

ORIGINAL RESEARCH

The higher you go the less you will know: placing camera traps high to avoid theft will affect detection

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Camera trap placement, camera trapping, detection zone, heat-in-motion cameras, passive infra-red sensors, remote cameras

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Abstract

Vandalism and theft of camera traps is common, imposing financial and data losses on wildlife professionals. Like many 'victims', our response to a spate of thefts was to attempt to install camera traps at heights we suspected would reduce detection and interference by vandals. We sought to determine if placing camera traps above humans' eye line, to reduce the likelihood of detection and theft by vandals, would compromise predator detection in road-based surveys. Our efforts to resolve this problem led us to discover the importance of placing camera traps at a height commensurate with the height of the animals being studied. Monitoring stations comprised of two camera traps, one at 0.9 m and another at 3 m above ground level, were established at regular intervals along trails during two survey periods. We also conducted a pilot trial to compare vertical (facing downwards) to horizontal (facing across) orientation of camera traps to detect medium-sized mammals. We compared images recorded by the pairs of camera to consider whether height made a significant difference to detections of predators. We found that cameras placed 3 m high and those facing downwards reduced the detection rate of all species compared to those at 0.9 m, so placing camera traps higher than normal significantly compromised our survey data. It is important to note that such data loss would not necessarily be apparent without a robust comparison between deployment strategies. Saving camera traps but concurrently sacrificing data quality is unlikely to be an acceptable outcome for many wildlife professionals. This study reports that placing camera traps too high will reduce the detection of animals and compromise the quality of the survey data.

Introduction

Camera trapping is a global phenomenon that has replaced many historical survey practices in wildlife research and management (O'Connell et al. 2011). Broad demand has encouraged a large number of manufacturers to enter the market. The resulting suite of camera trap models vary in their settings, functions and appearance, but many share camouflaging and security features designed to mitigate detection and theft (Swann et al. 2011; Meek and Pittet 2012). Because camera trap theft is frustrating, costly, and common in some locations (Meek and Butler 2014),

wildlife practitioners are forced to address it (Kelly and Holub 2008). The financial loss from camera trap thefts can be devastating, especially since the lost data and camera traps cannot be easily replaced. Between 2011 and 2016 the projects managed by these authors lost an estimated \$50 000 AUD (\$35 300 USD) from theft of devices ($n = 50$), all in uninhabited Australian localities.

Recommendations for minimizing loss of camera traps include deterring would-be-thieves with signage, consultation with the community, personal messages (Clarín et al. 2014) restraining camera traps with cable locks, installing units inside security boxes or attempting to hide the

devices (Fiebler et al. 2007; Kays et al. 2008; Meek et al. 2013a). Several manufacturers offer the chance to record data separate to the camera, either by physically separating the data storage components or by sending data to smart phones, personal computers or email accounts. Although data protection is some consolation, it does not overcome the cost of stolen or damaged equipment. As such, we proposed that placing camera traps above the eye-line of humans on service tracks in surveys for Wild dog (*Canis familiaris*), Red fox (*Vulpes vulpes*) and Feral cat (*Felis catus*) could be a solution to limiting theft. We conducted a trial to measure whether there would be any detection effects on our study species from placing camera traps much higher than normal.

An examination of the camera trap literature ($n = 250$) found that the placement of camera traps described in eighty manuscripts (Australia $n = 40$; International $n = 40$) ranged from 20 to 300 cm above ground level. Australian practitioners reported a height range of 20–150 cm (mean 57 cm, SD 29 cm) above ground level (see Meek et al. 2015a for a detailed list) while camera traps at European, North American and Asian study sites were set between 20–300 cm (mean 65 cm, SD 40 cm) (Table 1). Given that some practitioners set camera traps at 300 cm above ground, which is beyond the normal human eye-line, and is out of reach even when standing on a vehicle bonnet, we chose to test this height. We also compared camera traps placed several metres above tracks facing downwards at 300 cm (vertical orientation) to normal horizontally placed camera traps to determine if animal detection was effected.

Although confident that increasing the deployment height for camera traps would reduce the likelihood of vandals detecting and accessing them, we were concerned that fewer detections of target individuals and/or species might occur. Primarily because the passive infra-red (PIR) sensor is not directly in line with the heat signature of the animal

and less likely to detect radiant heat-in-motion by the PIR and therefore trigger an image capture. Consequently we sought to test a null hypothesis of equal detection probability for target animals by comparing data collected by camera traps at two heights, i.e. our previous standard survey height (90 cm) and a relatively greater height (350 cm), under field conditions. Despite our intent of testing ways to reduce theft, our results also have serious implications for effective placement of camera traps in wildlife research and monitoring. The results provide the first field-based evidence that placing camera traps at a height that is relative to the height of the study animal is important.

Materials and Methods

Study site

Green Gully, in the World Heritage Listed Oxley Wild Rivers National Park, is approximately 40 km east of Walcha, New South Wales, Australia (Fig. 1). Located in the Apsley-Macleay gorge system, it is comprised of dry sclerophyll Eucalypt forest, grassy woodlands and small mesic forest remnants over metamorphosed and volcanic sediments.

Bellinger Heads State Park is situated approximately 5 km south of Urunga New South Wales, Australia (Fig. 1). Its dune ecosystems are dominated by coastal grasses/weeds and coastal forest with underlying Quaternary fluvial sediments. Local forest is predominately *Banksia* (*Banksia integrifolia*), Tuckeroo (*Cupaniopsis anacardioides*) and Bitou Bush (*Chrysanthemoides monilifera*) with some littoral rainforest elements. There is a reasonable amount of human activity in these coastal sites.

High versus low camera trap height trials

Twenty camera monitoring stations were established at ~0.5 km intervals along the 10 km-long vehicle trail that

Table 1. Recommended height and distance settings for camera traps in eleven organizational manuals.

Group or Project	Authors	Species	Height (cm)	Distance (cm)
TEAM Network	TeamNetwork (2011)	Multi-spp.	30–50	200
Bornean Biodiversity and Ecosystems Conservation Programme (BBECP)	Ancrenaz et al. (2012)	Multi-spp.	30–40	200–300
CONABIO	Chavez and Ceballos (2006)	Jaguar	40–50	200
Wildlife Conservation Society	Henschel and Ray (2003)	Leopard	40	200
Wildlife Conservation Society	Silver (2004)	Jaguar	50–70	200
Wildlife Conservation Society	O'Brien (2010)	Multi-spp.	30–50	200
Wildcount	Parks and Wildlife Group (2010)	Multi-spp.	100	200–300
Department of the Environment and Conservation, Western Australia	Davis (2011)	Multi-spp.	Na	Na
Invasive Animals CRC	Meek et al. (2012)	Multi-spp.	50–200	Na
Victorian Department of Sustainability and Environment	Nelson and Scroggie (2009)	Multi-spp.	20–100	150–500
Norwegian Institute for Nature Conservation	NINA (2012)	Multi-spp.	20–100	400–500

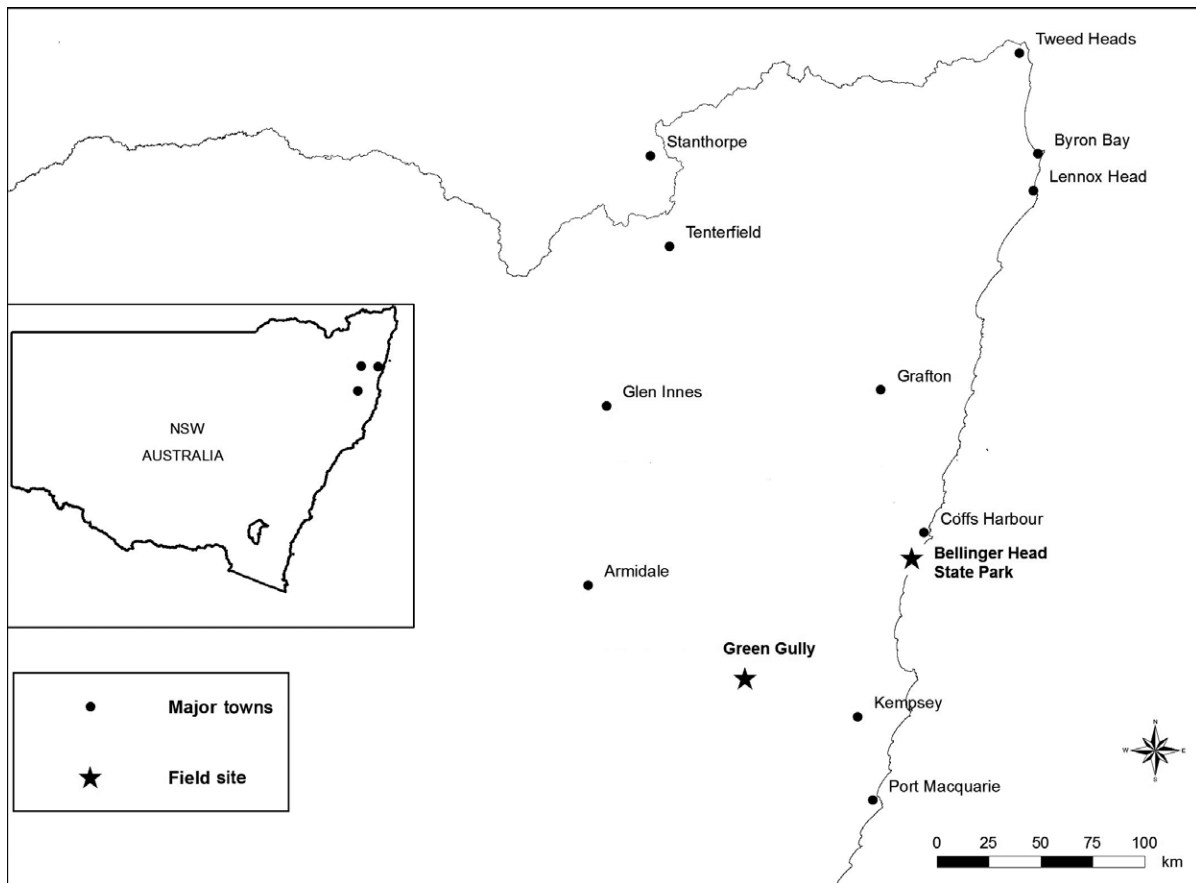


Figure 1. The two camera trap height study sites in Northern New South Wales, Australia.

descends into the Green Gully, from Kangaroo Flat. Each station comprised two Reconyx HC600 camera traps; one at 350 cm (high) and one at 90 cm (low) above road height. Each camera in the pair was temporarily affixed to the same tree using steel strapping, *sensu* Meek et al. (2012), and angled to face the centre of the road, 6 m away. Cameras faced predominantly in a southerly direction to reduce sun flare.

Camera traps were deployed in January 2011 for seven consecutive nights and again in April 2011 for 16 consecutive nights. Each camera was programmed to take five photos per trigger on 'Rapidfire' with no delay and set on high sensitivity (Table S1).

Vertical versus horizontal camera trap pilot trial

During November-December 2011 a pilot test was conducted using 10 Reconyx HC600 camera traps at Bellinger State Park, in the Urunga sand mass. At each of five sites one HC600 unit was placed in a horizontal (H)

orientation approximately 90 cm above road level and another was positioned in trees above the road (~350 cm) facing down in a vertical (V) orientation. The horizontal aligned camera trap was placed at an angle of incidence of 23 degrees to a straight section of the road. The vertically aligned camera trap was fixed to overhanging branches above the road and faced down with the detection zone running parallel with the track. This orientation was chosen because the Reconyx detection is zonal (Meek et al. 2012) and facing the sensor parallel with the road is supposed to increase the chance of detection. Each camera was programmed to record 10 images per trigger event. Cameras were set on high sensitivity, 'Rapidfire' with no delay between detections (Table S1).

Coding and analysis

Image files were renamed using Renamer™ to enable site specific file names for each image. Every image was labelled with metadata tags per the species detected using EXIFPRO™. Where a sequence of images was

triggered but no object was detected, we recorded this as 'Nil' to reflect the false positive detections. The main species of interest in these road-based survey sites were wild dogs, fox and feral cat. Where an image of a macropod was taken but species identification was not possible, it was labelled as 'Macropod'. Eastern grey kangaroos (*Macropus giganteus*) and Red-necked wallaby (*Macropus rufogriseus*) were clumped as the 'Macropod' category due to few detections. Two local species of bandicoots, the Northern brown bandicoot (*Isoodon macrourus*) and Long-nosed bandicoot (*Perameles nasuta*), were also grouped as 'Bandicoot' because species-level classification via camera trap images is unreliable (Meek et al. 2013b).

The total number of detections was initially compared between Hi and L and H versus V camera traps by calculating a mean number of events for species, vehicles or people per camera per height and orientation. An event was defined by the number of images taken per trigger with an interval exceeding one minute. At Green Gully the number of photos per trigger was five, and at Bellinger Heads State Park the number of photos per trigger was 10. We used Microsoft Excel for basic manipulation and analysis of data. Further analysis of high and low camera trap sites were undertaken using the statistical package R Version 2.15.3 (R Development Core Team 2012). We applied a generalized linear mixed effects models (GLMM) approach (Bates et al. 2013) to account for the variance in event detections across the sampling units, and accounted for the fixed effects of camera trap height. Models were fitted to the number of detection events for:

- total detections,
- bandicoot detections,
- feral cat detections,
- wild dog detections,
- fox detections
- spotted-tailed quoll detections.

Expressed in the following general forms;

$$D_i = \beta_0 + \beta_1 O_i + S_i + N_i + \epsilon$$

where

$$\epsilon \sim N(0, \sigma^2)$$

Number of Detections $\log(D_i)$ was the count of the number of detection events of the species of interest, Intercept (β_0) the average number of detections term, Orientation Effect ($\beta_1 O_i$) an additive term describing the impact of orientation on the number of detections, Site (S_i) a random effect additive term accounting for site specific changes in detection rate, Null Detections (N_i) term for random machine and environmental effects to account for the tendency of a unit to take photos, and

Error (ϵ) the error term in the model describing the difference between the model predictions and the actual number of detections observed.

Due to its small sample size, the data in the pilot trial was analysed by comparing the percentages of detection for all animal and non-animal categories in both the horizontal and vertical camera trap orientations.

Results

Camera trap survey effort at the two study sites is presented in Table 2. We defined twelve animal categories and two non-animal categories at Green Gully over 920 trap nights (39 740 images; 6492 events) and seven animal and two non-animal categories at Bellinger Heads State Park over 190 trap nights (11 530 images; 1153 events).

High versus low height trial

Five camera traps at Green Gully malfunctioned for unknown reasons and were subsequently excluded from the analysis. Thirteen fauna species were identified at Green Gully. Brush-tailed rock wallaby (*Petrogale penicillata*), feral cat, fox and wild dog were more commonly detected than other species. Wild dogs, feral cats, spotted-tailed quolls (*Dasyurus maculatus*) and foxes were regularly detected along the transect and at the same camera trap locations.

The height comparison revealed that camera traps set lower to the ground had a statistically higher detection rate than cameras set high in a tree (Tables 3 and 4). The data in Table 3 present summary detection data and a

Table 2. Camera trap effort at Green gully in Oxley Wild Rivers National Park and Bellinger Heads State Park, NSW Australia.

Primary 1	Green Gully
Camera deployment (Days)	7
Active camera traps	36
Inactive camera traps	4
Trap nights	280
Primary 2	Green Gully
Camera deployment (Days)	16
Active Camera traps	39
Inactive Camera traps	1
Trap Nights	640
Pilot 1	Bellinger Heads SP
Camera deployment (Days)	19
Active Camera traps	10
Inactive Camera traps	0
Trap Nights	190

Active refers to an operational device and inactive is where the device was not recording images.

comparison of the mean number of detections across species and between camera heights. Table 4 presents the results of the GLMM's examining the effect of orientation (as measured by the slope term β_1) and assessing whether or not it is significant (as measured by the P -value).

The activity of vehicles on the Green Gully track was relatively high and represented the most detection events with both camera trap orientations, although there were slightly fewer detections with the lower placed camera trap. Failed detections or false triggers (nil) were greater where camera traps were placed higher (17.3%) than lower (12.5%); a similar observation is discussed in the following section for vertical orientations.

Vertical versus horizontal pilot trial

During this study the Urunga sand mass habitat was being sprayed for weeds and as such there was an abnormal occurrence of humans and vehicles. Seven taxa were recorded in the BHSP; foxes were the most commonly detected species. The detection of species (expressed both as the number and as a relative percentage of total detections) for horizontal and vertically oriented camera traps did suggest a trend where horizontal oriented camera traps detected more species than vertically oriented (Fig. 2). For instance horizontally oriented cameras detected 93% of all foxes in the trial (12.5 times more horizontal than vertical; $H = 75$, $V = 6$). A similar result was observed for macropods (92%, $H = 23$, $V = 2$), 11.5 times more horizontal than vertical, and high percentages were observed for other species, e.g. wild dogs (67%, $n = 10$); two times as many detections with horizontal than vertical ($H = 10$, $V = 5$). Importantly, the 'nil' category (false positive detections) was the only case in which the vertical orientation resulted in more detections than the horizontal oriented camera traps. Vertically oriented camera traps had a higher number of false positive detections (79%, $n = 951$) compared to horizontal camera traps (21%, $n = 257$). At two of the vertical oriented

Table 4. Generalized linear mixed model parameter estimates and P -values for the slope term β_1 (for orientation effects).

Response	Slope estimate	Slope standard error	Z value	P -value Pr(> z)
Total Detection Events	11.35	1.72	6.59	4.33e-11
Feral cats	0.69	0.13	5.11	3.15e-7
Foxes	1.06	0.16	6.77	1.29e-11
Wild dogs	0.58	0.24	2.41	1.60e-2
Bandicoots	1.19	0.44	2.70	6.90e-3
Quolls	0.98	0.49	1.99	4.67e-2

All P -values are statistically significantly different from zero ($P < 0.05$).

camera traps sites, there were approximately 6 times as many 'nil' events ($n = 738$) compared to the horizontal camera traps ($n = 117$) at the same sites.

Discussion

Our trials revealed that placing camera traps high in trees, in this study beside roads, significantly compromised detection of both our target fauna and other species compared to a 'typical' lower deployment strategy.

This finding is analogous to that of Swann et al. (2004) who found that relatively lower placements performed better for their target species of interest. More importantly, it reinforces that survey protocols benefit from pilot trials designed to assess the relative merits of alternative deployments prior to implementation. Poor data can lead to poor management decisions, and there is growing recognition that use of sub-optimal camera trap placements can contribute to this via compromised survey data (Burton et al. 2015; Meek et al. 2015b). Our need was to maximize detection, because we were interested in developing trail-based indices (*sensu* Catling and Burt 1995; Allen et al. 1996; Fleming et al. 1996) to inform managers about the impacts of control programs on local fauna. We note that without the ability to compare data

Table 3. Detection events for five species detected by camera traps in a head-to-head comparison between two height classes (high and low).

Contrast	Events (H)	Events (L)	#CTD (H)	#CTD (L)	%CTD (H)	%CTD (L)	Mean (H)	SE (H)	Mean (L)	SE (L)
Total Detections	181	417	57	71	71	83	34.45	0.94	40.66	0.63
Feral cats	83	167	23	26	66	74	2.40	0.07	4.77	0.15
Foxes	56	161	14	23	40	66	1.60	0.08	4.60	0.20
Wild dogs	29	50	12	11	34	31	0.80	0.05	1.43	0.07
Bandicoots	7	23	3	6	9	17	0.20	0.02	0.66	0.06
Quolls	6	16	4	5	11	14	0.17	0.01	0.46	0.05

#CTD is the total number of species detection events for all camera traps in the two height classes, %CTD refers to the percentage of camera traps in a height class that detected each species. The mean number of detections with standard errors for the two camera heights allows the impact of no detections to be incorporated.

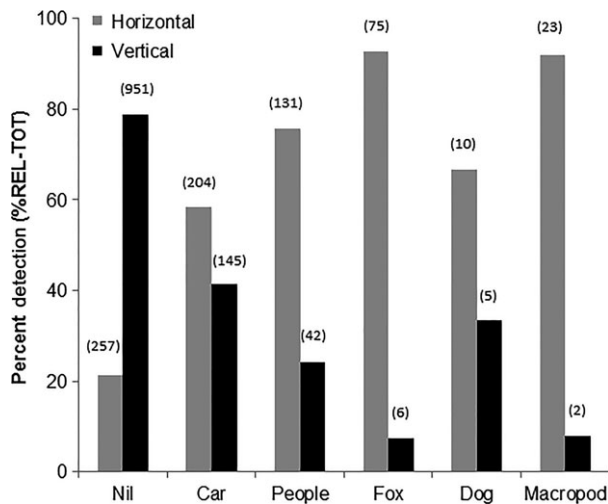


Figure 2. Comparison of the detections recorded by camera traps placed in a horizontal and vertical orientation at Bellinger Heads State Park, NSW Australia. The values displayed for each orientation are the per category percentages of camera trap detection events (%REL-TOT) and the per category total number of detection events (#TOT) (presented in parentheses). Note that the %REL-TOT values add up to 100% across the vertical and horizontal orientations for each category and are therefore reporting the relative percentages of the vertical and horizontal orientations in the detection of each category. Low numbers of detections of birds, rats, goanna and an echidna were also recorded for the horizontal orientation but none in the vertical orientation and are therefore not presented.

from the 'low' deployments, it would not have been evident that the new, 'high' placement was deficient. We recognize that changing the height of the camera trap to 3.5 m would have marginally increased the focal point on average by 65 cm, but we do not consider this to have any consequence on detection rates.

Although Kelly (2008) raised concerns that increased camera trap height may reduce detections of animals, this fundamental aspect of camera trapping has not been thoroughly investigated in the field. Several camera trap manuals provide recommended heights for specific investigations, ranging from 20–300 cm depending on the target species (Table 1). We note that these recommended deployment heights tend to increase with target animal size, but other than Swann et al. (2004), evidence supporting the suitability of deployment heights is rare. The results presented in this study highlight the importance of camera trap height. Failure to place these devices to optimize detection of fauna will lead to substandard data collection that may have serious implication for data analysis, interpretation and conservation outcomes. The results of our pilot trial comparison of horizontal versus vertical placed camera traps for detecting predators on roads also showed a trend towards reduced detection

from vertical placement. The interpretations of these results were constrained by sample size but infer a reduced detection rate. However, the practicality of using a systematic survey design with vertical orientated camera traps on trees beside forest roads is problematic. Simply because over-hanging trees and branches are not always available in a suitable location which may bias survey design through the inappropriate selection of camera trap sites. Moreover, a reliance on placing camera traps on limbs overhanging thoroughfares that can move in the wind caused high numbers of false detection events, precluding further testing of this method.

A limitation of the analytical approach that is presented in Table 3 is that it does not account for the prior probability of encounter of a particular species. For instance species with low population densities (e.g. quolls) might not result in many opportunities for encounter with the camera trap and hence a lower mean detection rate will result. Importantly for a given species and a fixed number of survey hours the comparisons between mean detection rates of cameras at different heights can still be made but when the probability of encounter is lower the uncertainties around the estimated mean number of detections will be increased (to reduce this uncertainty the number of samples and hence the survey effort is greatly increased). To address this issue we presented the numbers of detection events for each species. Since this research is only interested in the overall detection performance of the camera traps at each height and not the performance of each individual camera, it was possible to pool the detections of species across cameras for each height and examine differences in detections (percentages %CTD and numbers #CTD) solely at this level of contrast. Presenting the data in this format allowed the key contrast (detections between camera heights) to be examined irrespective of the low number of detections of specific species for certain camera trap units. In this manner the impact of the species specific prior probability of encountering the camera trap is minimized, and the impact of the different heights on detecting a particular species could be examined in more detail.

Although it may be appealing for wildlife practitioners to seek to overcome vandalism and theft by raising camera traps above the eye level of humans, our trial suggests the resulting data would likely be significantly compromised, relative to those from cameras in more typical, lower placements. Moreover, higher placed camera traps in trees are more prone to false triggers from tree movement, causing excessive battery use and reduced card storage capacity. Further efforts and innovation are required to address the serious problem of theft and damage to camera traps without undermining the data quality of camera trap surveys. Future camera trapping trials

should evaluate additional security options (Meek et al. 2013a) and alternative survey designs that may reduce the likelihood of human-induced equipment and data losses.

However, the important finding of this study is that the higher a camera trap is placed, the lower the detections will be. Our research has shown that camera trap height is important in optimizing detections. This can be explained by the orientation of the detection zone in relation to the size of the animal and the line of passage past the camera trap. The height of the PIR (and as such the alignment of the detection zone) and its proximity to the heat signature of a target animal are intrinsically related, so it is critical that camera traps are set at a height commensurate with the main heat sources on the animal's body (Meek et al. 2012).

Data Accessibility

Data collected and analysed in this manuscript will be lodged with the University of New England library, Armidale Australia.

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Conflict of Interest

The authors have no conflicts of interest associated with the submission of this manuscript.

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Supporting Information

Additional supporting information may be found online in the supporting information tab for this article.

Table S1. Camera trap methods used at Green Gully (GG) in Oxley Wild Rivers National Park and Bellinger Heads State Park (BHSP), NSW Australia. Hi = high, L =low, H = horizontal, V = vertical orientation.