenzie 1989). A broad-scale fox control program was established in southwestern Australia after a series of studies demonstrated that with fox control, populations of many species of native mammals, including the chuditch, increased significantly (Friend 1990; Kinnear 1990; Kinnear et al. 1988; Morris et al. 1998, 2003). The 'Western Shield' fauna recovery program, initiated by the Western Australian Department of Conservation and Land Management (CALM, now Department of Environment and Conservation DEC), uses dried meat or sausage baits containing the toxin sodium monofluoroacetate (1080) to control fox numbers (Bailey 1996). This toxin occurs naturally in Western Australian endemic legumes in the genus *Gastrolobium*, and native fauna has evolved enhanced tolerance to 1080 (King et al. 1978, 1981, 1989; Mead et al. 1979). Introduced species such as the red fox, however, have very low tolerances to 1080 (McIlroy 1981; McIlroy & King 1990). Fox populations are now controlled in this manner on approximately 3.5 million hectares of DEC–managed land (Wyre 2004). This conservation program has resulted in population increases of several native species (Orell 2004). Three species, the woylie (*Bettongia penicillata*), quenda (*Isoodon obesulus*), and tammar wallaby (*Macropus eugenii*), recovered to such an extent that they were removed from the State and Commonwealth threatened fauna lists (Morris et al. 1998; Start *et al.* 1998).

The recovery of populations of medium-sized mammals within southwestern Australia has resulted in a unique challenge for researchers attempting to survey less common species such as the chuditch. In the period 1996 to 2005 within many forest systems the fox control program resulted in a dramatic increase in the density of medium-sized mammals. For example, within Kingston State Forest the trap success rates for mammals (all species combined) were less than 10% in 1992. Fox control began in 1993 and the corresponding increase in native mammals resulted in trap success rates greater than 70% since 1998 (Morris et al. 2001; Wayne unpublished data). The majority of these captures were woylies resulting from increased densities and their ease of capture. Trap saturation (i.e. greater than about 60% capture rate) and interference by animals reduces trap availability to less abundant species such as the chuditch. Similar problems have been encountered with other medium- to long-term studies within other jarrah forest sites such as at Batalling (Morris et al. 2003) and Perup (Burrows & Christensen 2002).

With the success of the Western Shield fox-baiting program, the problem of trapping rarer species in the presence of woylies may expand. Simply placing a greater density of traps than the density of woylies, to ensure that some traps remain available for other species incurs logistic and economic challenges that make this strategy impractical. This paper describes a trap-bait trial that sought to overcome this problem. The objective of this trial was to find an alternative lure that is less attractive to woylies than the extensively used 'universal bait', but provides a greater potential for capturing chuditch and possibly other less abundant native mammals.

MATERIALS AND METHODS

Kingston Study Area

Initial bait trials were conducted in Kingston, Winnejup and Warrup State Forests, 25 kilometres north-east of Manjimup, Western Australia. These field trials were conducted in association with the 'Kingston Project', a large-scale study into the impacts of timber harvesting and associated activities on the vegetation and fauna of the jarrah forest (Morris et al. 2001). The study area is approximately 15,000 hectares of open forest and woodland dominated by jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*). The area lies in the transition between high-quality and low-quality forest (Abbott & Loneragan 1983) within the intermediate rainfall zone (annual rainfall approximately 900 mm) and on primarily lateritic soils with deeper loams and sands lower in the valley profiles. Selective high quality jarrah timber harvesting was conducted in the area in the 1920s and during the 1940s to 1970s (Heberle 1997). Shelterwood creation and gap release harvest treatments (Stoneman et al. 1989) were also conducted within the area between 1994 and 1997. Fox control using 1080 impregnated dried meat baits has been maintained within the study area and surrounding forests using standardised baiting methods since 1993 (Morris et al. 2001).

Trapping trials of the alternative bait were conducted using 36 kilometres of road transects established for the Kingston Project (Morris et al. 2001). Sheffield wire cages (20.5 cm wide, 20.5 cm high, 55 cm deep; Sheffield Wire Co., Welshpool WA) were individually spaced 200 metres along these transects, and covered with thick hessian to protect trapped animals from weather exposure. The road transects were separated into two groups: northern transects (92 traps) and southern transects (88 traps). The shortest distance between the northern and southern transect traps was greater than two kilometres but was generally greater than five kilometres.

The principle of using a meat-based bait to catch chuditch had previously been used by Serena and Soderquist (1989) who used traps baited with raw meat or a mixture of peanut butter, tinned pet food, tuna and dried fish meal. The same authors also used similar bait variants on other occasions (e.g. Soderquist & Serena 2000). After we experimented with ingredients an alternative meat-meal based bait was developed along the same principles. Bait development criteria included it being primarily meat-based and practical considerations such as the ready supply and storage of ingredients, ease of bait preparation, bait longevity in the traps and ease of presentation (i.e. no packaging or containment required, suitable for hanging off trap 'hooks' to avoid soiling and reduce ant problems, etc). The final recipe used in these trials was as follows:

'Chuditch Bait'

3 kg	Dried meat meal (53% crude protein, 14.2–20.2% crude fat, 6.8–9.9% phosphorus, 5.9–9.2% calcium, 1.1% crude fibre, and 0.7–0.85% salts).
750 g	Sardines
500 mL	Fish oil (preferably tuna or something equally strong-smelling of fish)
<1 L	Chicken oil (95% chicken fat, previously used as cooking oil by a takeaway chicken outlet)
~1.5 kg	Quick-cooking rolled oats

All the dry and solid ingredients were combined with the fish oil and supplemented with enough chicken oil to produce a consistency that enabled a golf-ball-sized portion to hold together and remain attached to a closed wire bait hook. Occasionally a small amount of flour or cornflour was added to help as a binding agent and achieve the required consistency. Quantities are estimated to be sufficient to maintain about 100 traps for four nights.

'Eau de chuditch'

1 kg of low-fat red meat in 10 L of water was left to putrefy at room temperature in a well-sealed container for a minimum of two weeks. Strained of solids, the liquid was transferred into dispensing spray bottles.

Less than 5 mL was sprayed around (including on shrubs and forest debris < 1 m above ground) and within 150 cm radius of each trap and re-applied daily.

Chuditch bait trials in Kingston and surrounding State Forests

In August 1997 a preliminary paired comparison of the chuditch bait with the universal bait (peanut butter, rolled oats and sardines) was conducted by placing a trap with chuditch bait on the opposite side of the forest road/ track and at least 20 metres away from an identical trap with universal bait. A total of 180 paired traps were trialled over four consecutive nights.

The main comparative bait trial was conducted over four trapping sessions, approximately three months apart: December 1997, February 1998, May 1998 and August 1998. During each trapping session the northern and southern transects were operated synchronously, each transect with a different bait type. After four consecutive nights of trapping, there was a three to four day 'pause' before the traps and baits were alternated between the north and south and trapping recommenced for four consecutive nights.

Chuditch bait trials at Batalling and Honeymoon Pool forests

The Batalling forest area is 35 kilometres east-north-east of Collie, Western Australia. Batalling supports jarrah- and marri-dominated open forest and woodland on shallow sands and loams (Friend et al. 1994; Mathew 1996). The average annual rainfall is less than 700 mm. Timber harvesting in the area began in the early 1900s, woylies were re-introduced in 1983 in association with limited fox control. Regular fox control began in 1991 (Friend et al. 1994).

Three consecutive nights of trapping at Batalling were conducted in April 1999 in which a transect of 60 pairs of Sheffield cage traps (one for each bait type, placed on opposite sides of the forest transect tracks) were spaced 200 metres apart along forest tracks.

Honeymoon Pool in the Collie River valley (20 kilometres west-south-west of Collie, Western Australia) was used to test the preference of chuditch to the two bait types in the absence of woylies. Located on the Darling Scarp, Honeymoon pool (Lennard State Forest at the time of the study, now Wellington National Park) supports jarrah- and marri-dominated forest within the high-rainfall zone (average annual rainfall greater than 1200 mm) and is a popular recreation and camp site.

The preference trials at Honeymoon Pool involved 50 pairs of Sheffield traps with alternative baits, spaced less than one metre apart and roughly facing each other. Trap spacing between pairs was 200 metres apart in forest alongside Lennard Drive and River Road. These transects were surveyed for three consecutive nights in February 1998. 'Eau de chuditch' was not used in these preference trials.

At all study sites captured chuditch were individually marked with small titanium ear tags (National Band and Tag Company; Kentucky, USA) and details of their age, sex, reproductive condition, pes and head size, and body weight were recorded and the animals released. For all other animals captured, only their species, sex and age were recorded before they were released. From February 1998, the status of traps that did not capture animals were recorded (i.e. whether traps were open or closed, with or without bait).

RESULTS

The trapping results from comparative trials of the 'chuditch' and 'universal' baits at Kingston, Batalling and Honeymoon Pool are summarised in Table 1. In the preliminary comparison of the two bait types conducted at Kingston in August 1997, more than five times the number of woylies were captured on the universal bait than on the chuditch bait. Conversely, the chuditch bait caught eight times more chuditch than the universal bait. During the Kingston bait trial there were more chuditch and quenda, and fewer woylies and koomal (common brushtail possum, *Trichosurus vulpecula hypoleucus*) caught using the chuditch bait than the universal bait. These differences between the bait types were significant for all four species (Fishers Exact Test, two-tail: $p=3.73 \times 10^{-13}$, $p=0.0031$, $p=3.25 \times 10^{-73}$ and $p=0.0011$ respectively). Although more traps were disturbed (Fishers Exact Test, two-tail: $p=0.042$), substantially more traps remained available (Fishers Exact Test, two-tail: $p=2.04 \times 10^{-61}$) and potentially capable of capturing animals using the chuditch bait compared to the universal bait. Furthermore, the numbers of captures of 'other' species using the chuditch bait (nine species) were collectively double those caught in traps using the universal bait (5 species; Table 2).

A total of 39 individual chuditch were captured (from 87 chuditch captures) during the Kingston bait trial (Table 3). Of these, 36 were caught on the chuditch bait and nine were caught on the universal bait. Six individuals were caught on both bait types over the duration of the 12-month trial. Of these six, there were five instances where the same individual (three adult males, one sub-adult male and one adult female) was caught on both baits within the same trapping session. In all five cases, individuals were caught within the same area but in both four-day periods within a trapping session and therefore on different bait types in alternate periods. There was a significant male bias among the chuditch caught with a 32:7 male:female ratio ($X^2=42.2$, $p<0.0001$). It was not possible to determine whether the sex bias was unique to the chuditch bait due to the small sample size of individuals caught on universal bait. There were only five sub-adult captures, four of which were male. Each individual was trapped during the trial between one and seven times and between zero and five times within any one of the four trapping sessions. During the trial females were caught on average 3.57 times each and significantly more frequently (p=0.0133; 2-tail unpaired Students t-test) than males (mean 1.84 captures each).

Results from the 'Kingston Project' (Morris et al. 2001, 2003) indicate that between 1994 and 1998, the average annual trap success rate for chuditch on the road transects using universal bait was 0.74% (SE± 0.20; annual mean of 2902 trap nights). Chuditch captures from identical traps and bait on associated trapping grids (3 x 3 traps spaced 80 m apart; Morris et al. 2001) resulted in an annual average trap success rate of 0.26% (SE± 0.10; annual mean of 2840 trap nights). The difference in the trap success rates between transects and grids was significant (p=0.0304; one-tail paired Students t-test).

The results from the chuditch bait trial at Batalling forest were generally similar to those from Kingston: substantially more chuditch, and fewer woylies and koomals were caught using the chuditch bait than using the universal bait. Quenda captures were equally very low on both bait types (Table 1). The extent of trap disturbance did not differ greatly between the two bait types, however the number of empty traps remaining potentially available to capture animals was more than five times greater with chuditch bait. Formal statistical tests on the differences between the bait types were not conducted on the Batalling data (or Honeymoon Pool data) because of the relatively small datasets and absence of repeated trials as in the case with the Kingston trials.

At the bait preference trial at Honeymoon Pool, there were 13 chuditch captures using chuditch bait and 14 captures using universal bait. Twenty-one chuditch individuals were involved. A total of 19 reptiles (predominantly *Egernia kingii*), a *Rattus rattus* and a koomal were also captured.

DISCUSSION

Traps using chuditch bait resulted in about half the woylie captures of traps using universal bait at both Kingston and Batalling forests. Trap availability and chuditch captures were substantially greater using chuditch bait. The chuditch bait is thus more efficient at surveying chuditch in the presence of large numbers of woylies than universal bait.

Although the number of chuditch captures at Honeymoon Pool was small, the results suggest that there may not be a clear preference by wild chuditch for either bait. Further preference tests would determine the role of the 'Eau de chuditch' given that this was not tested at Honeymoon Pool. Additional preference trials elsewhere would also more rigorously assess whether there are population differences in bait preferences. This has been difficult given that sites where chuditch are abundant and woylies are sparse or absent have been extremely limited. Despite the limitations of the Honeymoon Pool dataset, it may be deduced that the increased chuditch captures using chuditch bait at Batalling and Kingston were likely a result of substantially increased trap availability through decreased woylie captures, rather than a difference in bait preference by chuditch.

The male sex bias in chuditch captures and the tendency for females to be caught more frequently over time than males may be explained by the species having a solitary nature, gender differences in territorial behaviour and the gender differences in the extent of movement and home-rages. Females are intrasexually territorial and occupy smaller home-ranges (3–4 km^2), whereas males tend to range further (5–15 km^2) and have greater range overlap with other males and females (Mathew 1996; Morris et al. 2003; Serena & Soderquist 1989). As a consequence, a series of well-spaced traps within the landscape are likely to be within the home-range of more males than females. By virtue of female home-ranges being smaller, the chance of a female chuditch encountering a limited number of traps is greater than that for a male individual within its larger home range. These differences highlight the general principal that it is not possible to comment on what the actual sex ratio may be within a population without first having detailed information on their home-ranges and density – a commonly made mistake.

There is some indication that the chuditch bait may also be useful in surveying a greater number and diversity of other small and medium-sized vertebrate species that are sympatric with abundant woylie populations. In particular, the results from Kingston suggest that quenda and larger lizards may be trapped more effectively using chuditch bait. The extent to which the increased trap availability and species-specific preferences for bait types accounts for this trend, remain to be quantified. The chuditch bait may not be an appropriate alternative to universal bait for other species such as those that are predominantly herbivorous. These species might be expected to be attracted more by vegetable based lures rather than meat based products. This could explain why, compared with the peanut-based universal bait, the meat-based chuditch bait caught significantly fewer woylies, which are mainly mycophagous and herbivorous (Christensen 1995). Similarly and as expected, the generalist and herbivorous koomal (How & Kerle 1995), was also trapped less frequently on the chuditch bait at Kingston and Batalling.

In this context, the capture of three ngwayir (western ringtail possum, *Pseudocheirus occidentalis*) on chuditch bait at Kingston was particularly interesting and unexpected. This specialist arboreal herbivore was rarely caught on universal bait at Kingston over six years despite the trapping intensity and their local abundance (Morris et al. 2001; Wayne unpublished data). On all three occasions during the bait trial, it was not apparent that the trapped ngwayir had consumed any of the chuditch bait. Therefore, their captures may possibly be explained by a combination of an increased opportunity to be trapped, a curiosity for the strong smelling chuditch bait and perhaps a limited attraction to the universal bait. Differences in the effectiveness of lures and survey methods for the ngwayir and koomal are provided in Wayne et al. (2005).

This study demonstrated that where woylies were abundant, the chuditch bait generally favoured trapping greater numbers of a more diverse array of vertebrate species while the universal bait was more efficient in capturing the woylie and koomal. When using universal bait, however, there needs to be consideration for having sufficient trap density to avoid 'trap saturation' problems that may subsequently affect the ability to interpret and analyse the results.

The importance of the spatial distribution of traps being appropriate for the target species is highlighted by the difference in trap success rates for chuditch caught on grids and transects at Kingston (i.e. trap density should correspond to density and movement patterns of the target species). For example, given that chuditch typically have low densities and large home ranges (Mathew 1996; Morris et al. 2003; Serena & Soderquist 1989), the most efficient trap densities will be relatively low (e.g. 200 metres between traps along transects). There is also the possibility that the association of trapping transects with roads and tracks may improve the capture of chuditch if they favour travelling along them. This may be a preferred strategy for predators in habitats with a dense understorey. However, in the case of chuditch in the Kingston jarrah forest, the vegetation is unlikely to be dense enough for this to be a major factor.

An additional improvement to trapping technique is the use of free-swinging bait 'hooks' made of fencing wire. These are an effective means of reducing potential problems associated with ants. The 'hooks' should, however, be a completely closed loop rather than a hook in order to avoid injury to trapped animals, which has been observed (A. Wayne personal observation).

The quality of the meat meal used in the 'chuditch' bait is also particularly important. Meat meals may be highly variable between suppliers in their content, texture, consistency, smell and look. Darker coloured, strong smelling meat meal was thought to be more effective in deterring woylies and capturing chuditch than lighter coloured less pungent meals that appeared to have a higher fat and/or bone content.

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Table 1

Comparative trap success rates (%) for medium-sized mammals between 'chuditch bait' and 'universal bait' at Kingston, Batalling and Honeymoon Pool forests, Western Australia: Kingston bait trial percentage data are presented as the mean and standard error of four trapping sessions; ^ calculated from three trapping sessions; * 'Eau de chuditch' applied with chuditch bait; Chuditch/Universal (C/U) ratio of captures from traps with different bait.

	PRELIMINARY KINGSTON TRIAL			**KINGSTON BAIT TRIAL**			**BATALLING**			**HONEYMOON POOL**		
Bait type	Chuditch	Universal	C/U ratio	Chuditch	Universal	C/U ratio	Chuditch	Universal	C/U ratio	Chuditch	Universal	C/U ratio
Number of trap nights	720	720		2859	2895		180	180		150	150	
	%	%		%	%		%	%		%	%	
D. geoffroii	1.1	0.1	**8.00**	2.6 ± 0.7	0.4 ± 0.1	**7.00**	9.4	1.7	**5.67**	8.7	9.3	**0.93**
B. penicillata	7.0	42.9	**0.18**	25.5 ± 2.5	48.5 ± 2.5	**0.53**	37.8	67.2	**0.56**	0.0	0.0	
T. vulpecula	4.0	10.6	**0.38**	13.3 ± 1.4	15.8 ± 2.5	**0.84**	5.6	6.7	**0.83**	0.7	0.0	
I. obesulus	7.8	4.9	**1.60**	6.5 ± 0.8	4.6 ± 0.6	**1.42**	0.6	0.6	**1.00**	0.0	0.0	
Other captures	0.1	0.1	**1.00**	2.3 ± 0.7	1.1 ± 0.7	**2.05**	0.0	0.0		8.0	5.3	**1.50**
Total trap success	21.0	58.6	**0.36**	50.2 ± 3.0	70.3 ± 2.2	**0.71**	53.3	76.1	**0.70**	17.3	14.7	**1.18**
Traps disturbed	not recorded			^22.7 ± 1.3	^18.6 ± 1.1	**1.22**	17.8	18.3	**0.97**	not recorded		
Traps available	not recorded			^24,8 ± 3.8	^9.1 ± 2.0	**2.72**	28.9	5.6	**5.20**	not recorded		

Table 2

The number of trap captures for species caught during the comparative trial between 'chuditch' and 'universal' baits conducted in Kingston forest, Western Australia.

BAIT TYPE **TRAP NIGHTS**		**CHUDITCH BAIT** **2859**	**UNIVERSAL BAIT** **2895**
Woylie	*Bettongia penicillata*	730	1403
Koomal	*Trichosurus vulpecula*	379	453
Quenda	*Isoodon obesulus*	183	133
Chuditch	*Dasyurus geoffroii*	76	11
Southern Heath Monitor	*Varanus rosenbergi*	32	10
Bobtail Skink	*Tiliqua rugosa*	16	18
King's Skink	*Egernia kingii*	4	3
Black Rat	*Rattus rattus*	3	1
Wambenger	*Phascogale tapoatafa*	0	1
House Mouse	*Mus domesticus*	4	
Ngwayir	*Pseudocheirus occidentalis*	3	
Splendid Fairy-wren	*Malurus splendens*	2	
Feral Cat	*Felis catus*	1	
Gould's Monitor	*Varanus gouldii*	1	

Table 3

Gender and age distribution of chuditch individuals caught during the comparative bait trial ('chuditch bait' versus 'universal bait'), conducted in Kingston forest, Western Australia.

CHUDITCH CAPTURES	**CHUDITCH BAIT**	**UNIVERSAL BAIT**	**BOTH BAITS (C & U)**	**OVERALL**
No. Individuals	**36**	**9**	**6**	**39**
No. Male individuals	31	5	4	32
No. Femal individuals	5	4	2	7
No. Adult individuals	33	6	5	34
No. Subadult individuals	3	3	1	5