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Comparative temperature in funnel and pit traps

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Abstract. The temperature in pit and funnel traps with various shade-cover treatments on the two hottest days in Perth in the summer of 2008/09 were examined. Lethal temperatures for small mammals and reptiles were experienced in pipe and bucket pit-traps and funnel traps without covers on both days. Funnel traps with shade covers provided similar or better protection from solar radiation than buckets, pipes and funnel traps without covers. A breeze reduced temperatures in funnel traps more than it did in bucket and pipe pit-traps. It is recommended that all funnel traps deployed during fauna surveys be protected by a shade cover and during hot conditions a second shade cover should be used.

Introduction

Funnel traps are now frequently used in terrestrial fauna surveys in Australia (Thompson and Thompson 2007; Ninox Wildlife Consulting 2008; Ecologia Environmental 2009; Everard and Bamford 2009); however, concern has been expressed about their potential to expose captured animals to higher levels of heat stress when compared with other trap types. For example, Thompson and Thompson (2007) suggested that reptiles and mammals caught in funnel traps were more exposed to heat stress than those caught in pit-traps, and Biota Environmental Sciences (2008) reported that funnel traps were not utilised during its survey of the Marandoo mine site during both its March/April and November surveys owing to high diurnal temperatures that would potentially increase the incidence of trap deaths. In 2008, the Western Australian Government released a tender to undertake a comprehensive survey of the fauna on the Dampier Peninsula to support a strategic environmental review and recommended against the use of funnel traps in the wet season because of the potential for extreme weather conditions to adversely affect captured animals.

A diverse trapping methodology is necessary to adequately assess the vertebrate fauna assemblage for an area and this should include funnel traps (Sealander and James 1958; Greenberg *et al*. 1994; Jorgensen *et al*. 1998; Thompson *et al*. 2005; Thompson and Thompson 2007). If some trap types are more prone to heat, researchers, environmental consultants and naturalists undertaking fauna surveys are confronted with an ethical dilemma. They can undertake a survey using a diverse range of traps and risk killing more animals due to heat stress or exclude specific trap types from the survey and acknowledge that they have not accurately represented the faunal assemblage in the survey sample.

The objective of this investigation was to compare the temperature in funnel traps with those in pit-traps and to make recommendations on how to minimise the potential impact of heat stress on captured small vertebrates for both trapping procedures.

Methods

This investigation was conducted on the hottest two sequential days during the 2008/09 summer in Perth, Western Australia. The experiment was undertaken on undeveloped open space in full sunshine. The substrate was grey sand with no vegetation.

PVC buckets (20 L) and PVC stormwater pipes (150 mm diameter), which are commonly used as pit-traps, and funnel traps were used in this experiment. Ten PVC buckets (290-mm-diameter opening and 390 mm deep) and five 500-mm lengths of PVC pipe were buried in the ground so that the surface was flush with ground level. Five of the buckets had their lid suspended 300 mm directly over the bucket, so that when the sun was directly overhead, it shaded the entire bottom. As the sun moved in either direction a section of the bottom of the bucket was exposed to sunlight until the angle of incidence changed and the entire bottom of the bucket was shaded. All buckets contained two sheets of white polystyrene (125 × 140 × 3 mm). These polystyrene sheets had slightly up-turned edges so that they provided a gap (~5 mm) between the sheets. In trapping surveys polystyrene sheets are placed in the bottom of buckets to provide caught fauna with protection from solar radiation and predation, and the sheets float when buckets fill with rainwater.

Twenty-five pairs of funnel traps (90% green shade cloth, 750 mm long and 180 × 180 mm square with a funnel opening of 45 mm diameter at each end) were used in this experiment, with five pairs of funnel traps being allocated to each of the following treatments. Funnel traps either had no cover (Funnel 0), a single shade cover (Funnel 1), two shade covers (Funnel 2), one shade cover that was covered with a sheet of aluminium foil

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(Funnel 1+1) or a single shade cover that was covered with a sheet of aluminium foil with a similar sheet of aluminium foil placed under the funnel trap (Funnel 1+2). Shade covers were placed on top of each pair of funnel traps and draped over the sides to cover most of the trap.

Shade covers are made from 90% green shade cloth and have wooden battens along two sides to ensure that they do not blow off. We included aluminium foil sheets over and under funnel traps to determine whether reflecting solar radiation and ground heat would provide added protection to trapped fauna from heat stress (see Hobbs and James 1999).

The two hottest sequential days (15–16 January 2009) in the summer of 2008/09 in Perth were selected for this experiment so that the highest potential trap temperatures might be recorded and therefore demonstrate the extreme temperatures that captured fauna can experience.

The surface temperature in the bottom of the pit-traps was measured every hour from 08:00 hours until 18:00 hours (sunrise was at 06:25 hours). Temperature was recorded using a non-contact infrared Digitech (model QM 7221) thermometer with dual laser targeting. When all or part of the bottom of a pit-trap was exposed to sunlight, the temperature was recorded in the shade, in the sun and the coolest place under the two layers of polystyrene. The surface temperature in the middle of the inside of the bottom of each funnel trap was also recorded using the Digitech infrared thermometer. Ambient temperature was recorded ~1 m above the ground in an area that was in constant shade all day and surface soil temperature was recorded adjacent to the first bucket pit-trap. All surface temperature recordings in traps were taken in locations where captured animals would typically be found during standard fauna surveys. No animals were caught during this experiment.

Data analysis

Each trap was sampled on 11 occasions each day (e.g. hourly) for two days; as a consequence, 'time' and 'day' were treated as two repeated factors in an ANOVA (Statistica V7). In the primary analysis, the coolest temperature (e.g. in the shade when the bottom of the pit-trap was exposed to partial sunlight) was used. In addition, when the bottom of a pit-trap was exposed to partial sunlight, a comparison was made between the temperature in the sun and in the shade, and for buckets also under the polystyrene sheets, using a two-factor repeated-measures ANOVA. A comparison of temperatures in all trap treatments was also made at 10:00 hours, ~3.5 h after sunrise. This time was selected because on days with high ambient temperatures we would endeavour to have cleared all traps by this time. A *post hoc* Tukey test was used to determine differences among treatments in the ANOVA.

Maximum ambient temperatures recorded on 15 and 16 January 2009 at the Perth Bureau of Meteorology (http://www.bom.gov.au/climate/dwo/200901/html/IDCJDW6111.200901.shtml) were 39.7°C and 41.8°C respectively with minimum ambient temperatures of 18.8°C and 22.7°C on these days. There was no cloud cover on either day and a slight breeze was noticed on Day 1 between 14:00 and 15:00 hours. There was almost no breeze on Day 2 until just after 11:00 hours, when the wind speed increased until it declined again between 15:00 and 16:00 hours. Wind speed was not measured, but was noted by the recorder as 'no wind', 'slight breeze', 'breeze' and 'windy'.

Results

There was a significant difference in temperatures for the various trap-types and a significant interaction between trap-type temperatures, time of day and day (Table 1; Figs 1, 2). A major contributor to the interaction between days was the breeze on Day 2 that resulted in a drop in the temperature in funnel traps that was not evident for buckets and pipes.

At least a part of the bottom of all buckets was exposed to partial sunlight when the temperature was measured between 12:00 and 15:00 hours. There was a significant difference ($F_{23,216} = 25.6$, $P < 0.001$) among temperatures for the area exposed to direct sun, the area in the shade and the area under the polystyrene sheets, with a significant interaction among day, time and treatment in buckets (Table 2). There was a significant difference ($F_{2,27} = 63.7$, $P < 0.05$) in the temperature in buckets in the sun, under the polystyrene covers and in the shade, with the temperature in the sun being the highest on all occasions. In addition, the temperature in the shade in the bucket was significantly lower ($F_{1,18} = 5.8$, $P < 0.05$) than under the polystyrene covers. Temperatures in the sun at the bottom of the buckets were higher than the ground temperature, and temperatures in the shade at the bottom of the buckets were higher than ambient shade temperatures.

Temperatures were significantly higher in the sun than in the shade when pipes had partial sunlight on the bottom when measured at 13:00 and 14:00 hours (Table 2). Temperatures in the sun at the bottom of the pipes were higher than ground temperatures and temperatures in the shade at the bottom of pipes were appreciably higher than ambient shade temperatures.

On Day 1, the temperatures recorded in Funnels 1+1 remained close to the lowest recorded temperatures between 12:00 and 16:00 hours, when the temperature in all traps except pipes were within 4°C of each other (45.6–49.50°C) and were probably lethal for most small mammals and reptiles (Fig. 1). The temperatures in Funnels 1+1 were ~1.5°C below that in Funnels 2. Funnel traps with shade covers showed a more rapid reduction in internal temperature than did pipes and buckets after the breeze increased. Temperatures in Funnels 1, 2, 1+1 and 1+2 dropped appreciably when the breeze strengthened after 11:00 hours on Day 2, but then increased again when the breeze dropped between 15:00 and 16:00 hours (Fig. 2). On Day 2, when the temperature in funnel traps was lowered by the breeze after 11:00 hours, the temperature in pipes continued to increase, peaking at 14:00 hours at a level similar to that in buckets without polystyrene sheets. Funnels 1, 2,

Table 1. ANOVA results for a comparison among trap types

Source	d.f.	*F*	*P*
Treatment (i.e. trap type)	7	13.74	<0.05
Day	1	99.11	<0.05
Time	10	746.79	<0.05
Day*Time	10	380.03	<0.05
Day*Treatment	7	7.58	<0.05
Time*Treatment	70	14.74	<0.05
Day*Time*Treatment	70	10.56	<0.05

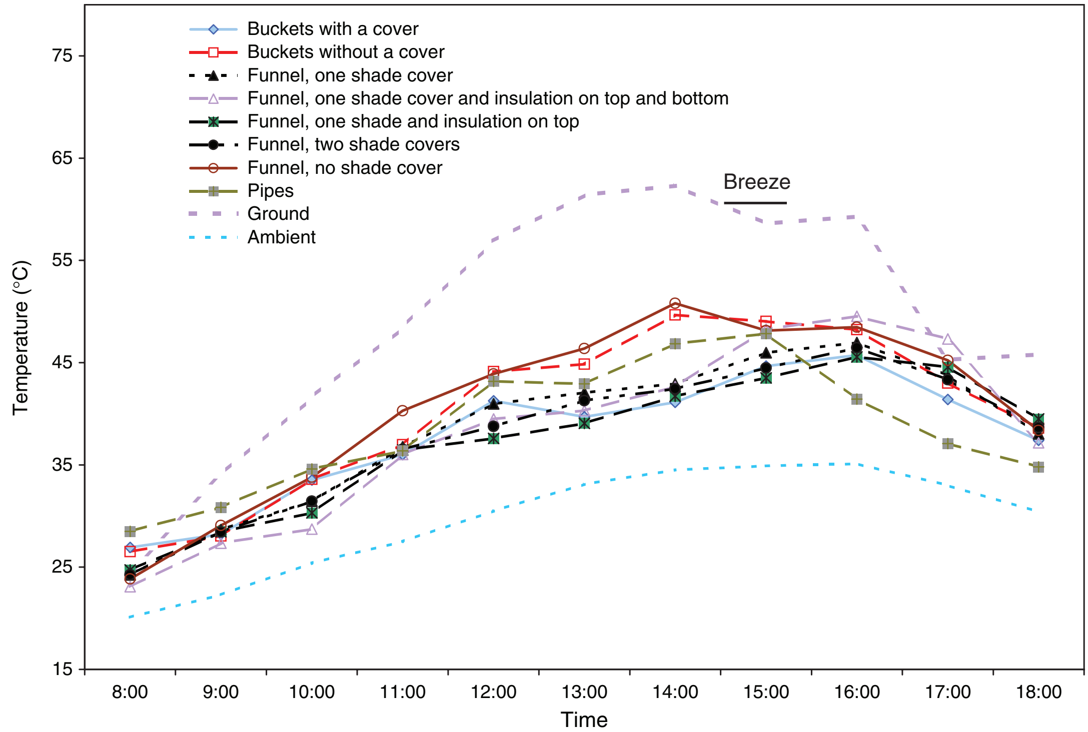

Fig. 1. Trap, ground and ambient temperatures for Day 1.

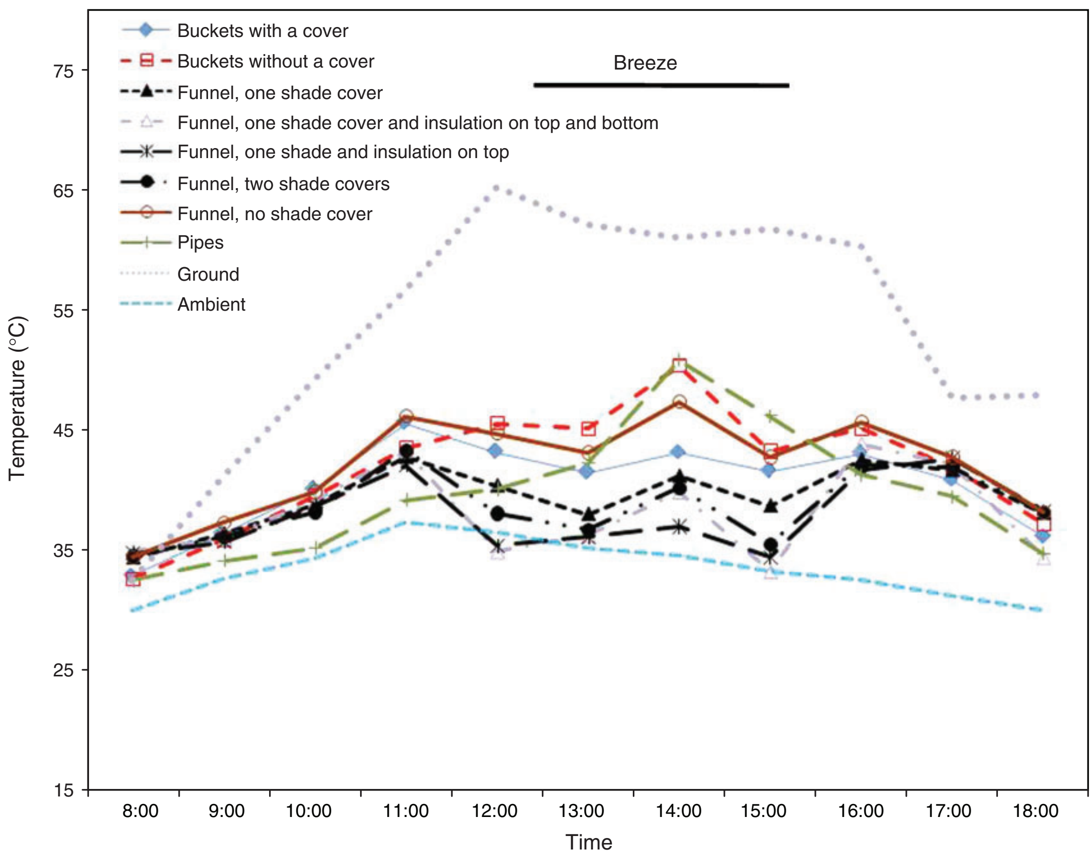

Fig. 2. Trap, ground and ambient temperatures for Day 2.

Table 2. Mean temperature (°C) on the bottom of pit-traps with no shade, shade and under polystyrene sheets
Letters in parentheses indicate that the temperature is significantly ($P < 0.05$) different from the temperature in the treatment corresponding to the letter

Day	Location		Buckets				Pipes	
			12:00 hours	13:00 hours	14:00 hours	15:00 hours	13:00 hours	14:00 hours
1	Sun (a)		68.2 (b,c)	63.1 (b,c)	70.0 (b,c)	68.1 (b,c)	72.4 (b)	81.3 (b)
	Shade (b)		42.7 (a)	42.3 (a)	45.4 (a)	46.9 (a)	42.9 (a)	46.8 (a)
	Under polystyrene sheets (c)		43.6 (a)	47.5 (a)	49.4 (a)	49.8 (a)		
	Ground		56.9	61.4	62.3	58.6	61.4	62.3
	Ambient air in the shade		30.5	33.1	34.5	34.9	33.1	34.5
	Ambient minimum for the day	18.8						
	Ambient maximum for the day	39.7						
2	Sun (a)		66.8 (b,c)	64.6 (b,c)	68.4 (b,c)	72.8 (b,c)	71.5 (b)	71.5 (b)
	Shade (b)		44.3 (a)	43.2 (a)	46.6 (a)	42.3 (a,c)	42.2 (a)	42.2 (a)
	Under polystyrene sheets (c)		46.4 (a)	47.8 (a)	53.3 (a)	50.5 (a,b)		
	Ground		65.2	62.1	61.0	61.7	62.1	61.0
	Ambient air in the shade		36.5	35.2	34.6	33.2	35.2	34.6
	Ambient minimum for the day	22.7						
	Ambient maximum for the day	41.8						

1+1 and 1+2 performed the best in keeping the temperature low after the breeze strengthened on Day 2.

There were significant differences among treatments (e.g. trap types) ($F_{1,7} = 13.19$, $P < 0.001$) and a significant interaction between day and treatments at 10:00 hours (Table 3). At 10:00 hours on Day 1, temperatures were lowest in covered funnels and on Day 2 they were lowest in pipes.

Discussion

Covers on funnel traps reduced the internal temperature during the hottest period of the day. During the middle of the day the hottest traps were pipes and buckets without polystyrene sheets and funnels without covers. A breeze had the greatest effect on reducing the internal temperatures in funnels with covers compared with pipes and buckets.

For most diurnal lizards, the preferred active body temperature is within the range 34–39°C, and for nocturnal geckos between 23 and 32°C (Light *et al*. 1966; Pianka 1986; Greer 1989). Agamids (32–39°C) and varanids (34–38°C) generally have a preferred body temperature higher than for skinks (30–34°C) (Pianka 1986; Greer 1989). Critical thermal maximum or lethal body temperatures are between 42 and 47°C for most reptiles (Curry-Lindahl 1979; Greer 1989). Periods of prolonged exposure often result in death at a lower temperature; however, many individuals are able to survive short periods at higher than recorded critical thermal maximum body temperatures (Curry-Lindahl 1979). For mammals, body temperatures of 42–45°C are often lethal (Erskine and Hutchison 1982), but the ability to actively regulate body temperature by panting and through other heat-loss strategies means that some mammals are able to survive in higher ambient temperatures for a short period before they become dehydrated.

Table 3. Mean temperature (°C, ±1 s.e.) in various trap types at 10:00 hours on each day of the study
$n = 5$ for each treatment

	Day 1	Day 2
Buckets with a polystyrene sheets	33.5 ± 0.78	40.0 ± 0.71
Buckets without polystyrene sheets	33.6 ± 0.55	39.5 ± 0.74
Pipes	34.6 ± 0.20	35.1 ± 0.50
Funnel 0	33.8 ± 0.57	39.8 ± 0.34
Funnel 1	31.4 ± 0.21	38.8 ± 0.08
Funnel 2	31.4 ± 0.25	38.2 ± 0.28
Funnels 1+1	30.3 ± 0.24	38.6 ± 0.24
Funnels 1+2	28.7 ± 0.14	39.1 ± 0.37

Ground temperature on both days increased beyond the lethal limit for all reptiles and probably most small mammals if they had to remain in the sun. On both days, any animals caught in pit-traps without polystyrene sheets would have almost certainly died when the sun was directly overhead. On Day 1, temperatures in funnel traps without shade covers would have been high enough to kill most of the small vertebrate fauna. On Day 2, before the breeze strengthened after 11:00 hours, the temperature in Funnels 0 and buckets with polystyrene sheets were probably near the lethal limit for most reptiles and mammals. However, any animal caught on Day 2 in Funnels 1, 2, 1+1 or 1+2 may have survived until the breeze dropped off after 15:00 hours.

Hobbs and James (1999) compared five covers for pit-traps (lids propped against the drift fence on the north and south aspects, brown cardboard in the bottom of buckets and a double-sided building insulation foil in the bottom of buckets and double-sided insulation foil placed over the drift fence to shield the bucket opening). Although foil stretched over the drift fence to cover the bucket opening was the most effective in reducing the temperature at the bottom of the buckets, it resulted in significantly fewer individual mammals and reptiles being caught. Bucket lids propped against the northern aspect of the drift fence were better at reducing temperatures in buckets than those propped against the south side. The plain brown cardboard in the bottom of buckets was about as effective as the lids propped against the south side of the drift fence, because it absorbed much of the solar radiation, heated up and radiated heat into the bottom of the bucket. Our data indicate that a cover directly over a bucket significantly ($F_{43,176} = 46.1$, $P < 0.01$) reduced temperature in the bottom of the bucket and the difference was greatest when the sun shone directly onto the bottom of the bucket without a cover. However, maximum temperatures for buckets with and without polystyrene sheets exceeded lethal temperatures for small mammals and reptiles after midday (with covers: 47.5 and 49.4°C; without covers: 60.1 and 53.1°C). It was anticipated that polystyrene sheets would have provided some protection from solar heat, but it was cooler in the shade in the bottom of the bucket than under the polystyrene.

If the trapped fauna are divided into two categories (those that are nocturnally active and those that are diurnally active) then clearing all traps before 10:00 hours on both days would have reduced deaths due to thermal stress for nocturnally active species. Many diurnal reptiles are very active in the early part of the morning before the ground temperature has increased to a lethal level, after which time they retreat to cooler microhabitats until later in the afternoon when the ground temperature becomes tolerable. To reduce the trapping deaths of diurnally active fauna, traps could be closed after they have been cleared in the morning; however, this would defeat the primary purpose of most fauna surveys, as most of the reptile fauna are diurnally active. Ensuring that all traps are cleared early in the morning should increase the survivorship of nocturnally active species but may increase the death rate for diurnally active species. If these individuals are caught in traps after they have been cleared in the morning, then they face the high temperatures experienced in traps between 12:00 and 16:00 hours. All animals trapped during this period would have almost certainly died on both days if caught in buckets and pipes without covers or funnel traps without covers. Most would have also died on Day 1 irrespective of the trap type or shade treatment. Animals caught in funnel traps with covers on Day 2 may have survived because of the effect of the breeze.

Clearing pit-traps before ambient temperatures become lethal in the morning will ensure that the death rate of nocturnal species is kept to a minimum. However, small mammals still die in pit-traps cleared early in the morning. Our experience is that a small number of rodents and dasyurids caught in pipes and buckets cleared before ambient temperatures reached 30°C in the morning with no direct exposure to solar radiation can often be found dead. These animals may have been caught in the traps early in the previous evening when the temperature at the bottom of the trap was still high from the previous day, or died due to stress associated with being caught.

Our data for the Goldfields (Thompson and Thompson 2005), the south-west and the Pilbara regions of Western Australia (unpubl. data) indicate that the highest number of individuals and number of species of reptiles and mammals are caught in trapping programs in the hottest months. Therefore, not trapping during the hotter months in these regions will result in a much lower trapping success rate, and could significantly bias the assessment of the fauna assemblage, which is likely to be the main objective for most surveys undertaken to support environmental impact assessments (EPA 2002).

Placing polystyrene sheets in the bottom of buckets provided a lower-temperature refuge than in the direct sun, but the temperature under these sheets was higher than in the adjacent shaded areas. These polystyrene sheets are also useful in providing protection from predators, and are certainly useful after heavy rain has flooded buckets. Sheet water flow across the terrain can quickly fill buckets in low-lying areas in the Goldfields and Pilbara, and we have frequently removed individuals from these traps that have used the polystyrene as a raft.

Summary and conclusions

Our data indicate that for the hottest two successive days in the Perth summer of 2008/09, temperatures in buckets, pipes and funnel traps without covers reached lethal levels for small mammals and reptiles. A single cover, or two shade-cloth covers over funnel traps appreciably reduced the temperature, prolonging the period before the temperature in the traps reached potentially lethal levels. Hobbs and James (1999) recommended the use of foil-covered shelters that are raised 50 mm above the bottom of the bucket. A new industrial insulation that has foil either side of air-cells enclosed in plastic (AIR-CELL Glareshield; http://www.air-cell.com.au/pages/glareshield.htm) is probably a superior product to foil sheets as it will also float if traps are filled with water, providing a raft for captured animals. For some surveys, there is the option of locating pit-traps and funnel traps either under or on the southern and western edges of vegetation. This placement will provide added protection for captured animals from solar radiation and is a recommended option.

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