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Usefulness of funnel traps in catching small reptiles and mammals, with comments on the effectiveness of the alternatives

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Abstract. Funnel traps were used in conjunction with pit traps (PVC buckets and pipes), Elliott traps and cage traps at 10 sites in southern Western Australia to examine sampling bias of trap types. Funnel traps seldom catch small mammals but catch more of the medium-sized and large terrestrial, diurnal snakes and some of the widely foraging, medium-sized skinks, medium-sized dragon lizards and arboreal geckos that climb out of PVC pit traps. For pit traps, buckets catch more reptiles, particularly smaller ones, than pipes. However, pipes catch more mammals than buckets. Elliott traps catch the same suite of small mammals as pipes plus some of the large, trappable species, such as *Rattus* spp. Cage traps are useful for trapping *Tiliqua* spp. and medium-sized mammals such as possums and bandicoots that are unlikely to be caught in pit and funnel traps. Funnel traps, pit traps and cage traps should be used in surveys of small terrestrial vertebrates to determine species richness and relative abundance in Western Australia and probably elsewhere. However, as cage traps are mostly useful for catching *Tiliqua* spp. and medium-sized mammals, they need only be used in faunal surveys undertaken for environmental impact assessments specifically targeting these species.

Introduction

Researchers and environmental consultants routinely employ a range of trapping and detection strategies in terrestrial fauna surveys. However, if trap types have sampling bias and some trap types do not generally catch particular suites of taxa, then this could limit the data analysis and affect the interpretation of results. For example, if the purpose of a survey was to identify biogeographic patterns, species richness and areas of high conservation value (Burbidge *et al*. 2004) and only used a single trap type this could seriously compromise the results.

Pit trapping is commonly used to survey small terrestrial vertebrate fauna in a particular habitat. Funnel traps have been used in the United States for many years (Fitch 1951; Greenberg *et al*. 1994; Enge 1997, 2001; Jorgensen *et al*. 1998; Crosswhite *et al*. 1999) but rarely in Australia. Thompson *et al*. (2005) recently demonstrated that PVC buckets and PVC pipes used as pit traps each have a trapping bias, with buckets catching more of the common small and medium-sized reptiles, and pipes catching more mammals. Our observations are that pit traps undersample medium-sized and large snakes and medium-sized and large varanids, and some reptiles are apparently wary of pit traps. It was also evident that some species of geckos (e.g. *Gehyra variegata*) are able to climb the walls of PVC buckets and pipes, which meant that these species were undersampled. For these reasons, we supplemented our pit traps with funnel traps in an attempt to catch species not readily caught in pit traps.

Herein we compare the trapping bias of funnel traps with PVC buckets and pipes used as pit traps. Because we often used Elliott traps and wire cage traps to catch small and medium-sized mammals, we also report on the comparative usefulness of these trapping strategies.

Methods

Traps

We used two types of pit traps, funnel traps, Elliott and wire cage traps. PVC stormwater pipe (150 mm diameter; 500–600 mm deep) and PVC 20-L buckets were used as pit traps. A small sheet of polystyrene was placed in the bottom of all PVC buckets to provide protection from solar radiation as small reptiles and mammals can easily get underneath the styrene sheets. Small holes (2.5 mm) were drilled in the bottom of all buckets, and pipes had a fly-wire mesh over the bottom to stop the pit traps from filling with water and captures from burrowing out the bottom. Funnel traps were made of shade cloth and were ~750 mm long and 180 × 180 mm square with a funnel opening of 45 mm diameter at both ends (Fig. 1; www.terrestrialecosystems.com/funnels.htm). Elliott traps were made of aluminium and were 330 × 100 × 100 mm with a treadle mechanism to close the door. Wire cage traps were ~550 × 220 × 220 mm with a treadle mechanism to close the door. Elliott and cage traps were baited with a mixture of peanut butter, rolled oats and sardines. Funnel traps, Elliott and cage traps were covered with 90% shade cloth to provide protection from solar radiation. Either 300-mm-wide strips of flywire or 3-mm-thick by 300-mm-wide rolls of black plastic were used as drift fences. Drift fences were dug ~50 mm into the ground. Traps that had an excess of ants were dusted with Richgro's 'Ant Killer' (Richgro Garden Products, Canning Vale, Western Australia).

Study sites and trap layout

The primary source of data for this analysis comes from vertebrate fauna surveys undertaken in the Ora Banda region of

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Western Australia. The vegetation around Ora Banda ranged from eucalypt–casuarina–mulga woodland interspersed with acacia to sparse spinifex (*Triodia* spp.). Each of the 10 trapping sites at Ora Banda sampled a different vegetation assemblage that was typical of faunal habitat found in the Goldfields around Kalgoorlie. Most minesite waste dumps in the region had been seeded with chenopods, acacias and eucalypts. Five of these sites were in relatively undisturbed habitats, and the other five sites were on rehabilitated mining waste dumps and adjacent undisturbed areas. One site was trapped only during January 2004; all other sites were trapped during January 2004 and January 2006. Each of the undisturbed sites had eight trapping lines, and each of the five sites with waste dumps had an additional 12 trapping lines on the waste dump. Each trapping line had three PVC pipe pit traps, three PVC bucket pit traps and three pairs of funnel traps alternating along a 30-m flywire drift fence (Fig. 2*A*). Pit traps were installed during June 2000 and closed when not in use. Funnel traps were set in place at the beginning of each survey. Surveys were undertaken for a period of 14 days in January 2004 and January 2006. All traps were checked daily, as early as possible to minimise death from heat stress. Each captured animal was weighed and measured before being released near the point of capture but far enough away to minimise immediate recapture. Animals that had died or had been partially eaten, and large elapids were not weighed.

Given that our analysis of the Ora Banda data (see below) indicated that funnel traps sample the small vertebrate assemblage differently than pit traps, we also incorporated trapping data from nine other fauna surveys (at Greenough, Cervantes, Rockingham, Koolanooka, Yakabindie, Yanchep, Yallingup, Australind and Mt Gibson). The trapping protocols used in these surveys were standardised, but the trappable vertebrate assemblages differed, which enabled us to better demonstrate the bias among trap types. For these latter nine sites, each trapping line had one PVC pipe pit trap, one 20-L bucket pit trap and two pairs of funnel traps alternating along a 10-m drift fence (Fig. 2*B*). Elliott traps and wire cage traps were placed within 10 m of each drift fence. A summary of the location, number of habitats surveyed at each site, trapping period and trapping effort is in Table 1.

Fig. 1. Pair of funnel traps located either side of a drift fence with a shade cover. Insert: funnel traps showing zipper and shape.

Data analysis

The number of reptiles and mammals caught in pit traps (buckets and pipes) and funnel traps were compared using Chi-square tests. We have equated a pair of funnel traps with a single pit trap for analytical purposes so that all three trapping strategies could catch animals on either side of a drift fence. For the Ora Banda trapping program, there was the same number of buckets, pipes and pairs of funnel traps on each trapping line; therefore, the hypothesis tested in each Chi-square test was whether the catch rate for individual reptiles, mammals and amphibians differed significantly from a ratio of 1 : 1 : 1 of buckets : pipes : funnels. For all other sites, the number of buckets and pipes was half of the number of pairs of funnel traps for each trapping line; therefore, the hypothesis examined in each Chi-square test was whether the catch rate for individual reptiles and mammals differed significantly from a ratio of 1 : 1 : 2 of buckets : pipes : funnels.

For the Ora Banda data, where the number of individuals caught was appreciably greater than for the other sites, a Chi-square value was calculated for each family of reptiles and all amphibians and all mammals together to compare the frequency of catches among trap types. For some species there was also sufficient data for a Chi-square test. This level of analysis was not possible for the smaller samples at the other sites, as the expected cell numbers often dropped below 5 and violated a basic assumption of the Chi-square test. Analyses of all sites other than Ora Banda were therefore restricted to comparing the frequency of reptiles and mammals caught in each trap type. For taxa caught across most sites (e.g. *Tiliqua* spp.), ANOVA was used to determine significant differences among trap types. For sites other than Ora Banda, the number of individuals caught in

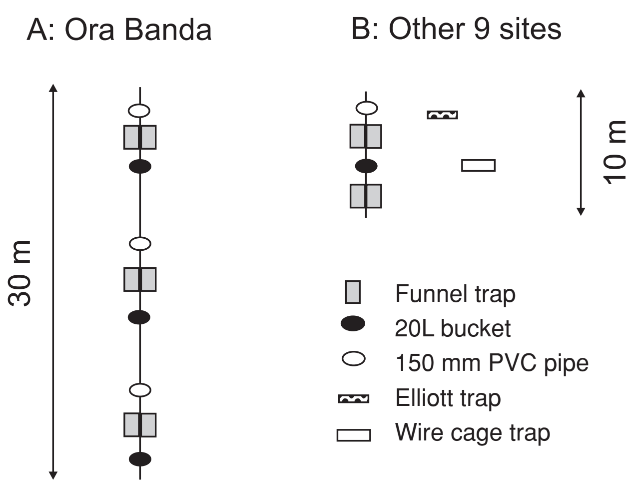

Fig. 2. (*A*) The layout of traps at Ora Banda. (*B*) The layout of traps at all other sites.

Table 1. Summary of the trap sites, trap-nights per habitat type and survey period

Site name	Latitude (S)	Longitude (E)	No. of habitat types	No. of PVC bucket trap-nights	No. of PVC pipe trap-nights	No. of funnel trap-nights	No. of Elliott trap-nights	No. of cage trap-nights	Survey period
Ora Banda	30°27′	121°03′	10	11424	11424	22848			14 days, January 2004 and 2006
Greenough	28°55′	114°40′	2	860	860	3440	1720	516	1–10 November 2005
Cervantes	30°30′	115°05′	1	555	555	2220	280	280	13–20 December 2004
Rockingham	32°12′	115°42′	4	600	600	2400	600	300	2–10 December 2004
Koolanooka	29°12′	116°12′	3	335	335	1340	335	268	16–25 March 2004
Yakabindie	27°08′	120°33′	3	760	760	3040	760	456	3–13 November 2004
Yanchep	31°32′	115°37′	2	785	785	3140	1570	580	14–24 November 2005
Yallingup	32°10′	115°02′	5	750	750	3000	1500	564	29 November – 9 December 2005
Australind	33°14′	115°43′	1	425	425	1700	850	425	7–15 March 2005
Mt Gibson	29°36′	117°24′	3	360	360	1440	395	288	8–16 March 2004

funnel traps was halved in the ANOVA because there were twice as many pairs of funnel traps as bucket and pipe pit traps. The Morisita–Horn similarity index score was calculated for the trapped assemblage in buckets, pipes and funnel traps using EstimateS (Colwell 1997) software for the Ora Banda data.

Body masses of all reptiles measured at Ora Banda were log-transformed and sorted into a monotonically increasing line. All log-transformed body mass data were then grouped into 10 categories (–1.2 to 2.80 at 0.4 intervals). A Chi-square test was used to determine whether the frequency of individuals caught in each of the body-mass groups differed among buckets, pipes and funnel traps. To determine significant differences among groups, $\alpha = 0.05$ was used for all tests.

Results

For Ora Banda, 2740 reptiles, 190 amphibians and 619 mammals were caught in pit and funnel traps during the two January survey periods. There was a significant difference in the frequency of reptiles ($\chi^2_2 = 125.1$, $P < 0.01$), amphibians ($\chi^2_2 = 52.5$, $P < 0.01$) and mammals ($\chi^2_2 = 314.3$, $P < 0.01$) caught using the three trapping methods. For reptiles, more individuals were caught in buckets, and fewer in pipes than would have been expected if trap type made no difference. Fewer amphibians were caught in funnel traps than in buckets and pipes. Of the 619 mammals caught, only five were caught in funnel traps, and more were caught in pipes than in buckets. Details of the number of individuals of each species caught in each trap type can be found in an online Accessory Publication at the Wildlife Research website.

The body mass ranges for reptiles caught in buckets, pipes and funnel traps differed significantly ($\chi^2_{18} = 94.2$, $P < 0.001$). Buckets caught more reptiles in all categories except the largest two (Fig. 3). Reptiles in the two largest categories were dominated by adult *Varanus gouldii*, which were only caught in funnel traps and pipes.

The Morisita–Horn similarity index scores indicated that the trapped assemblage for buckets and pipes was more similar (0.92) than for funnel traps and buckets (0.65), and for funnel traps and pipes (0.58). In all, 47 species of reptiles were caught in both buckets and funnel traps and 39 in pipes. Seven species of mammals were caught in buckets, nine in pipes and four in funnel traps.

Capture rates differed significantly for each of the reptile families. More agamids were caught in buckets and fewer in pipes ($\chi^2_2 = 24.1$ $P < 0.01$), more skinks were caught in buckets and funnel traps than in pipes ($\chi^2_2 = 34.7$, $P < 0.01$), more geckos

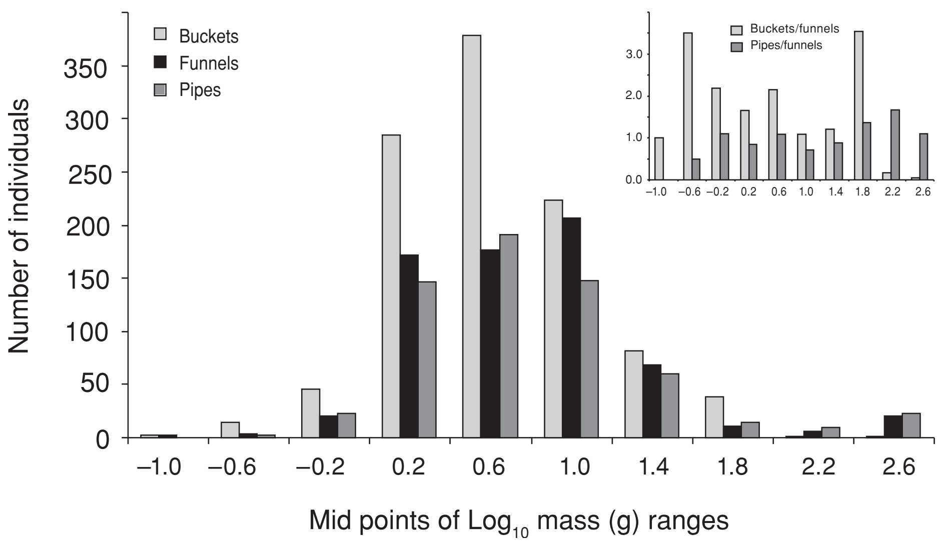

Fig. 3. Number of reptiles caught in 10 $\log_{10}$(mass) categories for each funnel and two pit trap types. The insert indicates the ratio between the three trap types.

were caught in buckets than in pipes (χ^2_2 = 68.0), more varanids were caught in funnel traps than in pipes (χ^2_2 = 11.6, $P < 0.01$), more blind snakes were caught in buckets than in pipes and funnel traps (χ^2_2 = 64.6, $P < 0.01$), and more elapids were caught in funnel traps than in buckets and pipes (χ^2_2 = 50.2, $P < 0.01$).

Some genera and species of reptiles were caught predominantly in one or two trap types. At the species level, there was no significant difference among trap types for nine species, but there was a difference for 28 species. *Underwoodisaurus milii*, *Tiliqua* spp. and *V. gouldii* were mostly caught in funnel traps. In contrast, *Diplodactylus* spp., *Pogona minor*, *Rhynchoedura ornata*, *Varanus caudolineatus*, *Delma australis*, *Ramphotyphlops hamatus* and *R. australis* were mostly caught in buckets. *Egernia inornata* was mostly caught in buckets and pipes.

A summary of the number of reptiles and mammals caught in pipes, buckets and funnel traps for the nine other sites (Greenough, Cervantes, Rockingham, Koolanooka, Yakabindie, Yanchep, Yallingup, Australind and Mount Gibson) is shown in Table 2 (and further detail of the catch by species is provided in the Accessory Publication). The proportion of reptiles caught in the three trap types differed significantly for six of the nine sites and for five of the sites for mammals. We had insufficient data to use a Chi-square test to examine difference for mammals at four of the sites. Catch rates varied appreciably for reptiles and mammals for each trap type among sites (Table 2).

Tiliqua spp. were significantly more likely (ANOVA: $F_{2,21}$ = 5.03, $P < 0.02$) to be caught in funnel traps than in pit traps at all sites where they were encountered (e.g. Ora Banda, Greenough, Yanchep, Yallingup and Australind). Medium-sized and large, diurnal, actively foraging snakes (e.g. *Demansia* spp., *Pseudonaja* spp., *Pseudechis* spp.) were significantly (ANOVA: $F_{2,21}$ = 5.6, $P < 0.05$) more likely to be caught in funnel traps than in buckets or pipes at all sites.

Elliott and wire cage traps

The only reptile species caught in wire cage traps at Greenough, Cervantes, Rockingham, Yanchep and Australind were *Tiliqua* spp. At Yallingup, 59 *T. rugosa* and one *Acritoscincus trilineatum* were caught in wire cage traps. Although the *A. trilineatum* individual was caught in the treadle mechanism of the trap. Elliott traps occasionally caught reptiles in addition to *Tiliqua* spp. Elliott traps frequently caught *M. musculus* and occasionally other small mammals. There was no difference in the number of small mammals that were caught per 100 trap-nights in Elliott and cage traps (ANOVA: $F_{1,16}$ = 1.55, P = 0.22), nor was there a difference in the number of small mammals caught in pipes and Elliott traps (ANOVA: $F_{1,16}$ = 0.71, P = 0.41).

Catch rates in Elliott traps varied from nil to 0.70 (mean 0.22) individuals per 100 trap-nights for reptiles and 0.25 to 4.64 per 100 trap-nights for mammals (mean 1.50) (Table 2). Catch rates in cage traps varied from nil to 10.64 for reptiles (mean 2.18) and nil to 2.50 per 100 trap-nights for mammals (mean 0.72).

Discussion

This study supports the conclusions of Thompson *et al*. (2005) that PVC buckets catch more reptiles and more of the common small and medium-size reptiles than PVC pipes, which catch more mammals and the larger of the small mammals. Greenberg *et al*. (1994) reported that in the sclerophyllous shrub-dominated ecosystem of Florida, pit traps and funnel traps sampled the fauna assemblages differently. Pit traps caught fewer species but yielded more individuals of many species. Pit traps caught more of the surface-active lizards, frogs and small semifossorial herpetofauna species, whereas the capture of large snakes was restricted to funnel traps. Greenberg *et al*. (1994) reported that

Table 2. Number of individuals caught in various trap types at the nine sites

P-values from Chi-square test comparing capture rates for reptiles and mammals in pipes, buckets and funnels (detailed information in the Accessory Publication) and number of individuals caught per 100 trap-nights; ‘insuf’ = insufficient data for a Chi-square analysis

Study site	Taxon	*P*	Buckets	Pipes	Funnels	Number of individuals caught per 100 trap-nights				
						Buckets	Pipes	Funnels	Elliott	Cages
Ora Banda	Reptiles	<0.01	1150	672	918	10.07	5.88	8.04		
	Mammals	<0.01	262	352	5	2.29	3.08	0.04		
Greenough	Reptiles	<0.01	42	13	147	4.88	1.51	8.55	0.00	0.97
	Mammals	<0.01	20	16	3	1.86	2.33	0.17	1.05	0.97
Cervantes	Reptiles	<0.01	14	4	100	2.52	0.72	9.01	0.00	2.50
	Mammals	<0.01	16	7	0	2.88	1.26	0.00	4.64	2.50
Rockingham	Reptiles	<0.01	65	14	128	10.83	2.33	10.67	0.00	0.67
	Mammals	<0.01	131	92	1	21.83	15.33	0.08	2.17	0.67
Koolanooka	Reptiles	0.005	18	3	31	5.37	0.90	4.63	0.00	0.00
	Mammals	insuf	1	3	2	0.30	0.90	0.30	2.99	0.00
Yakabindie	Reptiles	0.10	34	23	76	4.47	3.03	5.00	0.00	0.22
	Mammals	<0.01	9	14	1	1.18	1.84	0.07	1.32	0.00
Yanchep	Reptiles	<0.01	75	28	280	9.55	3.57	17.83	0.70	2.76
	Mammals	<0.01	21	23	1	2.68	2.93	0.06	0.51	0.00
Yallingup	Reptiles	<0.01	100	23	303	13.33	3.07	20.20	0.67	10.64
	Mammals	insuf	2	1	1	0.27	0.13	0.07	0.27	0.00
Australind	Reptiles	<0.01	158	86	109	37.18	20.24	12.82	0.59	1.88
	Mammals	insuf	6	6	0	1.41	1.41	0.00	0.35	2.35
Mt Gibson	Reptiles	0.06	22	9	37	6.11	2.50	5.14	0.00	0.00
	Mammals	insuf				0.00	0.00	0.00	0.25	0.00

pit-traps and funnel traps yielded similar estimates of relative abundance for lizards and frogs, but not for large snakes. Jorgensen *et al*. (1998) reported a bias in catch rates for the iguanid *Uta stansburiana* and the whiptail teiid *Cnemidophorus marmoratus*, with pit traps catching more of the whiptail skink. We report here both similarities and differences in the bias between pit and funnel traps for herpetofauna. More large snakes were caught in funnel traps than in pit traps, as reported by Greenberg *et al*. (1994); however, more of the widely foraging, medium-sized skinks were caught in funnel traps, which is different to the results reported by Jorgensen *et al*. (1998). Funnel traps are also better at catching medium-sized dragon lizards and the arboreal geckos that climb out of pit traps.

Reptiles in pit traps and funnel traps

Relative to buckets and pipes, catch rates for funnel traps varied appreciably and this was related to the composition of the species assemblage trapped. For example, at Cervantes, funnel traps caught more reptiles than did buckets and pipes combined, because most of the reptiles caught were *Ctenotus fallens. C. fallens* is a medium-sized, robust, widely foraging terrestrial skink. This same skink was also caught in appreciably higher numbers in funnel traps than in pit traps at Rockingham and Yanchep. A similar pattern was also evident for *Ctenotus australis* at Yanchep and for *Morethia lineoocelata*, *A. trilineatum* and *C. impar* at Yallingup. However, at Australind, *M. lineoocelata* was caught in higher numbers in buckets than in funnel traps and pipes. The mean catch rate for buckets and pairs of funnel traps for reptiles at all sites were very similar: 10.43 versus 10.19 per 100 trap-nights respectively. Catch rates for reptiles in pipes was much lower, with a mean for all sites of 4.37 per 100 trap-nights.

Some species were either caught only in funnel traps, or only the juveniles of the species were caught in pit traps. For example, all *Ctenophorus cristatus* caught in buckets at Ora Banda were hatchlings, whereas those caught in funnel traps were adults; at Mt Gibson, the four *C. cristatus* caught in funnel traps were all adults, and none were caught in buckets or pipes. *C. cristatus* is a medium-sized agamid with long hind limbs that is wary of being caught in pit traps, and adults can jump out of PVC buckets. The *Demansia psammophis* caught in a pit trap at Ora Banda was a juvenile; the rest were adults caught in funnel traps. An unusually high number of *D. psammophis* were caught at Greenough, and, had funnel traps not been used, then it is unlikely that any would have been caught. Most medium-sized and large terrestrial and diurnal snakes were also predominantly caught in funnel traps. We have watched *Pseudechis australis* and *Pseudonaja affinis* move along a drift fence going into every bucket and pipe, devouring any trapped prey before moving on. Very few large snakes were ever caught in pit-traps, so we presumed that almost all that entered pit-traps got out. More medium-sized and large snakes were caught in funnel traps, and we are unsure how many got out as it is possible for them to find the opening at either end. We can only conclude that more snakes were caught in funnel traps than in pit traps.

Arboreal geckos, such as *G. variegata* and *Strophurus* spp., can climb out of PVC buckets and pipes. It is therefore highly likely that these species are undersampled if only these two trap types are used. Robust, widely foraging skinks, such as *C. fallens* and *C. australis*, are generally caught in much higher numbers in funnel traps than in buckets or pipes. The obvious consequence is that if only pit traps are used, then these species are likely to be under-represented in the sample.

Elliott and cage traps are useful for catching *Tiliqua* spp. These relatively large skinks are seldom caught in buckets or pipes.

Mammals in pit traps and funnel traps

In contrast to reptiles, few small mammals were caught in funnel traps, and more were caught in pipes than in buckets. The reason why few mammals were caught in funnel traps is not fully understood. However, small rodents and marsupials readily chewed a hole through the shade cloth and escaped from funnel traps. It is also possible that they escaped out of the two funnel holes. It is probable that more mammals are caught in narrow, deeper pipes than in buckets because it is more difficult for them to jump out of a pipe than a bucket (Thompson *et al*. 2005).

Elliott traps

Elliott traps caught many of the small mammals, such as *M. musculus*, *R. fuscipes*, *R. rattus* and *Pseudomys* spp., but these same species were also readily caught in pipes and buckets. Elliott traps are much easier to deploy than buckets and pipes, and were used for this reason. With an adequate trapping effort, it is probable that all the small mammal species that will be caught in Elliott traps will be caught in pit traps, so, to an extent, Elliott traps duplicate pipes when used as pit traps.

Cage traps

Cage traps occasionally caught small mammals such as *M. musculus* and were useful in catching *Tiliqua* spp. However, they were most useful in catching the medium-sized mammals, such as *Trichosurus vulpecula* (common brushtail possum) and *Isoodon obesulus* (southern brown bandicoot), which can also often be detected by spotlighting, tracks and diggings. In most circumstances in Western Australia, a search of the Western Australian Museum database (e.g. *FaunaBase*) and the literature would indicate suitable habitat and the geographic distribution of these species. So instead of routinely employing cage traps in fauna surveys undertaken for the purposes of preparing environmental impact assessments, we suggest that they be used only when medium-sized mammals, such as brushtail possums, bandicoots, quolls, etc., are being targeted. In this circumstance, cage traps can be located in habitat likely to contain the species being targeted.

Funnel traps

Elliott and wire cage traps are routinely baited, but we decided not to bait funnel traps for two reasons. First, the peanut butter, rolled oats and sardine bait attracts ants, and ants will damage and/or kill reptiles and small mammals confined in traps for extended periods. Where we encountered an ant problem in an Elliott or wire cage trap we normally moved the trap a couple of metres to address the problem. Funnel traps were evenly spaced along drift fences and thus there was limited, if any opportunity for moving them to other locations. Second, washing and cleaning Elliott and wire cage traps at the conclusion of field work to get rid of bait is relatively easy, whereas cleaning bait from the cloth of funnel traps is often more difficult. Given these issues, we used funnel traps primarily to trap reptiles and used pit-traps, Elliott and wire cage traps to sample mammals. Our preference is not to bait funnel traps, but others may wish to use bait to increase catch rates, although these will be offset by problems with ants and cleaning traps.

Our experience is that reptiles and small mammals caught in funnel traps are more exposed to heat stress than those caught in pit traps. Pit-traps buried in the ground offer some protection against heat stress when the ambient temperature at ground level exceeds 40°C. In addition to covering Elliott and wire cage traps with shade cloth, we endeavoured to place traps under vegetation to minimise solar exposure. However, these strategies are not possible for funnel traps. Funnel traps therefore need to be cleared earlier in the day than pit traps to avoid deaths from heat stress on hot days. Shade cloth (70% and 90%) covers provide better protection than lower-density shade cloth.

Small mammals, centipedes and some beetles chewed holes in the shade cloth walls of funnel traps. This required damaged traps to be repaired and/or replaced. The first version of our funnel traps was constructed of much lighter netting and damage was more frequent than is the case for the funnel traps made with 70% shade cloth, which was used on an earlier model. In an earlier model the zipper was about one-third of the length of the funnel trap. This has been modified to extend the zipper along the entire length of each funnel trap (Fig. 1) to facilitate the removal of venomous snakes. However, we caution that care must be taken in catching small mammals and fast-moving reptiles from funnel traps with long zippers as they can easily elude initial attempts to be caught by hand and can escape through the zipped opening.

Catch rates

Catch rates varied among sites and trap types. For reptiles, mean capture rates indicated that one in 10 buckets and funnel traps caught an individual in each 24-h period, and pipes caught about half that number. For mammals, the catch rate was much lower, with 3–4 individuals being caught per 100 trap-nights in buckets and pipes in each 24-h period. The composition of the trappable assemblage, relative abundance of individuals, and ambient weather conditions significantly influenced catch rates.

Implications for fauna surveys

Where fauna surveys are undertaken to record the presence of species only (e.g. McKenzie *et al*. 2000; Burbidge *et al*. 2004), then it is important that the sampling program employs a range of trap types to maximise the probability of all species being detected, particularly if the trapping effort is low. For example, in the regional studies reported by McKenzie *et al*. (2000) and Burbidge *et al*. (2004), funnel traps were not used, and the trapping effort at each site was relatively low; therefore, it is probable that several species were undetected. In both of these studies, the catch rates for snakes, particularly the medium-sized and large ones, was very low, and the authors conceded that snakes were unlikely to be caught using their trapping protocols, so these species were deleted from the analysis. In the wheatbelt regional survey reported by Burbidge *et al*. (2004), only pipe pit traps were used, so it is likely that there was bias in the sampling and numerous species were not caught in each habitat type.

Where the objective of a survey is to record both species richness and relative abundance, the combination of trap types used will significantly influence the result. The Cervantes and Greenough data provide examples to illustrate this point. If only pit traps were used at Cervantes, then the very high number of *C. fallens* and possibly *S. spinigerus* would have gone undetected. At Greenough, the unusually high number of *D. psammophis* would have also gone undetected, and the conclusions about relative abundance of *S. spinigerus* and *G. variegata* could have been erroneous. So what combination of trap types should be employed to accurately assess species richness and relative abundance? For species richness, a combination of PVC bucket and pipe pit traps, funnel traps and cage traps is necessary. Even then, the larger mammals such as *Tachyglossus aculeatus* and *Macrotis lagotis* that are not attracted to the bait (e.g. peanut butter, rolled oats and sardines) will probably not be caught, because their diet is predominantly termites, ants, seeds, bulbs, fruit and fungi (Augee 2000; Gibson 2001). However, the presence of some of these species is easily detected because of their characteristic diggings and scats (e.g. *T. aculeatus*, *M. lagotis*). Large snakes (e.g. *Liasis olivaceus*) and goannas (e.g. *V. panoptes*, *V. giganteus*) might also be too large to fit into funnel traps and will easily get out of pit traps. Detection of these species in an area will require species-specific searches, which identify characteristics of their ecology and behaviour that facilitate finding them.

In contrast to more general faunal surveys, targeted species-specific searches will require that appropriate trapping strategies are employed to maximise catches. For example, Elliott traps have proven to be useful in catching mulgara (*Dasycercus cristicauda*), although this species can be caught in pit traps (Masters 2003).

Determination of relative abundance is much more difficult, as most trap types have a bias. This question can adequately be addressed only by sampling multiple areas with various trap types and then undertaking an exhaustive search of the area such that every reptile and small mammal is caught. This is an intensive, time-consuming and destructive process (Rodda *et al*. 2001).

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