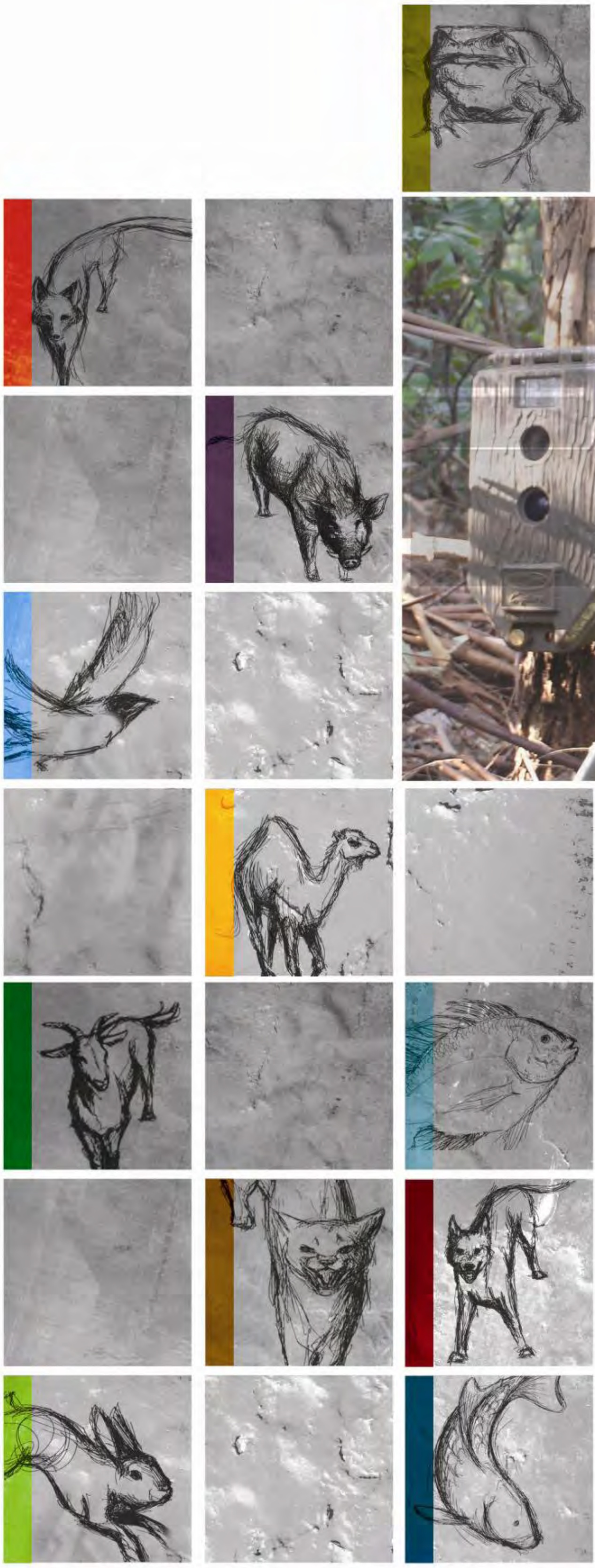
PESTSMART



An introduction to camera trapping for wildlife surveys in Australia

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An Australian Government Initiative
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Front cover photo: Trial of four camera trap models using tree mounting for small mammal investigations. Image: Paul Meek.

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Summary

Internationally, camera trapping is rapidly being adopted for diverse monitoring purposes, from wildlife research and management to asset protection. There are, however, myriad cameras of multiple brands with various models, which have different functionality and are fit for different purposes. It is difficult for any user to fully comprehend which camera trap to select and how to use it best. Despite an array of publications about camera trapping, most users learn from 'doing'.

Through widespread informal consultation with private citizens, public land managers and research groups, the Invasive Animals Cooperative Research Centre (IA CRC) and the NSW Department of Primary Industries (Vertebrate Pest Research Unit) identified a need for a document that brought together a range of information on wildlife camera trapping to encourage some consistency in the collective approach to camera trapping in Australia. Based on our collective experiences with camera trapping, this document aims to provide users with 'one-stop-shop' information on most aspects of camera trapping for wildlife monitoring and research purposes, such as suggestions on selecting a fit-for-purpose camera, designing camera trapping surveys and means of managing and analysing camera trap data. We proposed some standards and included information on the history of camera trap use to provide context. We also explained common terms and described how camera traps actually work.

In preparing this document, however, it became increasingly apparent that it would likely take many years to provide robust recommendations on specific details of the methodologies for some surveys. Some of the information in this guide may be quickly superseded as technology and our understanding of ecology continue to advance, and it is important to acknowledge that we do not have all the answers. Consequently, we propose to maintain this as a living document, to be updated as our collective knowledge of camera trapping advances. For similar reasons, readers will note that we have tried to avoid recommending particular brands or models of camera traps throughout the document, as they are likely to be superseded over time.

Importantly, in developing this document we surveyed camera trap users to compose a standard datasheet and database for site recording. The resulting documents can be downloaded from www.feral.org.au. A Microsoft Access database can also be downloaded from this site.

Glossary of Terms

Burst mode A camera trap setting that allows continuous images to be taken following a trigger event, see also rapidfire

Camera trap A term used to describe a heat and motion sensing camera that captures images of wildlife automatically

Camera trap set Connotation of a trap ‘set’ which describes the immediate area where camera/s are placed

CF card The acronym for Compact Flash cards, a mass storage device used by older camera traps, virtually all new models (at the time of publication) now use SD cards (see below)

Convert surveillance Use of cameras set to catch illegal actions by people

Delay A program function available on some models. This setting has many forms but typically allows the user to set a period of time where the camera trap is inactive or ‘hibernating’ before or between photos.

Depth of field Not often adjustable in remote cameras. This refers to the aperture setting and its effect on the focus of objects in the front and rear of the photograph.

Detection zone The area in which a camera trap is able to detect the heat signature and motion of a target

Event The period of time from first trigger to the last photo in a sequence, where the sequence is encompassed by the extent of independent behaviour by the target/s

Focal point Usually the centre of the image (if the photograph is composed correctly), the subject of interest, the lure, pathway or track centre or bait device

Field of view The area captured in a photograph, usually between 35 and 45 degrees

Fresnel lens A lens used by camera traps to direct infrared energy onto the passive infrared (PIR) sensor. These lenses are commonly seen in lighthouses and cause refraction of light.

Incandescent A white flash used by a camera trap

Lures A generic term referring to an attractant used to encourage animals to investigate a specific point within the detection zone. These may be auditory, olfactory, visual, or some combination of these in nature.

Non-strategic inventory	*Ad hoc* use of camera traps (ie not using a standard approach to conduct a survey – 'Look-see' use)
Performance measuring	A Monitoring Evaluation & Reporting (MER) term referring to monitoring changes in response to an intervention
PIR sensor	Passive detectors of Infrared light
Rapidfire	A camera trap setting that allows images to be taken continuously following a trigger event - see also burst mode
Resource condition monitoring	An MER term referring to monitoring of population trends to detect change
SD card	The acronym for Secure Digital cards. A removable digital storage medium that is currently the standard in camera traps
Sensitivity	A setting, often adjustable, that reflects the camera's response to heat in motion for PIR sensors. Higher sensitivity is associated with more images, and lower sensitivity with fewer images. Increased sensitivity, however, does not guarantee detection of a target.
Strategic inventory	Refers to survey design. A strategic inventory has a reasoned plan underpinning data collection.
Time lapse	A program function available on some camera traps. The time-lapse function, or similar, typically allows a user to prescribe times of day and/or night when the camera is inactive, regardless of activity within the detection zone. Some time-lapse cameras (see below) do not have a PIR and, instead, capture images at prescribed times or intervals.
Time lapse camera	Camera traps that do not have a PIR sensor (see above) and can be programmed to take photographs at predetermined times throughout the day regardless of any triggers
Trigger speed	The difference between detecting heat in motion and capturing an image. Also known as response time. Slower trigger speed (ie more time elapsing between trigger and image capture) may decrease the likelihood of capturing a target.
Walk test	A program function available on some camera traps. Walktest, or similar, can be used to identify where a camera will respond to heat in motion. Consequently, it can be used to 'focus' the camera's detection zone, as desired.
Xenon flash	An incandescent or white flash that illuminates the subject at night in full colour
Synonyms for camera traps	Remote cameras, remotely activated monitoring cameras, trail cameras, spy cameras, wildlife cameras, camera traps, remote-sensing cameras, remote sensing cameras, game cameras, photo-trapping, sensor cameras, heat-and-motion sensing cameras

1. Introduction

The use of camera traps in wildlife monitoring and research has escalated in Australia over the last 10 years. Camera traps are used as a tool to conduct surveys or record general observations, often with the inherent assumption that they will result in high quality data with less investment by staff, thereby improving cost-benefit ratios. This has been reinforced by claims that camera trapping provides better results than standard surveys, such as live-trapping (Paull et al 2011). Such assumptions and claims, however, need validating for the range of species and situation of interest. That is, considerably more research is required before many existing methods can confidently be replaced with camera trapping alternatives.

Australian agencies currently use camera traps for two purposes:

- covert human surveillance where damage or pollution is a threat to property (eg arson or poaching)
- wildlife inventory, monitoring and research (eg assessing the impact of wildlife management interventions).

This manual is focused on the latter.

In the absence of best practice guidelines, the types of camera traps people use, how they use them and how they store and analyse the resulting data vary considerably. In many cases, despite good intentions, camera traps are being purchased and used in ways that are not fit for purpose.

To this end it is important to note that the uses of camera traps are still being refined. There is enormous progress to be made in regards to survey methods, standards and the choice of fit-for-purpose equipment. Consequently, this document is a 'living resource' that provides basic camera trap information and will be constantly updated to cater for the rapid development of camera trap technology, survey methods and analytical techniques.

For now, this document has been prepared to:

- provide useful background information on camera trap technology
- describe the components and functionality of camera traps
- provide a decision guide for camera trap choice
- outline survey designs, methods and data management
- recommend a camera trapping protocol for a range of fauna surveys.

A standardised term for the technique of using camera traps for measuring animal populations, behaviour and activity is controversial. Throughout this document, the term 'camera trap' (see O'Connell et al 2011) has been adopted as a standard. It is interchangeable with terms such as 'remote camera', 'motion sensing camera', 'trail camera', 'game camera' and 'sensor camera'.

2. Use of camera traps in Australia

One of the first reported camera trap studies in Australia was conducted in 1960 by Inspector Hanlon, Tom McMahon and Eric Guiler on the Woolnorth expedition to find the Thylacine in Tasmania (Guiler 1985). This study trialled the deployment of a Bolex movie camera attached to what was probably a snare cable on a pop hole in a fence. The camera produced single-frame black and white photos using a white flash. On the third Woolnorth expedition in 1961, five camera traps were used (Guiler 1985). These units comprise G.45 aircraft 8 mm movie cameras with lighting and a treadle-plate trigger mechanism that were set below pop holes in fence-lines. In 1966 another camera trapping of the Thylacine was attempted using a modified version of the G.45 camera (Guiler 1985) but without success.

This early pioneering work resulted in the deployment of 25 camera traps between 1968 and 1972 by Jeremy Griffiths and James Malley, later to be joined by Robert Brown (Guiler 1985), the future leader of the Australian Greens Party. Following on from this early use of camera traps was a parallel camera trap surveys for Thylacine by Steven Smith (Smith 1981) and Eric Guiler (Guiler 1985). Smith rigged up a Pentax 35mm MX motor drive camera with 40 mm or 50mm lenses and a bulk film magazine (250 pictures). A Metz 45 CT-1 flash was attached and the unit was linked to a Sick Optik Elektorinik infrared source with an email relay and 5 m of cabling. Reflectors were set up a few metres from the camera and an infrared beam was projected across an animal path. As the beam was broken, the system automatically triggered the camera to take photos. Camera taps were left in the field for seven days during June-September 1980 and resulted in 111 camera-days with 420 photos of nine species but no Thylacine. Conversely, Guiler had 15 camera traps built at a cost of AUS $25 000 in 1978 that are probably the first step towards a modern-day designed camera trap. The device used pulsed infrared beams, circuit boards and a delay cycle; it even had a display to show the number of events recorded (Smith 1981; Guiler 1985). Despite the failed objectives of detecting a Thylacine, they were the pioneers of early camera trap developments between 1960 and 1980.

Carthew and Slater (1991) were the first authors to publish scientific papers that featured the use of camera traps in Australia. These authors used an early form of camera trap to monitor pollinators of flowers (Carthew 1993). Throughout the 1990-2000, the use of camera traps in wildlife research changed dramatically from primitive video cameras (Belcher 1998) to manual treadle mechanism (Glen and Dickman 2003), heat sensor triggers (Belcher 2003) and the first genuine infrared automated cameras distributed by Faunatech, the Digicam DC110 (Claridge et al 2004; Hayes et al 2006). In the period post-2004, the use of camera traps in Australia changed again as mainstream devices from the USA entered the market, and researchers saw great opportunities for the adoption of this new tool for a range of species and purposes (Cowled et al 2006; Nelson and Scroggie 2009; Vine et al 2009; Claridge et al 2010; Meek 2010; Robley et al 2010; Paull et al 2011).

2.1. Privacy, policies and the use of camera traps in Australia

It is important that camera trap users understand their relevant legal responsibilities, prior to deploying these devices. Generally the use of camera traps for wildlife-related purposes is not legislated by Australian laws. Nonetheless, the deployment of cameras where images of people are taken incidentally is regulated by privacy and workplace legislation (Appendix 1). Privacy legislation varies considerably between the states, territories and within organisations. In Australia it is not illegal to take and publish a photo of a person (see http://photorights.4020.net). If the images are being used in a legal proceedings, however, then law regulates how the information can be used and stored and ultimately how long the evidence can be kept before having to be destroyed. In Australia it is widely accepted that our laws do not provide a legal framework for the right of privacy to the individual (Butler 2005). It is essential that camera trap users seek clarification of their legal responsibilities, relating to camera trap use, data storage, analysis and publication within their state or territory. In NSW, for instance, there are legal obligations under the *Surveillance Devices Act 2007*. This Act and associated legislation govern how the agency must use cameras to protect the privacy of the public and the community.

In the case of camera traps used for wildlife monitoring and research purposes, there is no intent to capture images of people, meaning that these legal considerations are not applicable. All users, however, have a responsibility to ensure that a code of practice for deployment of camera traps for wildlife monitoring is adopted. There are two main issues of concern from a land management agency perspective: workplace issues and public matters. The minimum requirement before deployment of devices should be to advise local staff that cameras are being deployed in a reserve without being specific of when and where. Secondly, the placement of signs at main entry points to a reserve will provide a warning that camera traps could be deployed. The exact placement of signs is critical as it is important not to direct the public to expensive equipment in the area that may result in theft, damage and large numbers of additional images being captured (Figure 1). Placing a sign may also attract would-be-thieves to an area and result in damage or theft of equipment.

It is implicit that camera traps placed for wildlife purposes are not set to deliberately capture images of people – the intent must be for wildlife investigation. Nonetheless, if images of people are captured during surveys, the onus is on the investigator to manage such images appropriately, according to the relevant policy of your organisation. Under all of the surveillance acts, there are legal requirements for the storage of data collected from optical surveillance devices, including storing in a secure place and destroying the records after a defined period (eg five years). This obligation is the responsibility of all users. The privacy of all individuals must be respected, and where images indicate an illegal activity, appropriate recording of the event must be formally reported to a senior officer. This form of evidence becomes a matter for surveillance devices acts and regulations.

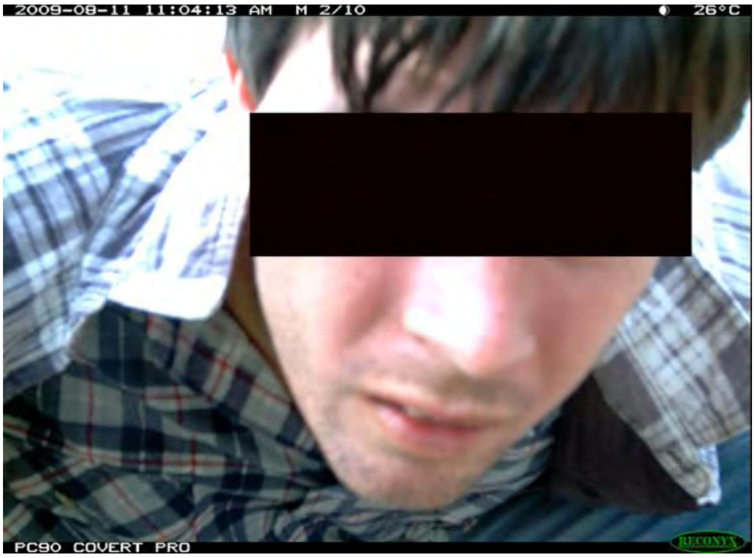


Figure 1. A member of the public tampering with a camera trap, set for wildlife monitoring purposes, within a national park (image: Guy Ballard).

For instance, under Part 1 Section 3 of the NSW *Surveillance Devices Act 2007* No 64 the following excerpt is relevant.

3 Relationship to other laws and matters

(1) Except where there is express provision to the contrary, this Act is not intended to affect any other law of the State that prohibits or regulates the use of surveillance devices.

Note: the *Workplace Surveillance Act 2005,* for instance, contains certain requirements in relation to camera surveillance. The applicable requirements of both acts will need to be complied with if camera surveillance is carried out.

In the event that camera trap theft is an issue and they are also being used to protect an asset, the relevant legislation for surveillance devices is 'switched on' and operators must be aware of their obligations for privacy. This will increasingly be an issue for a trapping given the significant investment in the technology and the escalating occurrence of theft. Covert and telephony technology already exists that can be simultaneously deployed to prevent theft of equipment, and as it becomes more affordable, this issue will become more relevant.

In 2005 a legal decision handed down by a judge in Queensland (Skoien SDCJ) in the case of *Grosse vs Purvis*, significant damages were handed down under a Tort of Invasion of Privacy. In general terms this decision has paved a way forward for prosecution where damages to an individual has resulted from their 'right to be left alone' (Butler 2005). Skoien SDCJ stated that in the above case the Tort of Invasion of Privacy was relevant under the following causes:

A willed act by the defendant;

which intrudes upon the privacy or seclusion of the plaintiff;

in a manner which would be considered highly offensive to a reasonable person of ordinary sensibilities; and

which causes the plaintiff detriment in the form of mental, physiological or emotional harm or distress, or which prevents or hinders the plaintiff from doing an act which he or she is lawfully entitled to do.

It could be argued that images of a person, or video recordings where sound is also recorded on a camera trap, is an impingement on an individual's privacy. In a recent review of the *Privacy Act 1988* (Australian Law Reform Commission 2006), listening devices were reviewed, but cameras for wildlife monitoring were not considered. In light of the findings of *Grosse vs Purvis* and the subsequent interest in developing legislature to recognise privacy, it is more than likely that this issue will confront camera trap users in the future.

A useful website that summarises much of the privacy legislation in Australia can be browsed at http://www.privacy.org.au/Resources/PLawsST.html.

2.2. Signage

Some users are reluctant to place signs to warn that camera traps have been set in the field. The NSW Office of Environment and Heritage (OEH) stipulate that signs (Figure 2) must be placed in areas where camera traps are being deployed and that they are to be placed at major road entrances but not necessarily close to the device. This warns people of camera trap deployment but not of the exact location. No other examples of equivalent signage were available from similar agencies at the time of publication.

Figure 2. NSW OEH camera-trap sign that must be deployed in all NSW National Parks and Wildlife Service Reserves.

2.3. Animal ethics and licensing

Some Animal Ethics Committees require investigators to apply to use camera traps in research involving animals. Camera trap users are encouraged to consult with their committee to determine requirements within their agency or institution prior to surveys. Although this may seem onerous, there is no doubt that some types of camera traps affect wildlife behaviour (Gibeau and McTavish 2009). Under the NSW OEH Animal Ethics Committee, for example, the following definition of research and monitoring was developed to evaluate whether ethics approval is required:

Use of remote cameras is research when the purpose of gathering the information is to survey the presence/absence or relative abundance of species in a systematic way, regardless of whether attractant or other behavioural modifiers are used. For example:

- *comparisons between different habitat types or between the same habitat in different locations*
- *comparisons over time or as part of a before-after treatment monitoring.*

Use of remote cameras is not research when the purpose of gathering the information is to identify species or individuals using a point location or small area, such as a water hole, a camping ground, a nest, when no attractant or other behavioural modifier is used, or lethal bait is used as a component of approved pest management activities. The information may be used to:

- *determine whether to adopt a particular on-ground asset or pest management action at a point location*
- *determine whether a rare species or species previously not known from the area is utilising the location (eg a bird of prey at a nest site).*

Under this definition the placing of cameras on roads to determine pest animal activity:

- *is research when the placement of cameras will be systematic (eg many roads will be surveyed prior to baiting, in order to determine where pest management efforts should be put, and surveyed after baiting to determine baiting success.)*
- *is not research when cameras will be placed along a single road or stretch of road simply to determine if pest animals are using the road, but there is no intention to compare abundances with other locations or remonitor after pest control activities.*

At the time of publication, Victoria required animal ethics approval to use camera traps for wildlife research (Nelson and Scroggie 2009). In Western Australia, the Department of Environment and Conservation (DEC) Animal Ethics Committee does not require licensing or competency standards for staff (Davis 2011a) and there are no requirements in Queensland, Victoria, South Australia, Northern Territory or Tasmania.

3. Selecting an appropriate camera trap

Camera traps are usually acquired for one of the following two reasons:

- 'opportunistic' - where money becomes available at short notice (eg at the end of the financial year)
- 'planned purchases' - where a predetermined number of camera traps are bought for a specific project.

Either way, deciding which camera traps to choose can be challenging for the novice and managers who have to approve purchases. Several approaches can assist in making such decisions, and a couple of examples are presented below.

The features and specifications of camera traps vary enormously and need to be evaluated when choosing between models. The intended use will often restrict the choice of camera trap but cost per unit must also be considered. Often the choice of camera trap to buy is driven by cost (Meek 2012) based on the perception that more devices are better than less, despite the consequences for data quality. Alternatively, some will buy camera traps like they would a normal camera: buying a few, or even one, expensive camera traps to ensure they have quality images.

Below is a quick guide to the range of prices (in 2012 AUS$) that can be paid for camera traps and a stepwise decision keys to choosing the best camera traps for general use to survey wildlife.

Table 1. Quick reference guide: camera traps for wildlife surveys (as of June 2012).

High end (AUS $500 - 1000)	Mid range (AUS ~$500)	Low end (AUS <$400)
Reconyx HC600/HC800/HC900	Reconyx HC500	Scoutguard SG560VB
Pixcontroller DigitalEye	Bushnell Trophy Cam	Moultrie M80 or M100
	Scoutguard SG560	Euovision 565
	Buckeye Cam Orion	Cuddeback Capture

3.1. Decision key

Step 1. Opportunistic Purchase

I can afford to purchase:

1-3 cameras — **Q:** Can I borrow some camera traps instead?

If not, refer to the recommendations in this manual and/or go to http://www.trailcampro.com/trailcameratests.aspx

5-10 cameras — This is an investment that requires careful consideration of the intended use.

Q: Can I pool my resources with other people and together increase our camera trapping capacity?

Q: What are the other requirements of buying these camera traps and does that influence my choices?

***Please read the Planned Purchase decisions key*.**

10 + cameras — This purchase should be strategic and planned.

***Please read the Planned Purchase decisions key*.**

Step 2. Planned Purchase

Before buying camera traps, consider whether camera trapping is the best tool for the planned survey or monitoring. Nelson and Scroggie (2009) provide a Decision Key to assist novice camera trappers in making logical choices in selecting camera traps that are appropriate for specific wildlife monitoring and surveys (Figure 3).

The Intended Use Flowchart below (Figure 4) is a further process aimed at assisting interested parties in deciding whether camera traps are the most suitable survey method to carry out the surveys you require.

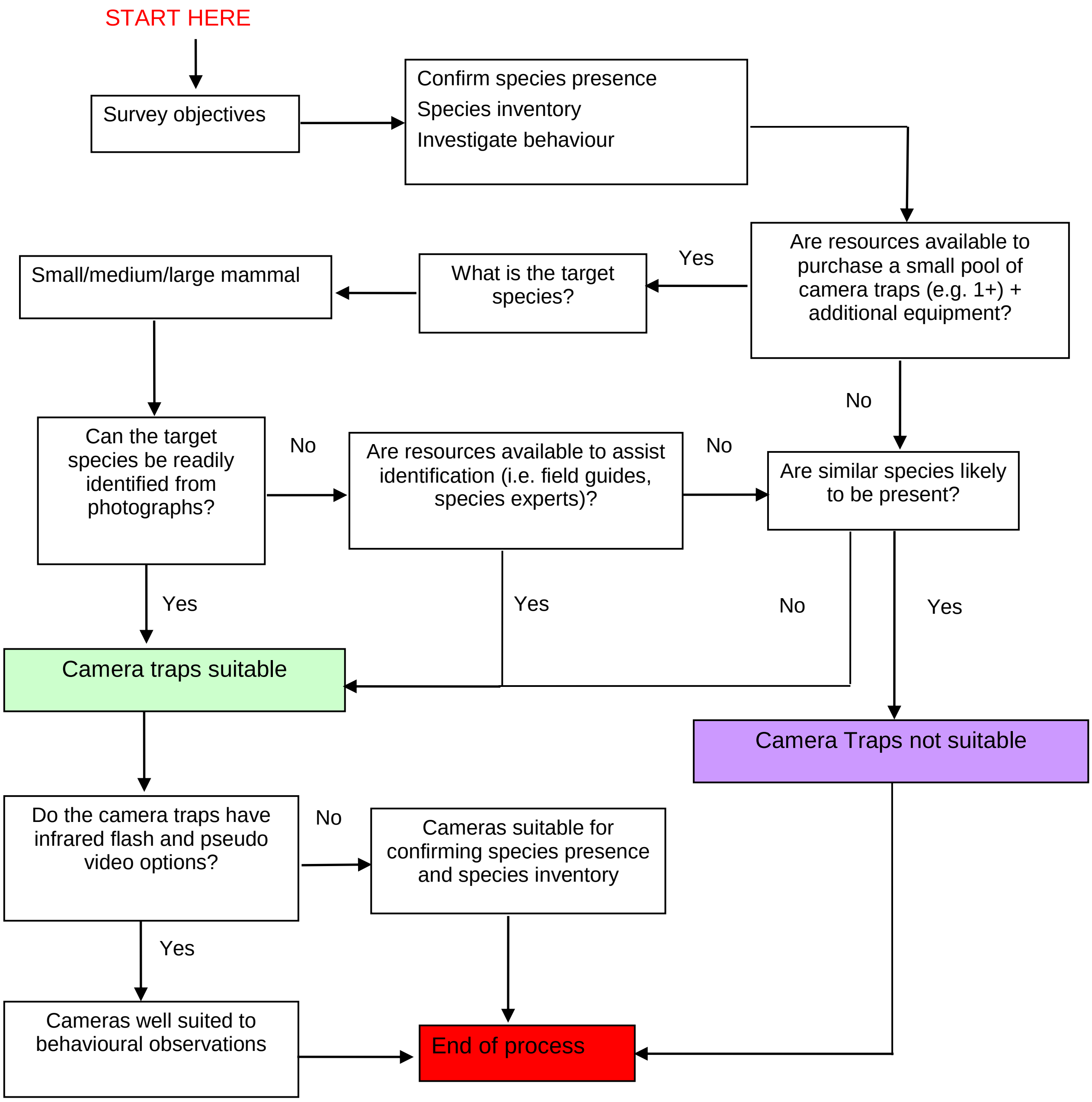


Figure 3. A stepwise process for assessing whether remote cameras are a useful tool for a particular project (Nelson and Scroggie 2009).

Intended Use Flowchart

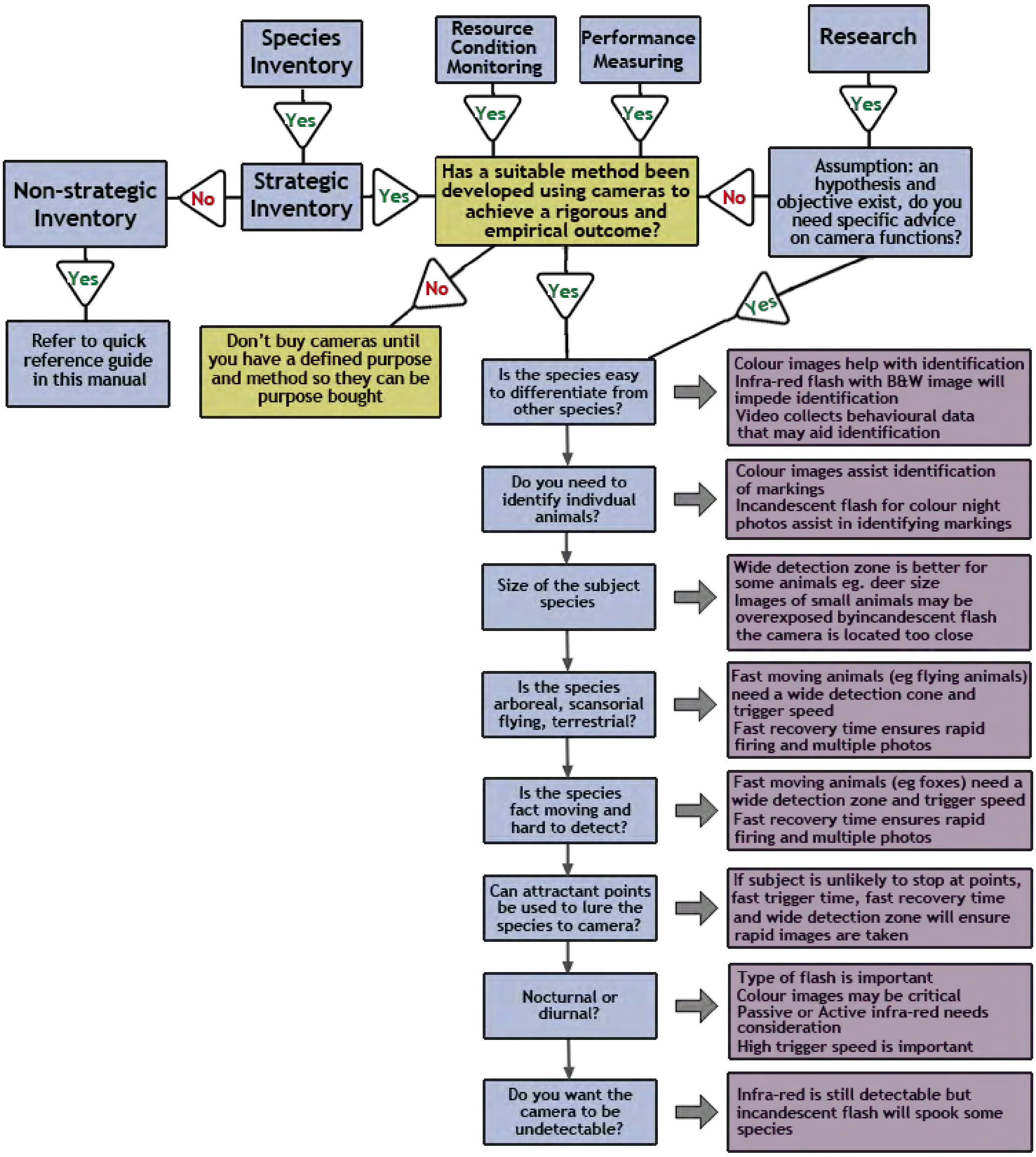


Figure 4. The Intended Use Flowchart is designed to assist users in deciding on suitable specifications and functions to suit their objectives. Non-strategic inventory refers to look-see inventories with no scientific design or purpose. Strategic Inventory are surveys with some planned approach and design. Resource Condition Monitoring (MER) monitors trends to detect change. Performance Measuring (MER) refers to changes in response to a remedial action. Research is where there is clear scientific design and a defined hypothesis.

Choosing the right camera trap can be complicated because purchasers often intend to use the devices for more than one purpose. Finding a camera trap that satisfies all the needs of wildlife management and research is not possible (Meek and Pettit submitted). Few camera traps offer both white and infrared flash with stills and video and sound capacity with quick trigger speeds, sensitive passive infrared (PIR) sensors and a great range of settings. This means choosing which model will be most suitable is complex and often impossible. Price is the most important factor in camera choice (Meek 2012), followed by infrared or white flash. These two types of camera traps are often mutually exclusive in wildlife surveys because they have distinctly different purposes. For example, using an infrared camera trap for small mammals where identification is difficult is pointless, as is using white flash camera traps for surveys where it is important not to influence the behaviour of animals. In the following sections, information will be provided on camera traps and their characteristics to help users make informed decisions about which equipment is fit for purpose.

4. How Camera Traps Work

The range of camera traps brands, models and types on the market is enormous, and the functions of camera traps vary with every new model. Understanding exactly what is available in a camera trap and how to use the functions effectively is critically important in choosing a suitable model.

4.1. Camera description

Camera brands and models vary substantially, creating a degree of inconsistency between them. Camera traps from popular brands, such as Scoutguard, Bushnell and Moultrie, can all look similar and can even be made in the same factory. Camera traps with separate camera units, such as those made by Pixcontroller, can be quite different in design, despite the use of similar components. Common camera trap components are identified in Figure 5. Although many key components are universal (eg lens, PIR sensor, LED arrays and light metres), others can be identified by jargon that varies between manufacturers (see Glossary of terms).

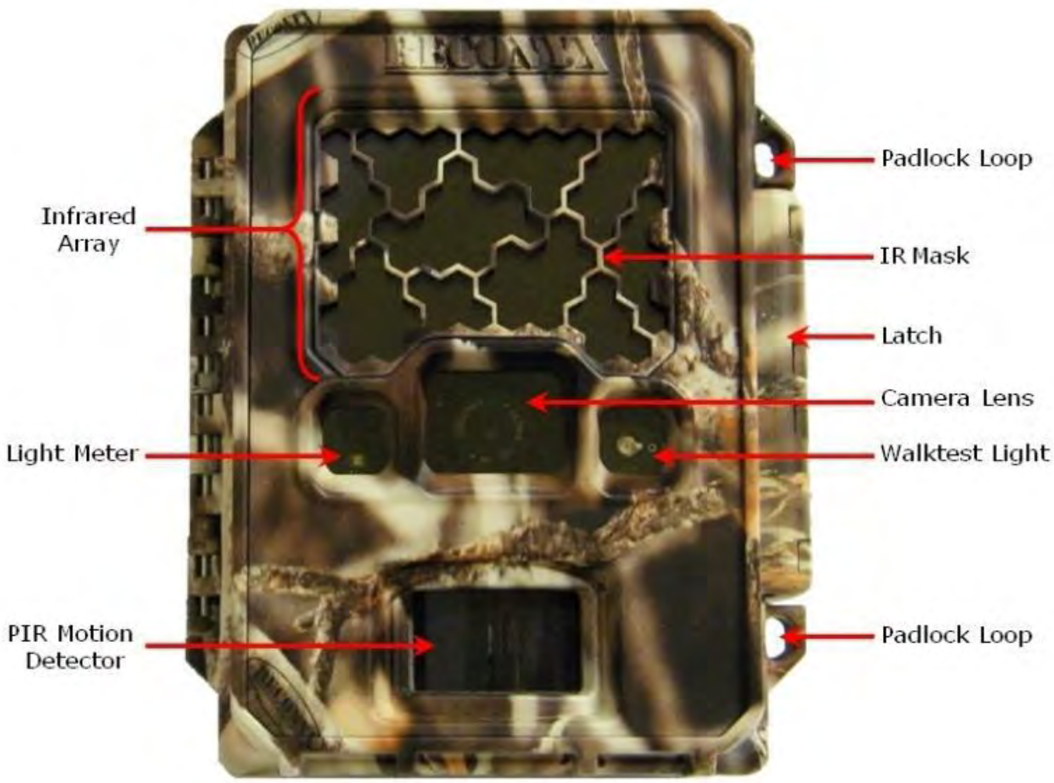


Figure 5. Diagram of a Reconyx HC600 showing the various components that are fairly standard in all camera traps (courtesy of Reconyx).

4.2. Camera trapping studies

Meek (2012) found that a common limitation of camera trapping programs, internationally, was the absence of a robust monitoring design. Furthermore, many users are implementing camera trap surveys without even a basic understanding of the limitations of the technology they are employing.

There are many examples of where substandard camera traps have been chosen as a tool for detecting animals yet no calibration to evaluate detection probabilities have been considered. This is often related to costs (Meek 2012) where researchers have a limited budget but need many cameras, often having to sacrifice quality for quantity (Karanth et al 2011). In some studies, researchers have to move camera traps around the landscape over long periods of time to increase sample sizes. It is in the early stages of planning that the numbers and types of camera traps to be used must be carefully considered.

Karanth et al (2011) provide a detailed summary of considerations related to camera trap survey designs, including season, survey duration, population closure, camera trap spacing and placement, sample area coverage and appropriate analyses.

4.3. Analysing camera trap data

The specific design of camera trap surveys depends on many variables. It is beyond the purpose of this document to provide specific guidance on this subject because of the complexities and nuances that are introduced as different camera trap types are used and different target species are selected. We strongly recommend seeking advice from a biometrician before beginning your survey.

4.4. Camera trap types

There are two broad types of camera trap currently in use throughout Australia for wildlife research: white flash and infrared flash. The flash power (range) determines the depth of view and clarity of the picture taken, and there is considerable variation between camera brands and models.

Camera traps with infrared flash

Infrared cameras use arrays of LEDs that emit infrared light, mostly in the range of 700-1000 nm. The images taken by these cameras are often in grey-scale (Figure 6) or may have a reddish-pink tinge. Infrared flashes tend to be less obvious to wildlife than incandescent ones. Infrared flash also uses less energy than incandescent flash, and models employing them tend to have quicker trigger speeds. The recent development of white LED technology has overcome this issue.

Figure 6. A typical infrared image of a red fox (*Vulpes vulpes*) traversing a road (image: Guy Ballard).

Camera traps with incandescent or white flash

Incandescent flash mostly use xenon gas technology to enable cameras to record clear, colour images during the day or night. Xenon white flash (the most common) illumination is bright but brief. Other gases, such as Krypton and Argon, can be used but these gases have different spectral output and some approach near infrared. The new Reconyx PC850 is the first and only camera trap to use white LED flash for illumination providing a fast trigger speed, good clarity and no 'white-out' effects.

White flash cameras have an important role in wildlife research and monitoring because often researchers rely on detailed colouration and markings to distinguish their target animals from other individuals or species. White flash cameras can provide sharp, full colour images even at night, often with better resolution than infrared models. Relative disadvantages of white flash models, however, can include increased battery draw, slower trigger speed and potential to change animal behaviour by subjecting them to bursts of visible light.

Passive Infra-Red (PIR) and Active Infra-Red (AIR) cameras

Passive infrared (PIR) detection refers to the sensing capacity of the camera and at what point in the field of view the camera will detect heat and motion and take photos. PIR detects the difference between the air temperature (ambient) and the animal's body temperature. This is the most commonly used infrared system in camera traps. Active Infra-Red (AIR) devices rely on two units spaced apart where an infrared beam is projected across a defined pathway. When the beam is broken, the device will take photos as programmed.

These cameras are often more expensive and more cumbersome for remote field work but are much more accurate (R. Meggs, personal communication, 2012).

Still or video

Video function is available on some models, either with still photos or as video only. Video can be a useful method of capturing behavioural information, particularly if the objective is to record a sequence of actions or movements as a part of a study (eg observing how an animal interacts with traps or baits). Video cameras tend to use more battery power than still-photo cameras and will not necessarily provide additional data in some instances. For example, a series of stills, say five or 10 in succession, may be animated with computer software to simulate video footage. Obviously, the particular issue of interest, as well as the response time, and lag period between successive photos, will be important factors in comparing still cameras with video cameras.

Time-lapse camera traps

Some camera traps, such as Brinno and the Wingscape BirdCam, are designed solely to take photos using a time-lapse setting. They are not triggered by heat and movement. Other cameras, such as Reconyx HC600, offer dual functionality, using both time lapse and heat in motion activation. The settings will vary with each camera, but in essence, the camera traps allow intervals to be set between photos, and some allow video and stills to be taken. These cameras are useful where heat differentials prohibit PIR effectiveness or where the subject is fauna such as insects and ectotherms that may not trigger a PIR. Time lapse camera traps may also provide an additional tool in situations like the desert where heat signatures can be masked by background heat. Some PIR camera traps also provide time-lapse options to be set together with heat and motion sensing settings.

4.5. Detection zone

A camera trap's detection zone is not necessarily equal to its field of view. Detection zones vary between camera trap models, and for some, only a small proportion of the field of view actually corresponds with the camera's detection zone. You should check the manufacturer's specifications to confirm the details of the detection zones of camera traps of interest (Table 2). For instance, detection zones are not always conical in shape.

Your choice of detection zone (ie camera model) should match your needs. A narrow detection zone requires the animal to move into a precise range and will not capture animals that move outside of that range. Hence, cameras with a narrow detection zone are best used in situations where the animal is being attracted to a point source of interest, such as a feeding station. Wide detection zones will often match the width of the camera trap field of view or just inside this area and are more suited to passive surveys or diffuse sources of interest. Hence, wider detection zones may be likely to pick up animals sooner and capture more images or video time.

Table 2. Detection parameters for commonly used cameras (modified with permission from Trailcampro).

Model	Detection width @ 9.1m	Detection angle	Field of view (FOV) width	FOV angle	Detection range	Detection zone area m^2
Reconyx HC500	6.7	40°	6.7	40°	30.5	324.1
Bushnell Trophy Cam	14.3	75°	7.0	42°	15.8	164.3
Scoutguard SG550	7.3	44°	7.3	44°	15.2	89.1
Leaf River IR-5	6.4	37°	6.1	36°	17.7	100.9
Scoutguard SG580M	7.6	45°	7.3	44°	11.6	52.7
Scoutguard SG565	11.3	53°	7.6	45°	9.1	38.6
Moultrie I65	6.1	36°	5.8	35°	10.7	35.8
Moultrie I35	6.7	40°	6.7	40°	9.4	31.1
Recon Viper	2.4	15°	6.1	36°	11.0	15.8
Cuddeback Capture IR	2.1	14°	6.7	40°	11.0	14.7
Predator Traileye IR	7.6	45°	7.3	44°	14.9	87.5
Stealth Cam Unit	11.6	63°	7.0	42°	11.6	73.7
Wildgame Innovations X6C	9.8	56°	7.0	42°	16.2	127.5
Uway Nighttrakker NT50	11.0	62°	7.0	42°	13.7	101.7
Primos Truth Cam X	11.3	53°	7.0	42°	13.7	87.0
Spypoint IR-8	8.5	50°	6.4	37°	13.7	82.0
Primos Truth Cam 60	2.4	15°	7.6	45°	21.0	57.9

The shape and way the detection zone works is fundamental to understanding how best to use your camera trap. The Reconyx range of camera traps has a unique detection zone in their non-professional range (Figure 7) that requires an animal to move within a horizontal and vertical zone before the camera will detect heat and movement. If an animal does not cross the sectors shown below from 1-6, while moving within the pink or 'warm' zone, the PIR sensor will not detect movement.

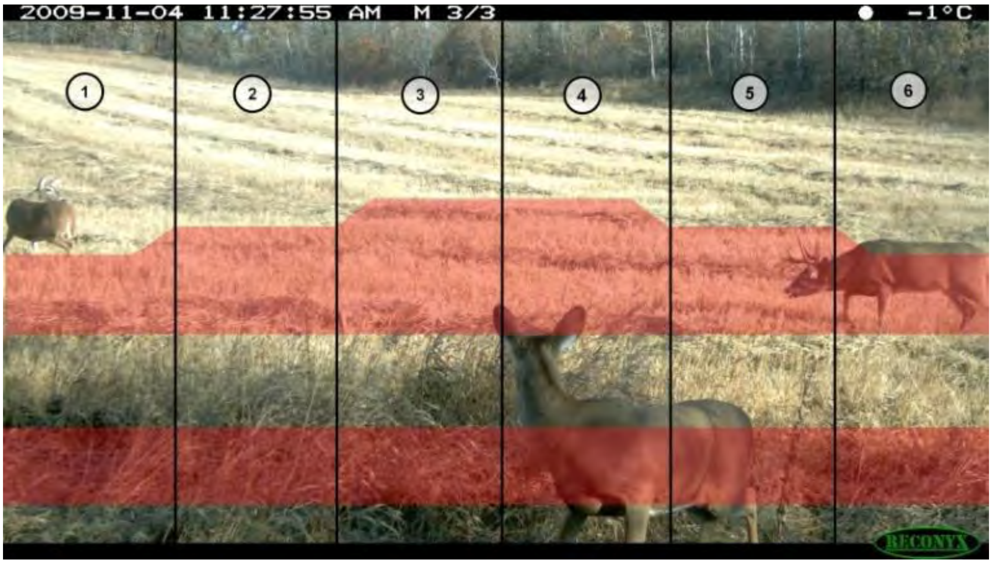


Figure 7. The detection zone in a Reconyx HC500, HC600 and HC800 camera trap showing the warm zones (noted by pink) and sectors where animals have to cross to trigger a photo. The deer in sector 1 would not have triggered the camera (image: Reconyx).

Detection zone type can be selected in some brands prior to purchase. For example, the Reconyx professional range offers two options: narrow or wide. PIR settings can be changed in some models; the Leopold RCX-2, for instance, has Dual Sensor Technology (DST). This allows the user to set the detection zone to either 10 degrees (ideal for focusing on a bait station) or 45 degrees, where a wide detection is required (Meek and Pettit submitted).

4.6. How do PIR sensors work?

There are two types of PIR

- a Ceiling sensor, which minimises dead zones
- a Dual Element, where there are breaks in the detection zone bands, thereby creating a detection zone error.

Most brands use dual element PIRs. This has implications for survey design as it changes detection probabilities. It is especially important where camera traps are being placed facing down or directly in the path of an animal (eg along a log or directly down a road).

A key limitation of PIR sensors is their inability or poor performance in detecting differences between the target and the background in some situations. Where the temperature differential between the background and target is low, some sensors may be incapable of detecting target animals right in front of the camera (see below). This can be especially problematic in desert or beach situations, where background heat and light mask the target, or where reptiles are being observed. Ideally, the temperature differential between the target and the background needs to be greater than five degrees Fahrenheit (J. Thinner, personal communication, 2012).

4.7. Temperature signatures and differentials

Animals have a heat signature. The intensity of heat produced by animals varies between different parts of the body, with eyes and face literally being hot spots (Figure 8). Table 3 shows the body temperature of a number of animals and the ambient temperature where PIR sensors may become unreliable in terms of recognising the temperature differential between the animal and the background. These data suggest that when ambient temperature ranges between 31.5 and 36.5 °C until 42.5 °C, camera trapping can be unreliable for some species.

Figure 8. Image showing the hotspots of furred animals. Note the higher values associated with the face and ears (images: by NASA/JPL-Caltech).

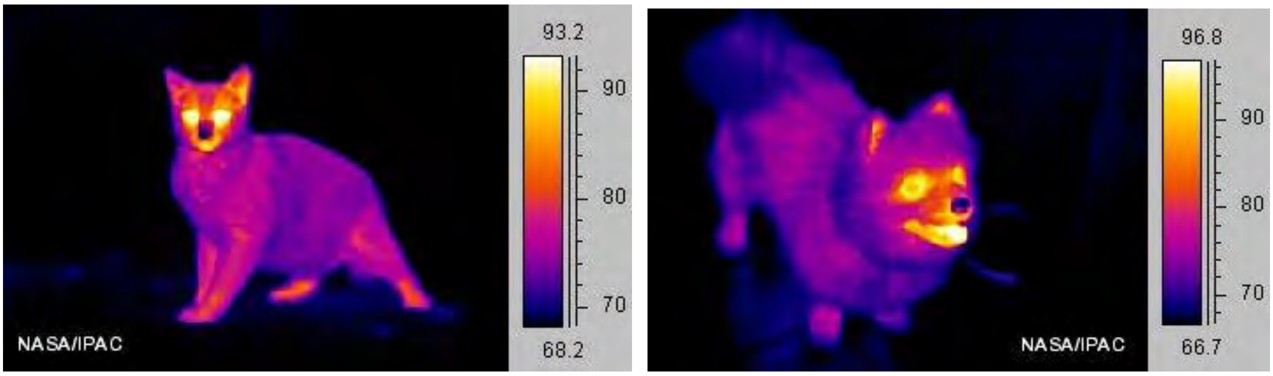


Table 3. Examples of animal core body temperatures and corresponding upper and lower ambient temperature limits for optimal PIR detection.

Animal	Body Temperature °C	Optimal PIR detection below this temperature °C	Optimal PIR detection above this temperature °C
Baboon	38.1	35.1	41.1
Camel*	34.5-41.0	31.5	44
Cats	39	36	42
Cattle	38.5	35.5	41.5
Chicken	42	39	45
Dogs	38.9	35.9	41.9
Elephants	36.5	33.5	39.5
Goat	39.5	36.5	42.5
Horse	38	35	41
Pig	39	36	42
Rabbits	38.3	35.3	41.3

*The camel's body temperature will vary with the time of day and water availability. When a camel is watered daily its body temperature rises from 36.5°C in the morning to 39.5°C at noon, if the animal has no water, the temperature range is 34.5°C to 41°C.

4.8. Non-PIR sensors

There are alternative options to PIR sensors available for some camera traps. Pixcontroller have manufactured their current camera traps to use seismic sensors (vibration), magnetic circuit sensors, pressure plates and normally-open-normally-closed switch sensors. These devices provide other detection options for situations where PIR sensors may be relatively unreliable. Historically, camera traps used passive infrared sensors (ie the camera trap was triggered when an infrared beam was broken by the animal). Other researchers have used treadle plates or trip wires to trigger camera traps (Glen and Dickman 2003).

4.9. Trigger speed

Trigger speed is an important function for many wildlife surveys. Table 4 summarises trials on 21 models of cameras, each with n=5 units, to determine their trigger speeds.

Table 4. The average detection times from first detection to first image of 21 camera trap models (data courtesy of TrailcamPro).

Model	Average Time
Reconyx HC500	0.197 s
Reconyx HC600	0.203 s
Leupold RCX-1	0.937 s
Leupold RCX-2	0.963 s
Spypoint IR-8	1.133 s
Bushnell Trophy Cam Black Flash	1.300 s
Bushnell Trophy Cam	1.344 s
Wildview Extreme 5	1.377 s
Scoutguard SG580M	1.449 s
Primos Truth Cam 35	1.557 s
Uway NightXplorer NX50	1.567 s
Moultrie M-80	1.581 s
Moultrie M-100	1.648 s
Stealth Cam Archer's Choice	1.760 s
Scoutguard SG565	1.858 s
Stealth Cam Unit	2.165 s
Bushnell Trophy Cam Black Flash XLT	2.438 s
Stealth Cam Sniper Pro	2.607 s
Moultrie D55 Incandescent	2.674 s
Moultrie D55 IR	2.681 s
Stealth Cam Rogue IR	4.206 s

A ‘fast’ trigger speed minimises the time between detection and image capture, thereby increasing the probability of a target being recorded. ‘Slow’ trigger speed can result in images being taken without the target in them. Fast trigger speeds may be unnecessary if your target will be within the field of view for some time (eg at a feeding station) and you only require presence-absence information. If, however, the target is likely to be within the field of view for a brief period, faster trigger speeds will likely increase your probability of detection.

4.10. Secure Digital (SD) and Secure Digital High Capacity (SDHC) cards

At the time of publication, Secure Digital (SD) and Secure Digital High Capacity (SDHC) flash memory cards ranged in storage capacity up to 64GB. In addition to capacity, card ‘speed’ is important as it relates to how quickly data can be written to the card from a source, such as a camera trap. This is particularly important for camera trap models that have multiple image and/or high-quality video function. Historically, card speed was described as a ‘Class’ with an ‘x rating’, but the new measurement unit is called the ‘Speed Class Rating’. Camera traps require a fast speed class. Class 2 is suitable for most camera trapping uses, and there is currently no speed-related benefit in those cards higher than a class 4. Some manufacturers make specific recommendations regarding cards so it is important to consult the manual prior to purchase. Camera manufacturer Pixcontroller have been using Eye-cards with Wi-Fi capabilities that enable images to be sent to a home computer, iPhone, iPad or Android device.

4.11. Batteries and other power sources

Like other vital accessories, batteries should be selected after consulting the camera trap manual. Some recent camera traps use a gel cell battery, but the three most common battery types used are Lithium, Nickel-Metal Hydride (NiMH) and Alkaline. The relative life or available power of these types of batteries varies (Figure 9), and their performance will also be affected by weather extremes.

Lithium

Lithium batteries are recommended for many camera traps because of their sustained capacity and high-power output (Figures 9 and 10). They are also unaffected by extreme cold weather. Their power resilience compared to other battery types is unsurpassed with power being delivered to the camera trap until <20% of power remains (Figure 9).

NiMH (Rechargeable)

Nickel-Metal Hydride (NiMH), or rechargeable batteries, have many advantages over alkaline and lithium batteries in that they are a multiple-use battery, and depending on the brand, they hold their charge for a long time (Figures 9 and 10). The initial cost of NiMH may be relatively high, but it has the advantage of multiple uses and minimises numbers of spent batteries going into landfills. The authors’ experience is that performance can vary considerably between brands (Figure 9). In Australia, the Eneloop batteries are good quality and have been recommended by experts.

Alkaline

Alkaline batteries are readily available, and consequently, their use in camera traps is widespread. They tend to be cheaper per battery than the other types above, but tend to discharge quicker than NiMH and Lithium. They also suffer in extreme cold weather, losing up to half their capacity in sub-zero conditions (R. Howe, personal communication, 2011). Despite these apparent disadvantages, many people consider them to be a convenient option that is ideal for short-term deployments.

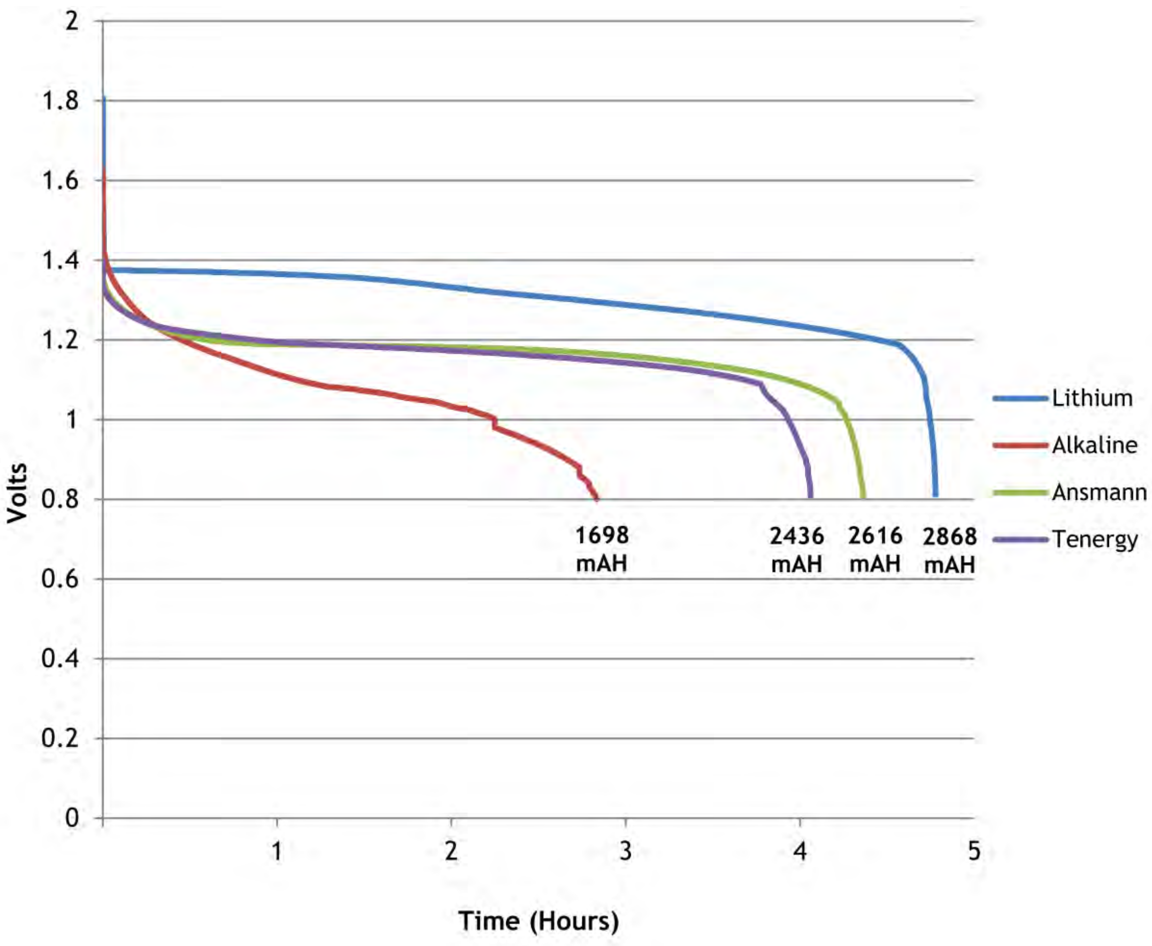


Figure 9. The power discharge of Lithium, Alkaline and two brands (Ansmann and Tenergy) of NiMH batteries mAH = milliamps/hour. (Data courtesy of TrailcamPro).

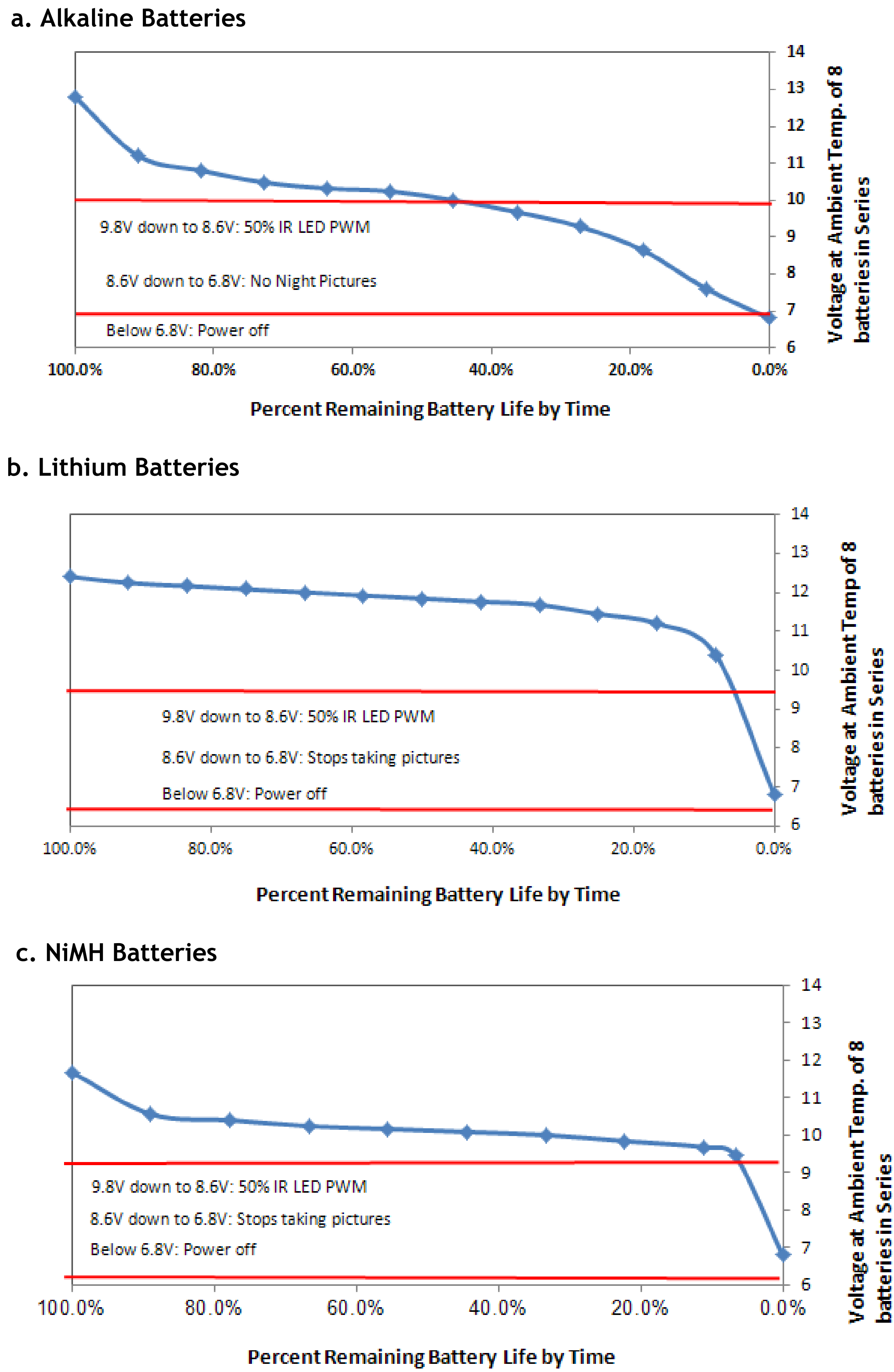


Figure 10. Battery life of three types of AA batteries (n=8) in series in a Reconyx camera trap (a: alkaline, b: lithium and c: NiMH batteries) (data courtesy of Trailcampro).

4.12. External Batteries

Some users choose to connect their camera traps to an external battery and/or a solar panel for extended use. However, only some camera traps afford this option, and it may only be useful to you if battery life, rather than memory, is limiting. That is, if your memory card fills up with images or video long before your batteries expire, the additional operating time is not being utilised effectively. Furthermore, where theft or vandalism is an issue, external batteries and/or solar panels may increase the likelihood of your camera trap being detected.

4.13. Camera care and storage

Most camera traps are reasonably robust, but you should not forget that inside they contain electronic components. Moisture, therefore, can be a significant problem. If rain or moisture humidity breach camera housings, then camera trap performance can be seriously affected and be rendered temporarily or permanently useless. At sites with high humidity, however, excluding moisture from the unit is almost impossible. Many researchers consequently use desiccant in their camera traps. Desiccant comes in many different forms. Some desiccant comes in single-use packets, whereas other types can be dried in a microwave or standard oven for re-use. A problem faced by many researchers has been trying to find a suitable location to place the desiccant, particularly in newer and smaller camera traps (Figure 11).

Figure 11. Finding a place to deploy moisture desiccant can be challenging. The best location in a Reconyx camera where a canister can be used is in the corner of the housing (image: Paul Meek).

Camera traps can also be damaged in transit, whether to or from the site of deployment. Protecting the lens and external sensors is particularly important to maximise the longevity of the equipment. Users come up with various solutions for this, but many buy commercial storage cases with foam inserts to minimise the effects of dust, moisture and impacts. Storage cases for transporting camera traps can be purchased to suit the number of cameras in your kit. Dust and water proof seals are a priority, and foam inserts can be fitted to provide impact suppression during transportation. Many brands are available in Australia. See http://www.rei.com/product/634288/rubbermaid-action-packer-24-gallon and http://pelican.com/case_category_single_lid.php?CaseGroup=Trunk&LidType=%.

5. Camera settings for wildlife surveys

Camera trap models vary in their features and functions, which you must take into account to suit the intended use. You can quickly exclude many camera traps in your decision process based on differences between functionality and intended use. Nonetheless, it is unlikely to be viable for users to buy many models to test for themselves, so it is advisable to discuss the settings and various advantages and disadvantages with colleagues and/or researchers to help fine-tune the settings and image data.

You can program the setting on your camera trap by either of the following ways:

- manually programming through the settings menu on the device
- installing software specific to the camera trap and programming through the SD card.

The latter is not always an option and will depend on the type of camera trap you have.

5.1. Time, date stamp and temperature recording options

Digital images are stored with time and date data (called EXIF files). Nonetheless, it is typically up to you to ensure that they have correctly set these initial values at the time of deployment. Using the time and date stamp data in association with photos is integral to many analyses (see Section 7 for further advice). Be aware that daylight savings and moving between time zones can have impacts on your data if you do not account for them. Some camera traps will also record moon phase and/or temperature data with each image. The temperatures recorded by many models, however, do not represent ambient temperature. Meek et al (in press) found that camera traps deployed together at the same location recorded substantially different temperatures. A camera in a shrub protected from the sun recorded a temperature of 26 degrees Celsius, but one in direct sunlight recorded 30 degrees Celsius.

5.2. Sensitivity

With many cameras, you can control how the camera trap responds to stimuli by changing the sensitivity. The Reconyx Hyperfire 600, for instance, can be extremely sensitive and may capture many images of moving vegetation with the 'high sensitivity', rather than 'medium' or 'medium/low', setting. Conversely, setting the sensitivity to high is important to maximise the sensitivity of the PIR's heat signature differential when ambient temperature approaches the body temperature of animals. In the Reconyx PC850, adjusting the sensitivity to high and shutter speed to fast will reduce flash illumination, which is ideal to survey a nocturnal small mammal. In the Pixcontroller, sensitivity settings can be programmed to reduce false positives by manual adjustment. Check the manual to see if sensitivity settings are available and trial them under various conditions to understand how it affects your camera trap's performance relative to your needs.

5.3. Trigger speed and delays

Trigger speed refers to the time between detection and capture of image or video. Some camera traps have user selectable trigger speeds, but it is common for it to be fixed. The nature of your camera trapping needs will govern the trigger speed you require. Situations involving relatively fast moving targets tend to require faster trigger speeds, such as where animals are moving quickly along a trail. When a target is being attracted to, and then encouraged to stay within the detection zone, such as at a feeding station, slower trigger speeds may be sufficient.

Equally dependent on your survey requirements is your need for the use of a delay period. Where target species' activity patterns are predictable, a delay period may be useful to activate the camera only during periods of interest, thereby preserving battery life and, potentially increasing independence of photographs.

5.4. Number of photos

A single photo can be sufficient to establish presence and identity and obtain demographic information for a target animal. Nonetheless, taking several successive photos increases the chance of obtaining the required information. This can be particularly useful for recording animal behaviour, and as raised above, bursts of consecutive photos can sometimes be used to simulate video.

The number of photos taken per event will depend on the model of camera trap. Some camera traps allow for bursts of sequential photos whenever the subject is within the detection zone, whereas others will only take one photo at a time with unavoidable delays between successive triggers. When multiple triggers are likely (whether due to target animals or not), setting a camera to multiple photos can quickly deplete the memory and/or batteries. Research to quantify the relative advantages of different strategies, with respect to number of images per trigger, is underway (Meek et al unpublished data).

5.5. Flash setting

Flash intensity of some camera traps can be adjusted for through overriding settings, such as sensitivity and/or various night modes, but generally, manufacturers have not provided opportunity to readily change intensity of illumination to suit the distance between the device and the target. It is sometimes possible to add additional flash units or to decrease flash intensity by covering some of the flash shield with opaque electrical tape, for instance.

Camera traps have rarely, if ever, been designed specifically to illuminate close subjects. This is problematic and often results in white-out of close-by animals. The Pixcontroller DigitalEye uses a Sony camera, which automatically sets the exposure settings instantaneously and rarely overexposes the subjects at 1-2 m. You may lose battery life if you change a sensitivity setting to heighten illumination intensity.

5.6. Recovery time

Related closely to number of photos, the recovery time of camera traps is important when using camera traps to survey wildlife. Recovery time is essentially the lag between successive triggers (ie how soon the camera is ready to be triggered again by activity within its detection zone after taking an image, or burst of images). Recovery time (eg instantaneous, within a few seconds, or after nearly a minute or more) will have significant impacts on surveys that require more or less continuous images. For example, if you are trying to capture images of a family group, say moving in single-file along a trail, or studying a behavioural pattern or activity, then it is easy to have a rapid recovery time to maximise the chances of photographing each individual. Conversely, if your focus is presence-absence data, say at a waterhole, a substantial delay between triggers may be acceptable.

6. Field deployment of camera traps

How you deploy camera traps depends on the objective of the study, the camera trap model and the nature of the local environment. It is not the intention of this document to provide specific details on the diverse range of possible survey designs or their particular analysis requirements. A number of authors have already attempted to provide insight and instruction in these areas (eg Kays and Slauson 2008; Karanth et al 2011; O'Brien 2011; O'Connell and Bailey 2011; Rowcliffe et al 2011; Rowcliffe et al 2012).

Cameras may be:

- permanently located
- returned to the same sites repeatedly
- reallocated within a site for successive surveys
- positioned temporarily for one-off investigations.

Some studies and locations may even require daily or nightly removal and replacement of cameras to avoid theft or vandalism. This approach was adopted at Mutton-bird Island (Coffs Harbour, NSW) where the risk of theft was deemed to be extraordinarily higher than elsewhere due to proximity to a town and high human visitation (Zewe et al submitted).

Camera traps are often attached to trees and or posts. Using trees may be quicker, but posts can allow precise, repeatable placement and further reduces the risk of damage to trees in conservation areas.

As a general rule, if you want to be able to maximise the usefulness of the data you are collecting, try to deploy cameras in the same way each time you survey your target species. Some camera traps' performance is a function of their height above the target and their angle of incidence relative to the target's direction of travel (Ballard et al unpublished data). Deployment consistency can avoid the issue of differential detection probabilities that will significantly affect some survey designs.

Reading the manual thoroughly is essential to understand the functionality of your camera and optimising survey outcomes. Before deploying your camera traps, ensure that you have enough batteries and memory cards and that you have settled on a means of placing/affixing the camera traps. For seamless data collection, it is ideal to have two memory cards and twice as many batteries as necessary per camera trap. Set and check the settings on each of your camera traps prior to deployment, including the date and time stamp. Although it may sound unnecessary, it is worth taking GPS locations and making notes about the specific deployment details for each camera trap (eg the type of tree or proximity to a local feature) to help you recover the equipment and data. Recovery can be easy if you have only one or two cameras or if cameras are spaced at regular intervals, but if you have many cameras, say 50 or more, that have been deployed randomly or haphazardly, the GPS locations will be invaluable.

6.1. Photographic principles

When designing camera trap surveys, remember that the fundamental tool being used is a camera. As such, the basic principles of photography also apply. The camera should be stable and positioned to account for its focal range. It should not face directly into the sun. Unlike a hand-held white flash SLR camera where the user can compensate for the conditions, camera traps rarely allow such flexibility. Consequently, you need to consider lighting throughout the 24-hour period, keeping in mind that shade can occur both during sunlight and moonlight. Shading can affect shutter speed; in low light the shutter speed may be slow, leading to blurring.

6.2. Camera trap height

The most suitable height to set camera traps will be determined by the target species, the objective of the investigation and the camera's functionality. Nelson and Scroggie (2009) made recommendations about camera trap height for a range of species. As a rule of thumb, the height of the camera should be similar to the core mass of the animals you are attempting to detect. In the case of small mammals, setting cameras <50 cm above ground level is the standard. In other species the height may be up to 2 m. Specific recommendations on height are in Section 8. Based on the protocols recommended by other organisations, camera traps are usually placed in the height range of 20-50 cm, but this has been decided by trial and error, not experimental data. Meek et al (unpublished data) compared camera trap data from two height classes in detecting animals during carnivore surveys. One camera trap was set about 90 cm above ground level and the other at 300 cm. There was a difference of approximately 40% in both events recorded and detections of species between the low- and high-set camera traps, and low sets were more successful.

6.3. Camera trap direction

In the southern hemisphere, facing camera traps to the south, south-east or south-west will reduce the likelihood of the camera traps facing into the sun (Figure 12). Depending on the sensitivity setting and the camera trap being used, false triggers can occur in the morning as the sun rises and starts to warm sunspots and vegetation. This can also occur where the sun is shining directly on the face of the camera. Avoiding this saves battery life.

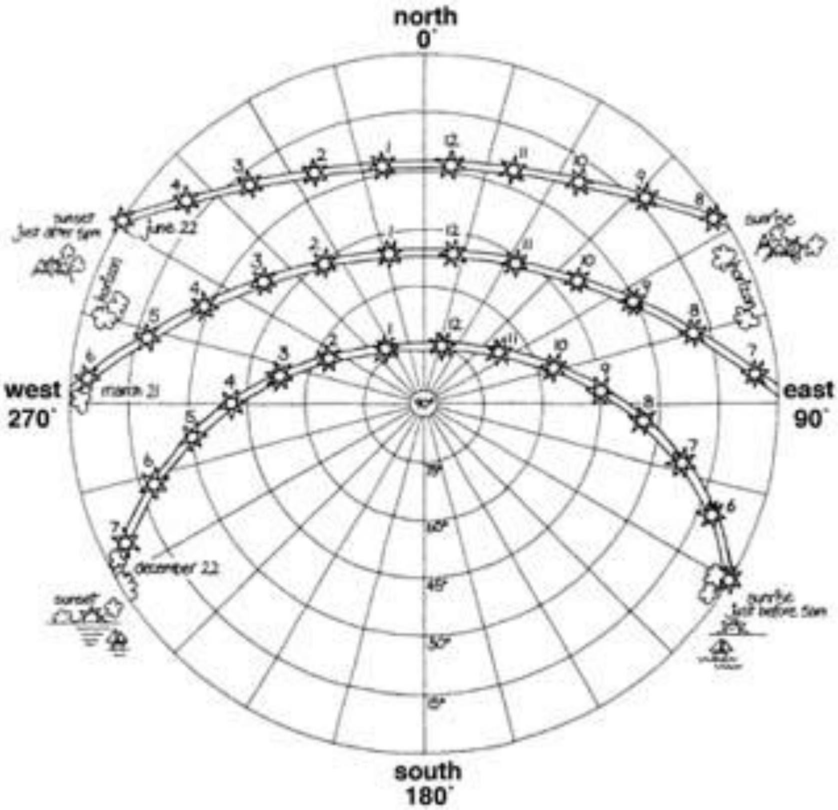


Figure 12. Observed pathway of the sun in the southern hemisphere (courtesy of Museum Victoria copyright).

6.4. Centralising the detection zone

Ensuring that the camera PIR sensor is optimally positioned to detect targets can be time-consuming. Many camera models have a walktest function, or similar, that allows you to check the placement for purpose. To use the walktest, position the camera, switch it on and select the walktest function. This will engage the PIR sensor to detect a passing heat signature, but rather than taking an image, an LED illuminates to signify detection. When available, we strongly recommend using this function during deployment of camera traps, even if viewers (below) are used to perfect the position of the camera trap.

Viewers can be a useful tool for improving the precision of camera trap placement (Figure 13). These can be a cheap card reader with a view screen or a laptop computer. In either case, you can review images from the camera trap, in situ, to refine the deployment prior to the survey. These tools help alleviate some of the problems of camera placement and detection zones. If you chose to buy a cheap camera, just take your SD card with images from your camera and see if the camera will read your images. There are several brands available on the internet: http://cuddeback.com/scouting_camera_products/cuddeview.html http://www.spypoint.com/EN/trail-cameras/accessories/viewer.html http://www.moultriefeeders.com/productdetail.aspx?id=mfh-vwr-11.

Figure 13. The Cuddeviewer (or similar device) allows you to view images taken by cameras that use SD cards and compact flash cards (image: Paul Meek).

Some camera traps, such as Leopold and Scoutguard, have a cable-connected programming device that can also function as a hand-held reader, with live-viewing or picture-reading capacity. These, too, can be used to assist in camera trap placement.

When you use trees to attach camera traps, the size and angle of the tree stem can affect how the cameras are set. The use of wedges, or sticks, to achieve a preferred angle is often necessary (Figure 14). Some camera traps, such as Moultrie, have a light beam that can be used to aim the camera at an optimum site in the landscape. Alternatively, a laser pointer can be bought from a stationary store and used in combination with the camera to work out a rough estimation of where the camera trap is pointing. Nonetheless, some trial and error may be necessary to determine the relationship between the detection zone and where the laser is pointing.

Figure 14. Attachment of cameras using wedges and sticks to aim the camera directly at the focal point (image: Paul Meek).

6.5. Attachment to poles, trees or tripods

A plethora of devices are available for fixing camera traps to trees, posts or other surfaces. The features of the camera (eg tripod mounts), location and objective of the study will determine what you use. Many users mount camera traps to trees with straps (Figure 15). Python locks and their equivalents are excellent for limiting theft, but even these cables can be removed (Ballard and Fleming 2011) if the thieves are determined, or worse still prepared. Most popular camera traps have commercially available theft-proof boxes and are widely available.

Camera traps, such as Reconyx, Leopold, some Scoutguards and Uway, do have standard tripod mounts that can be used where this is convenient and suitable (eg when risk of theft or interference is low to nil). Otherwise, there are numerous camera trap attachments to help set them in the field. Faunatech has a range of products (Figure 16). Moultrie has their Deluxe Tree Mount. Reconyx has five designs. A range of options are available (Figures 17and 18) and can be reviewed on trail camera websites. One of the cheaper brackets is the Outdoor Camera Mounting Bracket that retails for about AUS $20 (Figure 18), although this has a weight restriction (so check your camera trap weight).

Figure 15. Trial of three camera trap models using tree mounting for small mammal investigations (image: Paul Meek).

Figure 16. The Faunatech Rockpod is a sturdy and adaptable tripod-type device (image: Ross Meggs).

Figure 17. Ezi-Aim screw (top) camera trap mounting device for trees and a tripod-type mounting bracket design (bottom) by KORA (image: Paul Meek).

Figure 18. Outdoor camera mounting bracket and Reconyx steel-post fitting for attaching camera traps to pickets and posts (image: Paul Meek).

The use of Steel-strap bracing (available in rolls that can be cut to measure) is also cheap and convenient. Additionally, it allows for accurate placement of the camera's detection zone to maximise coverage (Ballard and Meek unpublished data, Figure 19). The value of the pliable steel strapping is one end can be secured into a tree, post, or a steel peg to create a solid base and then the strapping can be twisted to direct the camera trap exactly where it is required. With other camera traps, such as Scoutguards, the strap or bracket can be attached to the housing using gaffer tape.

Where the placement of a camera is precisely predetermined by survey design, trees may not be available in the right location to place cameras in areas such as beaches and deserts. In this case, a steel post may be required. In other situations where the ground may be too impenetrable to drive pegs, tripods may be necessary.

The number of cameras being deployed will also affect how camera traps are placed, meaning that using special fittings may be too expensive. In this case the cost-effective solution shown in Figure 19 may be a cheap and effective option. Security will also influence what placement method is used. Despite all camera traps being sold with nylon straps of various forms, these offer no deterrent to thieves. Nonetheless, there is no shortage of options available. The main constraints are cost and the type of camera trap brackets available for the model you are using.

Figure 19. This generic bracket can be attached to camera traps that have tripod fittings and screwed into trees or fastened with bolts to posts. Similarly, lengths of steel strap bracing, cut to length, can be used as a more flexible substitute. In either case, a short piece of threaded rod is used with wing nuts to secure the device (image: Paul Meek).

6.6. Spatial distribution of camera traps

Designing appropriate surveys can be complex and it is always advisable to consult a competent biometrician to ensure that the data you obtain are relevant to your question and can be analysed. How you design your camera trap arrays will be influenced by:

- the purpose of your study
- the species of interest
- local environmental variables
- the type and number of camera traps you have.

Deciding on the spatial distribution of camera traps (eg a linear transect vs a grid or some other allocation) can be difficult. Kays et al (2009) recommend that where the objectives are to document entire animal communities, a randomised design is imperative.

When determining the distance between camera traps, researchers have typically taken into consideration the size of the home range of the target species. For some species, inter-camera distances of as little as 25 m may be sufficient to record independent data (Kays et al 2009), but for others, hundreds of metres may be necessary.

6.7. Deployment time

A general rule for the duration of deployment of camera traps is 'the longer you leave camera traps deployed, the better the dataset' (Kays et al 2009). A common time frame for camera trap deployment is two to four weeks (Kays et al 2009), although this can vary depending on the species and habitat. In some cases, camera traps are set for less than two weeks (Kays et al 2009; Meek 2010). Paull et al (2011) suggest that a minimum deployment time for camera trapping studies on Australian small- and medium-sized mammals is 14 nights.

Nelson et al (2009) used camera traps to survey small mammals in Australia and detected Smoky Mouse (*Pseudomys fumeus*) for the first time on the 18th night, more or less over a period of 10 nights. The optimal deployment time, or asymptote, however, will depend on your target species, meaning further research is required for each species. For instance, an asymptote for long-nosed potoroo (*Potorous tridactylus*) is about 12 days, but there is no reliable asymptote for long-nosed bandicoots (*Perameles nasuta*) (A. Claridge, personal communication, 2010).

Table 5 is a summary of current camera trap asymptotes from the literature.

Table 5. The number of nights required for several Australian species to reach an asymptote in detection (H = horizontal placement; V = vertical placement).

Species	Author	Asymptote (survey nights)
Long-nosed Potoroo	Claridge (personal communication, 2010)	12
Southern Brown Bandicoot	De Bondi et al 2010	5
Southern Brown Bandicoot (H)	Smith and Coulson 2012	30
Southern Brown Bandicoot (V)	Smith and Coulson 2012	15
Long-nosed Potoroo (H)	Smith and Coulson 2012	97
Long-nosed Potoroo (V)	Smith and Coulson 2012	17
Smokey Mouse	Nelson et al 2010	10

6.8. Weather recording

Supplementary data, such as those describing local habitat and environmental conditions, are often collected to aid in the interpretation of wildlife survey results and are useful for camera trap surveys. For instance, data on ambient temperature at camera trap sites can be particularly useful as most camera traps used for wildlife surveys are heat and motion sensitive. Such data can be used to scrutinise likely temperature differentials between targets and ambient conditions, providing insight into detection probabilities (see Section 4).

You can also collect local weather data throughout the survey period using field-based weather stations or data loggers, such as i-buttons. These data can also be compared with EXIF data stored by camera traps.

6.9. Active survey designs

Active surveys use a lure to attract target animals into the detection zone of the camera trap. They rely on changing the behaviour of the target animal to increase detection probability.

Baits/Attractants

As in live trapping exercises, choice of bait for active camera trapping will depend on the target species (see for example, Paull et al 2011).

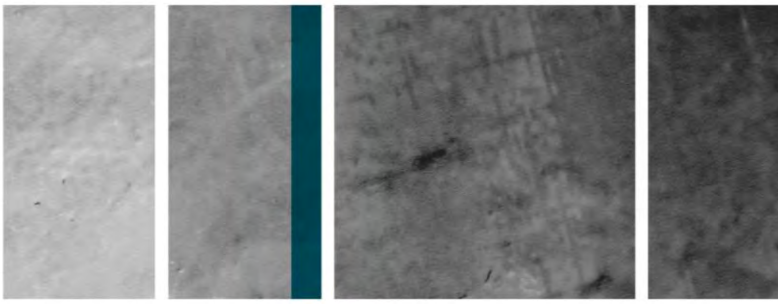
It is often necessary to use some form of permeable container or cage to maintain many food lures at the site of deployment. Tea infusers have been widely used for this purpose in live-trapping exercises for small- and medium-sized mammals, which can be adapted for use in camera trap surveys (Figure 20). The addition of a wire cage or cutlery draining rack (Nelson 2009) will prevent medium-sized mammals, such as possums, from removing the bait. PVC vent cowls (Figure 21), for instance, can be used (Paull et al 2011) and are easier to carry in the field (A. Claridge, personal communication, 2010).

Carcases may also be used in predator/scavenger surveys, particularly when trying to establish presence or absence, or a minimum known-to-be-alive value, for a target species in a particular area (Figure 22). Such techniques hold promise for enumerating mammalian carnivores but can be compromised by frequent visitations by abundant, non-target scavengers, such as corvids and varanids (Ballard et al unpublished data).

Figure 20. An example of a method for maintaining food lures used in northern NSW. A tea infuser containing bait is wired behind a cutlery drainer and suspended on a steel picket. The ruler can be fixed to the picket to assist with image scaling. By suspending the tea strainer inside the cutlery drainer the setup not only excludes small- and medium-sized mammals but ants too (image: Paul Meek).

Figure 21. PVC Vent Cowl used for active surveys of medium-sized mammals on the south-east coast of Australia (image: Andrew Claridge).

Figure 22. A wild dog photographed at the carcase of a dead horse on private land in north-east NSW (image: Guy Ballard and Sam Doak).



Camera trap placement

The target species, habitat and camera type (particularly the type of PIR sensor and detection zone) will dictate the optimum placement for camera traps. In studies where obtaining flank or neck shots are needed for use in identification, camera traps need to face perpendicular to the path of the animal, or be set in such a way to photograph the relevant body part (Figure 23). It is yet inconclusive whether horizontal or vertical is a better placement position for most species, but in most cases, the cameras are set horizontal to the ground. De Bondi et al (2010) and Smith and Coulson (2012) concluded that vertical placement was better to detect Southern Brown Bandicoot (*Isoodon obesulus*) and Long-nosed Potoroo. These authors recommend that camera trap users conduct pilot studies to determine optimal placement for their species of interest.

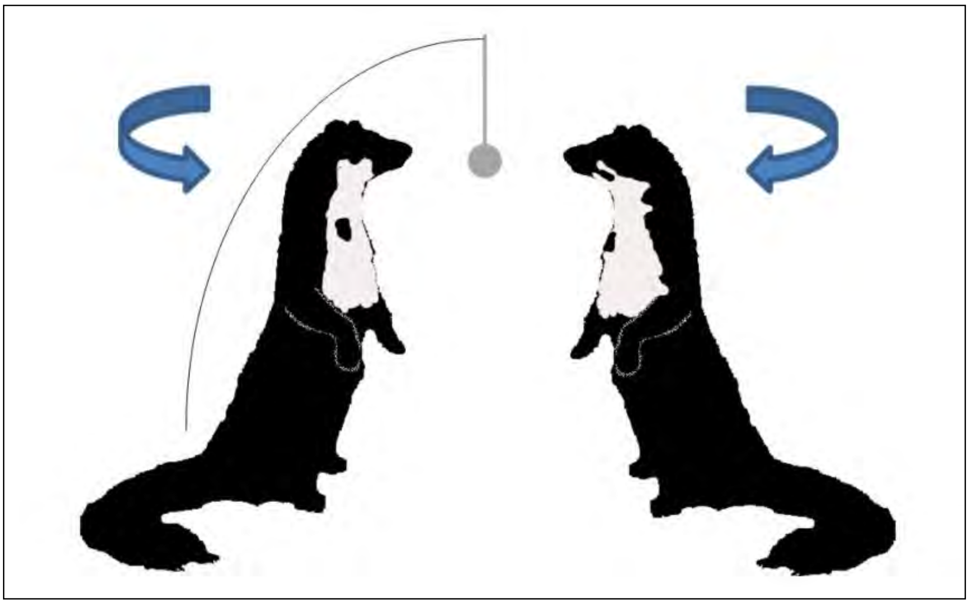


Figure 23. Pine Marten (*Martes martes*) bait delivery system to improve the opportunity for capturing images of the distinctive gula pattern used in image recognition software (Copyright: Erwin van Maanen).

6.10. Passive survey designs

Unlike active surveys, passive surveys use no bait or attractants to lure the target into the camera trap's detection zone when it is critical to the analysis that animal behaviour is not influenced. In Australia passive surveys are often used for carnivore studies to analyse indices of activity or abundance.

Camera trap placement

Most users deploy camera traps at a height equivalent to the core of the target species' body. In practice, this is often from 20-90 cm above the ground for animals ranging in size from quolls (*Dasyurus* spp) up to feral pigs (*Sus scrofa*).

6.11. Animal responses to camera traps

Widespread concern exists about negative responses of wildlife to white and infrared flashes, and there is some evidence to support this (Schipper 2007; Newbold and King 2009). Small mammals and possums in Australia did not avoid sites where white flash camera sites were used (Meel et al unpublished data). In contrast, Prasad and Sukumar (2010) observed a reduction in fruit consumption by frugivorous ungulates at camera trap monitoring sites in southern India. This problem was solved by locating the cameras above the eye line (ie overhead). Studies in Canada found 40% of wolves (*Canis lupus*) showed an adverse response to infrared cameras (Gibeau and McTavish 2009). Similar trials are being carried out in Australia (Meek et al unpublished data) to determine whether mammalian carnivores respond to various types of infrared camera traps.

A few camera trap models can have separate PIR sensors fitted so that they can be placed in more subtle locations, but this is not commonplace. The critical issue is how the animal behaves in response to the flash, whether this affects the data you are collecting and whether the long-term behaviour of the animal changes in response to the initial short-term behavioural response. Importantly, if the purpose of the investigation is merely to assess the presence and absence of an animal, then the startling effect will likely not matter. If, however, the survey relies on repeated visits to the site by the animal, changes in behaviour that reduce this probability may introduce serious bias.

6.12. Camera trap emissions: sounds and sights

Animals are often photographed looking at the camera trap. The reasons for animals' response to camera traps are unknown. Meek et al (unpublished data) hypothesised that infrared light or other light emissions might be visible to some species and these or audible outputs from the camera trap may be the cause. Tests to determine the audio output of IR camera traps produced evidence that all camera traps emitted audible noise in the range 12.5 Hz – 20 KHz (Meek et al unpublished data). These noises are well within the detectable range for feral cats, for example, so their detection by a cat would then be dependent on loudness and distance of the cat from the camera. Similarly, measurements of the infrared spectrum of a range of commonly used camera traps suggest that target animals in Australia, such as wild dogs, red foxes and feral cats, are likely to see camera traps when they are triggered (Meek et al unpublished data).

6.13. Camera trap security

Theft and vandalism are recognised as limiting factors in the use of camera traps worldwide (Kays and Slouson 2008). They are particularly relevant issues for surveys where cameras need to be set in high visitation or high visibility areas for humans (eg beside a track). There are a range of security options available when placing camera traps, such as:

- deterring people from accessing an area
- choosing sites with low human presence
- camouflaging and securing the devices with locks and other devices.

Python cables and their equivalents can be used to fix camera traps to trees or pickets, although an organised thief can cut these cables. Some cameras have purpose-built security boxes (Figure 24) that are thief proof, although they are cumbersome and time-consuming to erect. They can be purchased from all the Australian camera trap dealers, and specific information can be obtained from http://www.camlockbox.com. Many units have camouflaged surfaces, but this is typically based on vegetation from the northern hemisphere. Consequently, users sometimes glue foliage and/or barking to the outside of the cameras, or even recessing cameras into trees.

Some recent models have a camera lens separate to the processing hardware which can be buried underground (eg Bullet cam), or can be located up to 20 m away using a wireless system (eg Pixcontroller). As a last resort, some users place signs on or near the camera traps describing their purpose and asking they be left intact so that data are not stolen (Meek 2012).

Figure 24. A security casing for the Reconyx Hypefire (photo courtesy of Reconyx).

At long-term study sites, there may be little option other than installing permanent security housings (Meek et al unpublished data, Figure 25). These structures are obvious, but regular users of the tracks may become accustomed to their presence and unsure when cameras are inserted. These security posts use standard security boxes welded on steel posts with some modifications. The security box is faced slightly downwards at the front (10 degrees) with the standard front lock having been removed. A modified flat steel key has been manufactured to go through to the rear of the box, and a lock shield was constructed at the rear to reduce bolt cutters' access to the locking mechanism.

Alternatively, a covert camera trap can be set up at an entry point to the survey area to monitor people activity. If cameras are destroyed or stolen, the registration numbers of all vehicles entering the area will be captured. Using the new Xtern Farmcam, Buckeye Orion and Scoutguard SG580M, you can set the wireless motion sensor away from the covert camera, and where applicable, send images and detection messages to a mobile phone from the camera trap using a modem. In Australia a licence is required for these devices, and at present only one camera trap is legally approved for this use, the Buckeye Cam Orion (R. Meggs, personal communication, 2012).

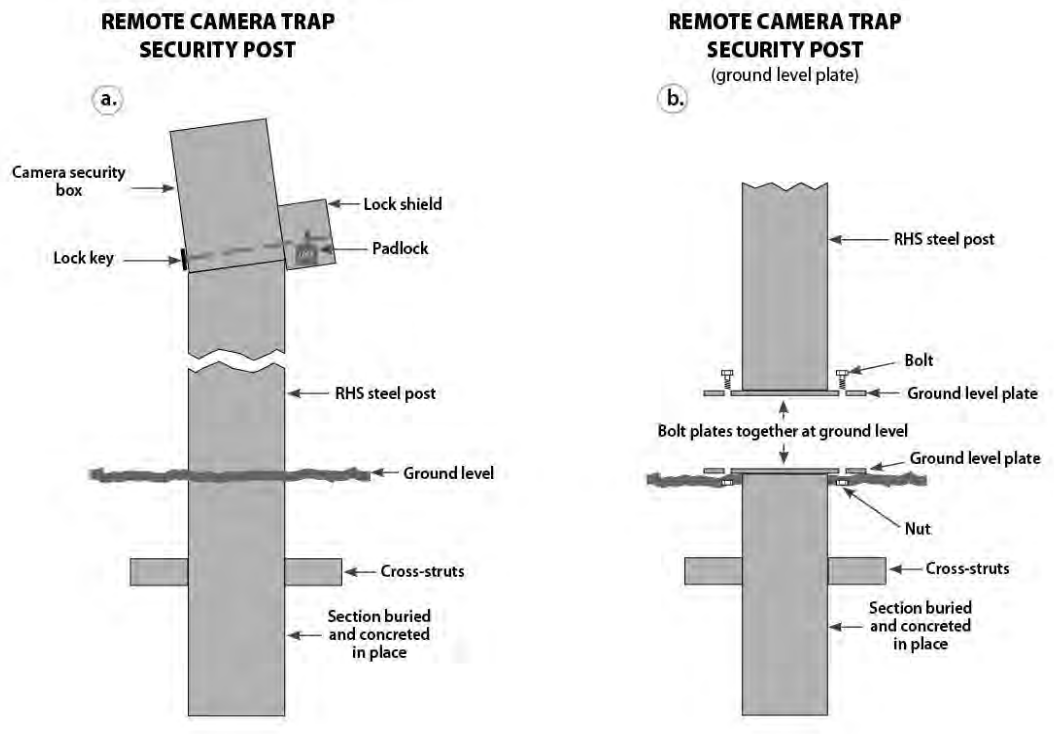


Figure 25. Schematic diagram of the camera trap security post. a) permanent set up b) removable ground level plate set up (Meek et al in press).

GPS tracking systems can also be used to locate stolen cameras (Bancroft 2010). At least one camera trap, the Pixcontroller Raptor, has a GPS telecommunications system designed to detect when a camera is moving and sends an SMS of the location to the user. As discussed in Section 2, the use of camera traps for gathering photos of people is subject to 'Privacy' legislation (Appendix 1). The use of camera traps for covert activities in this publication should not be interpreted as endorsement or a recommendation by the authors.

The use of dummy units placed in obvious locations can also be a useful option, distracting thieves from noticing another camera adjacent to the dummy.

Another option is to close access to the study site or sections of it for the duration of the monitoring, although this may only exclude some people from an area. Alternatively, you can choose times of year when activity by people is less likely to occur. For instance, in Switzerland they set traps in winter because fewer people are in the forest to encounter traps.

7. Data management and analysis

Storing camera trap images is an enormous management issue, but there has been no data-storage standard adopted in Australia. Many users adopt a simple folder system, but for long-term studies, where large volumes of images are being stored, implementing an appropriate database system, or similar, is vital.

The steps in camera trap data management are:

(a) Planning
(b) Collecting
(c) Data cleansing
(d) Coding
(e) Storing
(f) Backing up
(g) Accessing
(h) Analysing
(i) Reporting

(a) Planning

Prior to a survey it is essential to consider your survey design and analysis so that you gather the right data and can analyse the results. For instance, your data coding scheme determines how you store your data.

(b) Collecting

In addition to camera trap images and/or video, information about the survey, site and deployment should be recorded and maintained. A generic datasheet for this purpose is provided in Appendix 3. An electronic version and corresponding Microsoft Access database can be found at www.feral.org.au.

The use of a chalk board or white board to record the site details can later be used to correlate photos with a location (Figure 26).

Figure 26. Dry-erase or chalk boards allow a photo record to be taken at each site with specific site location details to ensure that images correspond to the correct site (image: Paul Meek).

(c) Data cleansing

When the survey has been completed and it is time to start analysing images, first you need to remove images taken during set-up and retrieval. It is important to record the total number of images taken, but when it comes to analysis, these images are superfluous and should be removed. You can use the site datasheet provided in Appendix 3 to record this information and, in turn, enter it into the camera trap database.

The images chosen to be stored will depend on the investigation and the objectives or hypotheses being tested. These choices will not be discussed in this manual and will require expert advice to ensure accurate assumptions and decisions without compromising the investigation.

(d) Coding

Coding allows you to quickly identify and sort camera trap images, either manually or using software. One coding strategy is to record location, time, date, site and camera code for each image, as per the following:

(a) Transect set

Use **CT_Ca_T1_C1** *where*

CT= Camera Trap survey type

Ca= Code for the location, in this case Carrai

T1= Transect number, in this case Transect 1

C1= Camera site, in this case camera Site 1

(b) Grid Set

Use **CT_Ca_G1_Tr4** *where*

CT= Camera Trap survey type

Ca= Code for the location, in this case Carrai

G1= Grid number, in this case Grid 1

Tr4= Camera site, in this case Trap 4

(c) Point set

Use **CT_Ca_S1_C1** *where*

CT= Camera Trap survey type

Ca= Code for the location, in this case Carrai

S1= Site code, in this case Site 1

C1= Camera site, in this case Camera site 1

Although these conventions may be appropriate in many situations, there will always be exceptions to the rule. As long as the core data are noted, the format is not as critical.

(e),(f) & (g) Storing, backing-up and accessing camera trap data

The importance of setting up a back-up system to save image data cannot be overemphasised.

Numerous tools can be used to review data. Ideally, a dual-screen computer system makes data analysis and data entry easier. Programs, such as DeskTeam, MapView and Camera base 1.5.1, provide viewing and coding options on screen. If you have numerous videos to watch, devices such as Xtreamer or VLC Media can be used for processing videos on televisions.

A number of Digital Asset Management (DAM) systems are available, specifically designed for managing images. Some are freeware and others are licensed. Programs include IDImager Pro, Imatch, Photomechanic, Geosetter, Auto Photo Organiser 2.4.739, Lightroom and ACDSee Pro 2. A useful review of packages is also available online.

The most common practice for data storage, however, is designing your own Microsoft Excel or Access database so that it is specific to your needs.

To cater for the specific needs of non-standard camera trap research investigations (eg occupancy or mark recapture), data can be entered into one of the databases descried below and then extracted into an Excel spreadsheet to carry out further coding of data. Use of this software can save an extraordinary amount of time entering metadata, although there are still some time needed to set up the databases before uploading images and processing the results. None of these programs are a panacea for problems of image management and analysis, but they do have various positive attributes and constraints.

MapView

MapView is developed by Reconyx for their professional series (PC) of camera traps and is only available when you purchase a PC model. The program has some useful functionality for basic data storage and mapping. The software accesses your data, extracts the metadata (EXIF), including photo quality data (eg saturation), and sends it to a database. MapView also has a fast viewing function that allows you to view images at a customised speed or manually. It uses Google Maps or a map of your uploading to allow camera trap sites to be marked and then relates future data to those points. Mapview also allows tagging and basic coding of your data. The data can also be exported in a CSV file and entered into your database of choice.

BuckView

This baseline Reconyx software program is available for use with the non-professional series cameras and provides a basic storage system for images. It has similar functionality as MapView with geo-coding and Google map access as well as image viewing options.

Scouting Assistant

The Chasing Game website has produced a basic software package for managing images, which also has the ability to stitch together images to create near-video clips with the options to assign music and text onto a video clip.

Plot Stalker

Moultrie has developed a software program for their plot-watching and time-lapse cameras called Plot Stalker. This program allows a series of images to be stitched together to create a video of the plot or feeder.

Cuddevision

The camera trap company Cuddeback provides a free software program called Cuddevision, which is designed for basic manipulation of image data. This program, however, is more suited to hunting data than scientific storage of images.

DeskTeam

TEAM Network is focused on presence/absence surveys of large carnivores in tropical rainforests around the world. For consistency in data collection between all of their projects spanning 17 countries, they have developed their own internal database called DeskTeam (TEAM Network 2011). This JAVA-based program allows SD card data to be uploaded and the EXIF data are automatically extracted and stored with the images. You can then access these data along with some identification field and code the data according to the world taxonomy list of mammal and bird species. It will also allow you to code groups of photos so that a series of images from the same event of the same species can be automatically coded. Uploading data from multiple sites over the internet is complicated, and the data upload can be slow. TEAM Network is now looking at using BitTorrent sites to upload the data. This database is only available to partner organisations at this time.

Wildlife Picture Index

The Wildlife Picture Index (WPI) is a program developed by the Wildlife Conservation Society (O'Brien et al 2010) in collaboration with many international conservation and research organisations to measure changes in biodiversity in tropical rainforest hotspots around the world. The program uses the state variable of occupancy of mammals and birds of 1 kg and above as the measure of health. It is based on camera trapping programs across many nations, and surveys are carried out annually so that early warnings of a declining WPI can be detected before the communities suffer irreparable decline. Although O'Brien et al (2010) did not clearly indicate how the camera trap data was provided, the strong links with TEAM Network suggests that the data are captured, stored and coded using the TEAM Network software.

Camera Base 1.5.1

This software program was developed by Mathias Tobler specifically for camera trapping data storage and analysis. It is based on his long-term experience in using camera traps for scientific research. The current version is Camera Base 1.5.1 although there have been some minor changes to enable access to data on networks. The manual is only version 1.4 (2010), but this is adequate for the operation of the program. The program requires Microsoft Access although there is a Runtime program to allow it to run without Microsoft Access.

Camera Base 1.5.1 allows camera trap data to be uploaded directly into the program where it automatically renames the data and extracts the metadata from each image and saves it into a file with the images. A valuable function of this program is the ability to enter data from two cameras set at the same location so that it can compare and calibrate detection between cameras.

The program is still being fine-tuned and modified to suit a range of needs. When attempting to share access, organisations encounter problems as each database is individual to each computer. Scripts are available from Mathias to resolve this problem. Similarly, Microsoft Access can cache and jam if moving between stored images too quickly - it is important to install the ImageRegistryFix.reg file to avoid this fault.

The program will allow you to analyse the data to obtain outputs, such as image summary data and reports, activity analysis, capture-recapture analysis as well as exporting data into formats for further analysis in Mark, Presence, Estimates and other programs.

Photospread

Photospread is a program developed in the USA for organising photos, primarily camera trap photos (Kandel et al 2008). This software allows you to load and manage photos and tag information as well as reorganising the images or sets of images according to your needs. The software also allows manipulation and coding of your data but does require some fundamental understanding of programming and basic scripts in Microsoft Excel. A demonstration is found at http://www.youtube.com/watch?v=rf7rA-roBlM.

Jim Sanderson's program

This unnamed software has been developed by Jim Sanderson to code, store, manage and analyse camera trap images. This Disk Operating System (DOS) program uses ReNAMER to manage file names. Using this software requires some fundamental knowledge of DOS and programming to set it up properly. The program is open source and can be downloaded from http://www.smallcats.org/CTA-executables.html.

(h) Analysing data

Analysis of camera trap data depends on the hypothesis (ie the survey design and nature of the data collected). There is a wealth of papers describing the statistical methods and analysis options for camera trap data (Rowcliffe et al 2008; Kays et al 2009; O'Brien 2011; O'Connell and Bailey 2011). We reaffirm the need for camera trap users to consult with a biometrician to make appropriate decisions in this regard.

Understanding how camera traps work is critical to sound scientific investigations and the interpretation of the data. The following factors can all affect the data you collect:

- detection zones
- how each model works
- trigger speed
- delay periods
- the number of images per trigger.

The area of detection can be determined using basic trigonometry if you know the focal length and chord:

½C x FL, where C = chord and FL = focal length.

In camera trapping this can only occur where the chord is flat and does not extend past a point, often encountered if the camera is facing down to the ground or is against a wall or a tree. In situations where the detection area extends to the periphery of the sensor and where it is most likely going to be shaped like a cone (Figure 27), calculating the area of the cone or sector will be:

$\frac{1}{2}FL^2\theta$, where FL is focal length and θ is the angle in degrees (Figure 27).

It is more challenging to work out the chord width at a given point and understand the distance from a given point (eg bait to the edges of the detection zone) and is calculated using the following formula, where;

a = chord

r = radius

d = detection distance

w = detection zone width

$$w = 2 \quad d \tan(\tfrac{1}{2}\theta)$$

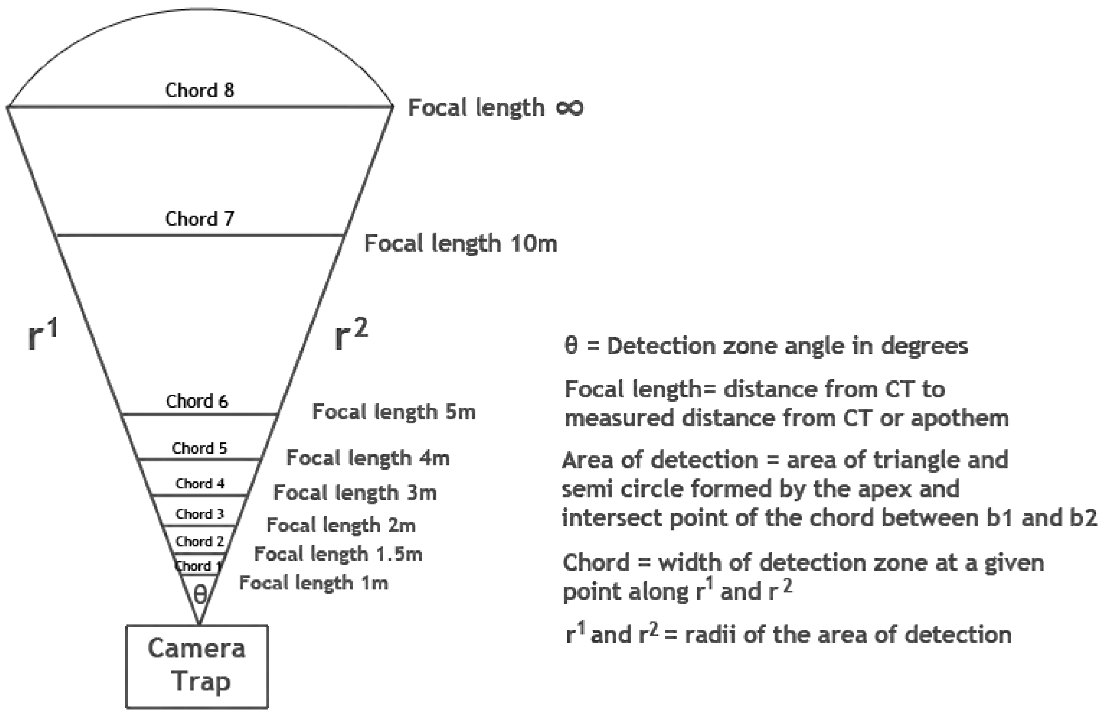


Figure 27. Diagrammatic interpretation of the detection area and elements of a detection zone required to calculate chord width and detection area for analysis.

(i) Reporting

The final task in any research is monitoring, which can be the toughest and most time-consuming and is often avoided. Reporting on research findings, however, is vital in science and management. Whether it is a newsletter, report, or scientific peer-reviewed paper, it is important to be transparent and to share your findings for everyone.

7.1. Types of camera trap surveys

Presence/Absence

One of the simplest measures that camera traps are used is detecting the presence or absence of species. It is often reported as the total number of events of a species over a set period of time and number of camera traps (trap nights).

Detection rate is one of the simplest methods of measuring animals that are photographed at camera trap sets (Kays et al 2009), which provides a general index of abundance, and is recorded as:

Detection Rate = Total number of events of a species/Deployment time

If each camera trap is queried separately, a probability of detection per site can be derived by calculating the detection of each species by each camera each day (Kays et al 2009).

Population trends

Measuring the performance, success or failure of management actions or trends on wildlife populations can be measured with camera traps (O'Connell et al 2011). This can be done by measuring visitation to poison baits by target species as a proof of concept (see Zewe et al submitted), or by monitoring fledgling success (eg Malleefowl and Little Terns following predator population intervention). In the case of pest animals, camera traps may be set to measure the success of a baiting program on carnivores using activity indices as described below (Diment 2010; Ballard et al unpublished data).

The use of camera trap data to measure population status over time and as an early detection system has been advocated by O'Brien (2011) and adopted by organisations across multiple countries (O'Brien et al 2010; Ahumada et al 2011; TEAM Network 2011). The measure of change is based on occupancy and uses the approach described above in the WPI (O'Brien et al 2010). These forms of monitoring networks require sound survey designs, detailed manuals and guidelines, good equipment, reliable personnel, effective data management systems and long-term commitment. The following sections describe the range of metrics used in camera trapping for measuring populations and population trends.

Animal activity, abundance and density

Activity indices are generally considered to be a poor option in population measures (O'Brien 2011), but they do have a useful role in pest monitoring, particularly when the targets are cryptic. The Passive Activity Index (PAI) is one of the most common activity indices (Allen et al 1996; Engeman 2005). In recent times, PAI sand pads have been commonly been replaced with camera traps (eg wild dog activity surveys before and after management interventions). The technique required to effectively sample a predator population is the subject of a long-term research program by NSW DPI and the IA CRC (the authors of this document). Specific outcomes relating to camera traps will encompass camera type, settings and positioning as well as sample size, deployment period and how to interpret of records and events.

Camera traps have been widely used for estimating animal abundance for large species, mostly big cats (Karanth and Nichols 1998), where markings enable accurate identification of individuals. In Australia it is possible to use individual markings for some species, such as quolls (Juczscak et al unpublished data), to estimate abundance. Occupancy is commonly used as a metric for estimating species' occurrence and is a function of abundance (MacKenzie et al 2003; O'Connell and Bailey 2011) as it concerns the probability of a particular animal being in a given site or patch. This method can be misused by only reporting on detection sites and ignoring non-detection sites, thereby failing to calculate the detection probability (O'Connell and Bailey 2011). The software program PRESENCE can be used for calculating occupancy.

Estimating animal density can be difficult with camera traps but is possible if designed accordingly (Kays et al 2009). A detailed overview and methodology for estimating density using camera traps is described by O'Brien et al (2010).

The use of capture-recapture methods using camera trap datasets requires the ability to uniquely identify all individuals captured, a method developed for large cats (Karanth and Nichols 1998). Some researchers have attempted to use paints and markers to automatically tag animals (J. Mulder, personal communication, 2011) to aid density estimation but this method requires more refinement. The Random Encounter Model (REM) (Rowcliffe et al 2008) uses a gas model approach to overcome this requirement based on the rate of contact between animals and camera traps.

Animal behaviour

Camera trapping has increased our ability to study the behaviours of animals under 'natural' conditions (Kays et al 2009; Bridges and Noss 2011). The ability to set the devices in such a way that unbiased data are gathered on how animals behave during their daily cycles is unprecedented. Using camera traps, Bridges and Noss (2011) sorted behavioural and activity patterns into six categories:

- circadian rhythms
- nest predation
- foraging
- niche partitioning and social systems
- habitat use and refugia
- reproduction.

Furthermore, using the time and date stamp functions of camera traps, researchers can now evaluate time partitioning or activity patterns of species whose biology was otherwise only known from radio tracking and trapping investigations (Fedriani et al 2000; Bridges et al 2004; Meek et al in press). Camera traps also provide a continuous opportunity to monitor visitation to nests to quantify visitation and actual predation (Major et al 1996), or feeding sites to record foraging behaviours (Claridge et al 2004) and visitation to inflorescence (Carthew 1993).

7.2. Image identification and recognition

Identification of animals on camera trap images can be challenging and may be complicated in some cases by similar-looking species and poor-quality images. For the most part, camera trap users select camera trap types that provide the best images. Hence, white flash camera traps are chosen where clear images are necessary and colour is important. Where speed is important and animals can be identified from night-time black and white images, infrared camera traps may be chosen. Animal identification and coding is one of the most time-consuming tasks in camera trap surveys, and there are currently no rapid identification systems available.

Individual animal recognition software enables the identification of individuals where unique coat markings can be recorded by photograph (Figure 28). The WildID program (Hiby et al 2009) uses an algorithm to analyse both sides of an animal's coat and at two body locations (body and hind legs) and then proposes some possible identification options with confidence scores. This program currently has about 15 species with matching algorithms.

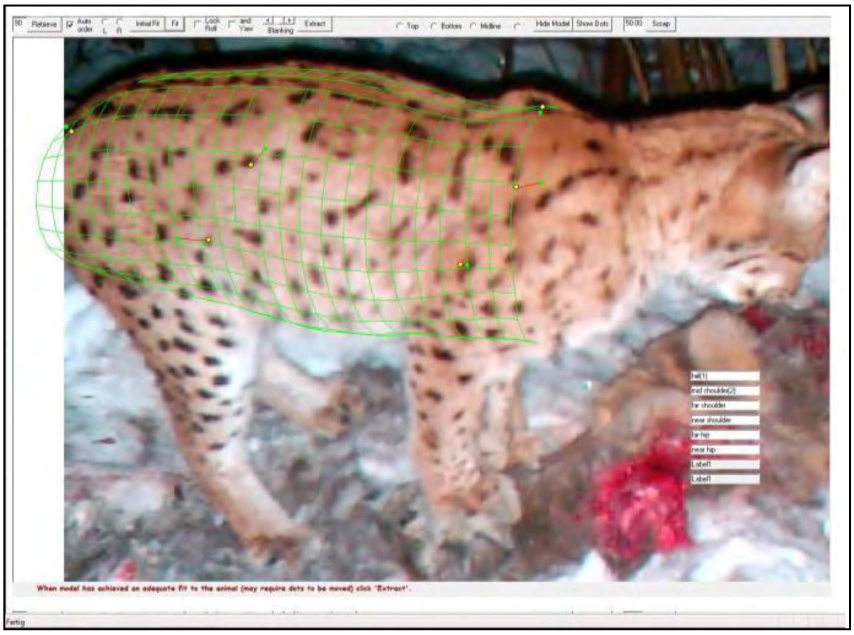


Figure 28. An extracted image of a Lynx being analysed using WildID to determine a known individual (image: Fridolin Zimmerman).

8. Survey designs and methodologies

Protocols for camera trapping surveys are available from a range of organisations. TEAM Network (TEAM Network 2011), University of Arizona, have their big cat protocol. Sky Island Alliance has a standardised protocol for Northern Jaguar. The Wildlife Conservation Society has Wildlife Picture Index (WPI) instructional guide and the African Leopard guides (Henschel and Ray 2003; O'Brien et al 2010). Panthera uses the guide by Silver (2004). KORA has a manual for the Balkans (Breitenmoser et al 2005). Some groups, such as the Alaskan Department of Fish and Game, support the preparation of books to formalise their camera trapping protocols (Mormann and Woods 2010; Magoun et al 2011).

Survey designs vary considerably throughout the world. The WPI (O'Brien 2011) recommends camera trap survey areas of approximately 200 km^2 are manageable for one person while still accounting for spatial distribution of most target species in tropical rainforests. Their design is based on one camera trap per 2 km^2 using 30-35 cameras. Camera traps are randomly located in this program and are always on 'game trails' about 4-6 m from the distal side of the trail and at a height of 20-50 cm above ground level. To extend battery life, they set a one-minute delay and deploy sets of camera traps for 30 days.

In snow leopard (*Uncia uncia*) surveys in Central Asia, the Snow Leopard Foundation provides some general prescriptions for the survey design and placement of cameras for detection investigations throughout 12 countries (Jackson et al 2005). Camera traps are set along the likely path to a marking point of snow leopard. To aid identification of markings, two cameras are placed at each set. To protect cameras and limit false triggers from heat and reflection, they are set in 'cairns', which are rock constructs (Figure 29). Camera traps in this project are set 35-45 cm above the ground in cairns at a minimum of two metres at 45 degrees from the path of travel. Cameras are set with a 20 second delay although a 3-5 minute delay is used where livestock are present. Surveys are conducted for 40-60 days and no longer.

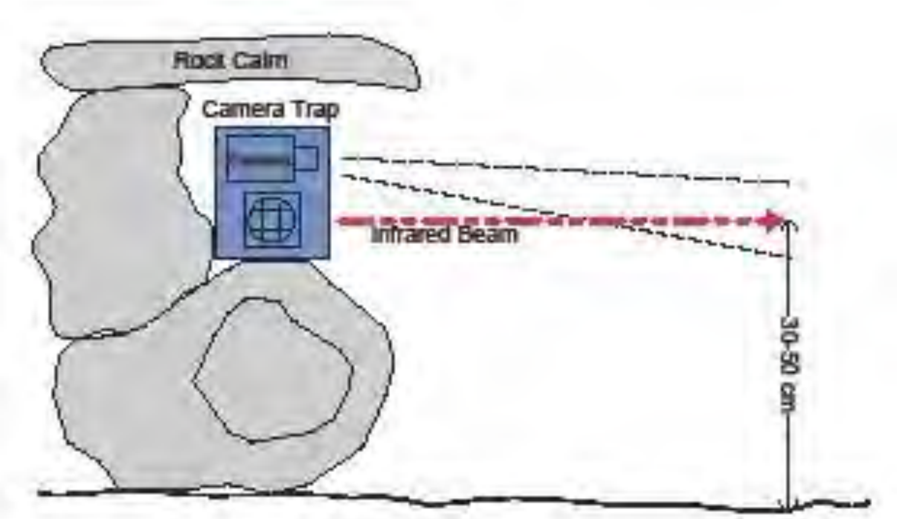


Figure 29. A cairn used to protect camera traps from weather extremes in Central Asia and limit false detections (Jackson et al 2005).

One of the largest groups using camera trapping in the world is the TEAM Network, and they have developed a manual to guide their field staff in survey design (TEAM Network 2011). Their objective is to monitor changes in ground-dwelling vertebrates in tropical rainforests but do not measure abundance. The survey design is closely related to the WPI (O'Brien et al 2010) and involves 60-90 camera trap points within 2-3 camera trap arrays set at a trap density of one camera trap/km^2. All arrays are passive, and sampling occurs over 30 trap nights and only uses Reconyx HC600 or PC800 camera traps. Cameras are set 30-50 cm above the ground and no less than two metres from the animal path. Settings are programmed on rapidfire to take three photos per event with no delay (TEAM Network 2011).

In Australia there are fewer formal standards. This document originated as a proposed guide for NSW OEH staff in 2009-10. Queensland has a draft protocol and Western Australia's DEC has the Standard Operating Procedure for Camera Trapping (Davis 2011b). NSW OEH has recently prepared a protocol for the WILDCOUNT surveys (A. Foster, personal communication, 2012) based on the principles outlined in a monitoring, evaluation and reporting program (Mahon et al 2011).

The following sections provide a range of options currently being used for monitoring wildlife using camera traps. We have refrained from making specific recommendations about the type/model of camera trap that is best suited for the purpose of research because few methods have been adequately tested. This section of the document will be updated as new information becomes available on camera trap methodology using appropriate tests and field trials.

There is considerable variation between, and sometimes within, camera trap models. None of the recommended methods for surveying Australian mammals should be considered absolute – they are reported here as starting points. Further refinement through empirical testing will improve camera trapping as a wildlife survey technique. Haphazardly selecting a camera trap and expecting it to be suitable for answering an ecological question is unreasonable.

8.1. Small mammal surveys

Although the detection of small mammals (eg rodents) using camera traps can be challenging, it is possible to detect *Antechinus*-sized animals (ie dasyurid marsupials) with the correct equipment (Meek et al 2012).

Infrared or white flash cameras can be used, although colour images of nocturnal animals typically require the latter. Active surveys are preferable for several reasons. Primarily, they attract small animals to a specific point and hold them long enough to record an image. Secondly, based on an assumption of repeatability, they allow the user to focus the detection zone to maximise detection rates.

Design of survey

There is a plethora of approaches for small-mammal camera trap surveys. It is often, but not always, advisable to stratify the study site by habitat type and then sample within strata. Kays et al (2009) recommend that camera traps be spaced at 25 metre intervals.

Camera type

The type of camera will depend on:

- whether the animals being surveyed can be identified easily under black and white night-time images and infrared lighting
- whether there are any sympatric species that cannot be distinguished without clear colour images.

Infrared camera traps, for instance, could not be used in some studies because of similar-looking species, such as *Pseudomys* and *Rattus* (Nelson et al 2009; Meek 2011; Meek et al 2012; Smith and Coulson 2012). Conversely, Zewe et al (submitted) did not face identification issues between east-coast rodents and successfully used infrared camera traps.

Camera settings

High sensitivity, bursts of at least three images with no or short delay periods are advisable.

Fine-scale site selection

The design and objectives of your study will govern the approximate location of your camera trap; however, it is the fine-scale location choices that can improve detection probabilities with small mammals. Standard trapping, spool tracking and radio tracking studies have shown the preference of rodents for logs and cover in eastern seaboard forest (Meek et al 2006; Kearney et al 2007), meaning that placing baits near habitat where small mammals can safely expose themselves is advisable. If water rats (*Hydromys chrysogaster*) are your target animal then, utilising the water edge is critical.

Active system

Bait is valuable to ensure that animals are detected and held in place for enough time to take a series of pictures. For instance, it has been proved to be successful to place a standard mammal mix of peanut paste and oats into a tea strainer and enclose it in a protective shell (Figure 20), or a sewer cowling (Figure 21) with food or food-based essences. Trials by Paull et al (2011) proved that standard mammal mix was the preferred mammal bait for small mammals. If it is revealed during pilot surveys that the animals move too fast for the camera to detect a heat and movement signature, it may be worth testing systems where bait is enclosed in a chamber with a camera set inside. This approach has been attempted for the small and fast-moving weasel in the Netherlands with some success (J. Mos, personal communication, 2012) (Figure 30).

Figure 30. The 'Mostela' device for capturing images of fast moving mustelids such as weasels (image: Jeroen Mos).

Horizontal vs Vertical

As a standard it is recommended to use horizontal placement although there is a lack of rigorous surveys that compare horizontal to vertical placement for a range of small mammals. The choice of placement will depend on the objective of the study and the target species. Evidence provided by De Bondi et al (2010) and Smith and Coulson (2012) is inconclusive for all small mammals. Based on this premise, the following methods are suggested.

Height and distance

Camera traps are best placed on tripods or posts so that the right placement can occur. Cameras traps should face directly at the bait and 90 degrees to a movement path (eg log). Facing the camera down the log may not trigger the PIR sensor in some models. Devices should be set about 20-30 cm from the ground and 1-1.5 m from the bait, although the focal length and detection zone of the camera trap will influence how close you can set the camera trap.

Survey duration

The detection rate of small mammals is still being determined for Australian species, and the asymptote is unspecified in the literature apart from Smokey Mouse (Nelson et al 2009). Deployment of camera traps for small mammals should range between 12-18 days (Nelson et al 2009; Paull et al 2011; Meek unpublished data).

8.2. Medium-sized mammal surveys

The size class of animals covered in this section include bandicoot-, potoroo- and quoll-sized mammals. Infrared and white flash cameras are suitable for surveys of medium-sized Australian mammals, although white flash will be required where species of similar genus and shape coexist. Identification of long-nosed potoroos and northern brown bandicoot (*Isoodon macrourus)* in north-east NSW can be challenging under infrared night light. In this situation white flash may be necessary to help distinguish between species.

Design of survey

As discussed above, the design of surveys cannot be prescribed in detail. Nonetheless you need to weigh up stratification of the survey points (by the preferred habitat of the species) against absolute randomised design.

Camera type

The choice of infrared or white flash camera and the model depends on your personal choice and the identification of sympatric similar-looking species at the site. In the case of species such as quolls, infrared cameras are preferred (Claridge et al 2004). Where bandicoots and potoroos are present, white flash may be more appropriate (Nelson and Scroggie 2009; Claridge et al 2010; De Bondi et al 2010).

Camera settings

The optimum settings for medium-sized mammals will depend on deployment time and whether your survey is active or passive. If you use an active system to capture images of animals that constantly visit the bait, the camera trap should be programmed to take 3-5 photos per event followed by a delay period of 30-60 minutes to maximise battery time. If the deployment time is 10-12 days, however, it may be decided to program the camera trap to an infinite number of photos per event with no delay. The disadvantage in this case is that battery will be drained quickly. In the case of the DigitalEye camera trap, the Sony camera battery is unlikely to last more than 10 days (Meek 2010). Setting the device on high sensitivity will also improve detection but may lead to many false positive detections and quicker battery drain.

Positioning and placement

The positioning and placement of the camera traps for medium-sized mammals will depend on the survey design and whether you are using a passive or active system. In general, placing camera traps at right angles to a trail or pathway reduces the time spent by a travelling animal in front of the camera trap and increases the chance of the camera being triggered without recording the animal that triggered the image especially if you are using a cheaper and slower camera and/or if the animal is fast-moving. When using an active system, the camera trap can be faced directly at the bait irrespective of angle, although sunrise and sunset should be considered. It is not important to place bait devices close to logs or harbour for medium-sized mammals as they seem less inclined to avoid open habitat.

Active System

Using a bait ensures that animals stay in front of the camera trap to obtain a series of pictures. A standard mammal mix of peanut paste and oats placed inside a tea strainer and enclosed in a protective shell, or a sewerage cowling with food or food-based essences has been successful. The type of bait used will depend on the target species. Seek advice from local researchers on the most successful lure for your purposes. In the case of an omnivorous generalist species, a standard mammal mix (Paull et al 2011) along with the addition of salami is successful (Meek unpublished data). Truffle oils are also a useful lure for potoroos and bandicoot (Paull et al 2011), and chicken wings are often used for quolls.

Passive system

It is less common to use a passive system for monitoring Australian native medium-sized mammals. Historically, standard baited trapping methods are used to survey small to medium-sized mammals. Setting camera traps on latrines yielded good images of quolls (Claridge et al 2004), and similar features could be chosen for other species that use burrow complexes (Borchard and Wright 2010). The main way of using passive detection is to find animal pathways or runways and set camera traps on those features to maximise the probability of encounter.

Horizontal vs Vertical

The detection of bandicoots and potoroos was greater with a vertical (ie facing down) camera trap deployment (De Bondi et al 2010; Smith and Coulson 2012). In these studies camera traps were placed on 1.3 m star pickets and pointed at bait devices at the base of the pole. This approach should be evaluated as an alternative option to a horizontal array for medium-sized mammals.

Height and distance

As a rule of thumb, camera traps should be placed to aim the PIR at the core body zone of the target animal. Based on the height of medium-sized Australian mammals (between 20-50 cm), Claridge et al (2004) set camera traps for spotted-tailed quolls at 20-30 cm above the ground with good results. The distance from the bait or feature should be 2-3 metres, depending on the camera detection zone range, size and shape.

Survey duration

The duration of camera trap deployments for Australian medium-sized mammals ranges from 5-97 days (Claridge et al 2004; De Bondi et al 2010; Smith and Coulson 2012). This deployment time will heavily depend on camera type, species and placement. Furthermore, detection rates were higher when camera trap arrays were vertical, rather than horizontal (Smith and Coulson 2012). Global camera trap programs in tropical rainforests deploy cameras for 30-day periods as a standard (O'Brien et al 2010; TEAM Network 2011), which provides some indicative maximum time to consider until more rigorous evidence of optimum deployment times are reported for Australian medium-sized mammals. Paull et al (2011) recommend a minimum deployment time of 12 nights for Australian small to medium-sized mammals.

8.3. Introduced carnivore surveys in Australia

The methods used around the world for carnivore surveys are highly variable. Nonetheless, most designs use passive systems of detection, favouring paths, trials, ridges and tracks. Baits will attract introduced carnivores (Robley et al 2010). It has been recommended that camera traps be placed at angles to known pathways of carnivores with the specifications of deployment variable according to the target species (Henschel and Ray 2003; Silver 2004; O'Brien et al 2010; TEAM Network 2011). In Australia the use of camera traps for wild dogs, foxes and feral cats is far less refined, and the following recommendations are based on unpublished research by the authors of this manual and are likely to be modified in the following years as the body of evidence increases with our research. In practice and for consistency purposes, camera trap survey designs for Australian wild dogs, foxes and feral cats mostly mimic the index of activity method used in sand padding (Allen et al 1996; Catling and Burt 1997).

Design of survey

To account for the large home-range size and habitat use of Australian introduced canids and felids, we recommend that you use road-based transects. The length of transect and camera placement will depend on the species. Transect lengths for wild dog/dingo should be 26 km long with camera traps spaced at 1 km intervals (n=25 camera traps). Those of foxes and feral cats can be 13 km long with 500 m intervals between camera traps, although 25 km transects may be desirable for regular detection, especially in sites where these species have large home ranges.

Camera type

When using passive survey designs to determine indexes of activity, animal behaviour should not influenced by the presence of the camera trap so that repeated visits occur as the animal patrols its home range. Nonetheless, as shown in Section 6, wild dogs, foxes and feral cats do recognise the presence of both white-flash and infrared camera traps. The variation in behaviour is yet to be fully understood, although intuition and some evidence suggests that white flash may have a more dramatic effect on animal behaviour. Moreover, infrared camera traps appear more likely to be detected by these animals when they walk towards the camera trap because of the low red glow of the infrared. Nonetheless, a white flash can be detected by animals passing the camera trap either way and may have a higher probability of detection and aversion. Hence, we recommend at this time infrared cameras with fast trigger speed when surveying Australian introduced carnivores.

Camera settings

Camera traps are usually placed within 1-2 metres of the road edge. For instance, camera traps that are placed on tracks or trails are generally close to the road edge, unless the habitat is agricultural or open understory where several metres are clear on either side of the road. To maximise detection, camera traps need to be placed facing down the road at an angle that allows the PIR to sense the animal approaching and take a photo before they walk past. The settings need to be fast to trigger as soon as possible. It is important that no delay is set and 3-10 photos are taken in quick succession. This reduces the challenges of attempting to identify a moving target under infrared lighting from one image. To conserve battery life and card space, 3-5 images per event often yields enough images. If using a Reconyx camera trap, a night setting (Night Mode) can be set to increase the clarity of the image under night lighting.

Positioning and placement

The position of camera traps for carnivore surveys on paths and trails will depend on the habitat. Ideally camera traps should be placed on the road edge facing across and down the track at approximately 22 degrees (Ballard et al unpublished data), where possible, facing a southerly direction to avoid the effects of heat and shadows from the sun's passage over the southern horizon (ie in Australia).

Some researchers use dual-set camera trap arrays for capturing photos either side of the animals as it passes the site (Robley et al 2010). This aids the identification of animals with markings and may be a useful technique to consider for quoll and feral cat capture-recapture surveys. In this case camera traps can both be faced down the track focused on the same point in the road, although Robley et al (2010) found no significant difference between dual-set and single-set results for feral cats (using baits).

Active or passive system

The objectives of using transect surveys for indices of activity are to record animals as they pass without modifying their movement and behaviour. Although it is still uncertain how infrared camera traps affect animals, baits should be avoided as they will bias the survey method based on the Catling and Burt (1997) and Allen et al (1996) design.

Height and distance

The best placement is 50 cm high and 22 degrees down the road (Ballard et al unpublished data). This height represents the core-body height of a medium-sized dog, and the angle to the road maximises the detection zone and time for the camera to capture several photos as the animal approaches the camera trap. The camera trap should face slightly downwards to focus on a point about 5-6 metres from the device and in the middle of the track. Facing camera traps at right angles at 5 metres from the road yielded poor results and is not recommended (Ballard et al unpublished data).

Survey duration

There is no research to date that recommends the minimum duration for carnivore camera trap surveys. As a standard we have been placing camera traps for carnivore research for periods of 12-14 days, but it has been an arbitrary time period as a result of resource availability and the mere volume of sites. For logistical purposes, a 13-day period allows deployment on a Monday and retrieval on a Monday.

8.4. Camera trap surveys for non-mammals

Camera traps that use heat and motion signatures to trigger the device require a temperature differential between the target animal and the background (see Section 4). Insects are often captured on camera trap images, although it is uncertain if the insect was the trigger or if they are merely incidental detections during false positive events. Using standard camera trap models for invertebrate surveys would be a questionable method, and time-lapse camera traps may be more appropriate (see below).

Reptiles and amphibians

In principle, reptiles and amphibians regulate their body temperature by external conditions. This means the optimum temperature differential is going to be in the morning as the animals use the sun to warm up. In contrast, surveys later in the day may be less desirable as the differential between body and ambient temperature is small.

Several researchers are currently experimenting with using camera traps for frogs, lizards and turtles. Somaweera et al (2011) detected salt water crocodiles (*Crocodylus johnstoni*) and Merton's Water monitor (*Varanus mertensi*) in the Kimberley using camera traps. However, there was no calibration to evaluate their detection probability and the potential limitations of the PIR sensor during the day when temperatures approached body temperature and beyond. Camera traps were ineffective at detecting Eurasian Otter (*Lutra lutra*) despite attempts to lure the animals to keep them at emergent marking rocks in water courses (which they rest on after emerging from the water). Pagnucco et al (2011) attempted to survey long-toed salamanders (*Ambystoma macrodactylum*) using tunnels, but heat and motion settings failed to detect the animals. It is these uncertainties that suggest a considerable amount of research is required in using camera traps for poikilothermic animals, especially aquatic species. Surveys of aquatic bird using camera traps may be spurious owing to the possible effect of water on cooling the bird and moist feathers (Lerone et al 2011).

Camera type

Whether to use infrared or white flash illumination for reptiles is important as photos will be mostly taken during daylight hours. In the case of nocturnal frogs and crocodiles, illumination is required during nocturnal-activity periods. As most amphibians coexist with species of similar size and shape, a white flash camera trap may be preferable for assisting in identification.

Alternatively, the use of camera traps with time lapse only, such as the Wingscapes Bird Cam 2 or Brinno camera traps, may be more appropriate. Time-lapse camera traps can be programmed to take photos or videos at predetermined intervals throughout the day or night irrespective of any movement and heat triggers. In situations where temperature differentials are compromised (ie reptiles), time-lapse camera traps could be set at sunning spots or nests and programmed to take photos at time intervals appropriate to the research questions.

Nonetheless, you should use motion sensing cameras to test whether it is effective to survey in early morning (ie before the reptiles and amphibians have time to raise their core temperature with increasing ambient temperature).

Camera settings

The use of heat and motion sensitive camera traps for herpetofauna is not recommended unless they are programmed to take time-lapse photos at one-hour intervals (Pagnucco et al 2011).

Positioning and placement

Horizontal arrays may be a more suitable placement than vertical as they providing clear identification features and markings. Camera trap should ideally be placed at 1–1.5 m above ground level and pointing at the chosen feature to detect the target animal.

Active system

Bait or lures are not necessary for most reptile and amphibian surveys. Nonetheless, camera trap surveys on crocodile nests in the Kimberley used active systems comprising cat food, chicken, beef and fish to mimic a food resource (Somaweera et al 2011). Experimental research is being conducted in NSW to test other forms of attractants for reptiles, and this will be reported when the investigations are completed.

Passive system

Using camera traps to survey herpetofauna under natural conditions/habitat should be designed according to the species being targeted. These sites may be bogs for non-riparian frogs, water pools for riparian frogs, hollow logs for snakes and lizards and sunning/bathing rocks.

Survey duration

The dearth of knowledge on using camera traps for herpetofauna has not been tested adequately. Somaweera et al (2011) deployed camera traps throughout the crocodile breeding season for two months. The survey duration was short because their objective was not to measure populations but to monitor crocodile nests. As an interim recommendation, herpetofauna should be surveyed for 2-4 weeks if time-lapse camera traps are deployed.

Birds

Camera traps have been used to survey birds, such as pheasants (Winarni et al 2009; Samejima et al 2012), Jerdon's courser (*Rhinoptilus bitorquatus*) (Jeganathan et al 2002), lapwings and flycatchers (Bolton et al 2007). The use of camera traps for bird surveys has been well documented, amounting to over 70 published research projects (O'Brien and Kinnaird 2008). In Australia, camera traps are being used for Malleefowl (*Leipoa ocellata*) surveys (Towerton et al 2008), water birds (M. Griffiths, personal communication, 2012) and rufous scrub birds (*Atrichornis rufescens*) (P. Redpath, personal communication, 2012).

Design of survey

When surveying pheasants, O'Brien and Kinnaird (2008) and Winarni et al (2009) used a stratified grid system based on their habitat and placed camera traps along their pathways. Many avian camera trap studies have focused on nests and burrows (Pierce and Pobprasert 2007; O'Brien and Kinnaird 2008) or fallen logs (P. Redpath, personal communication, 2012). Nonetheless, we cannot recommend specific avian survey designs because of the great diversity, habitats and behaviours of Australian bird fauna.

Camera type

It is appropriate to use either white flash or infrared camera traps for avian research. If identification depends on colour and bird activity is possible at night, white flash camera traps are necessary. Purpose-built video cameras are more widely used for bird surveys.

Camera settings

The camera settings will also depend on the type of bird being studied and their temporal activity patterns. Camera traps should be set for continuous triggers, 3-5 photos with no delay and set on sensitive to maximise detection.

Positioning and placement

A passive system is most commonly used in bird camera trap surveys. Nonetheless, attractants and baits have been used in some surveys (O'Brien and Kinnaird 2008) and may be appropriate for general presence/absence surveys. You should avoid facing camera traps down the hollow logs as this may interfere with the PIR sensor system depending on the camera model.

Height and distance

Camera traps for bird surveys need to be placed close to the ground to ensure the PIR sensor can detect the small body mass. The optimal height position should be 20 cm for terrestrial birds. On nests camera traps should be placed either directly above facing down or at the height of the top of the nest. The distance between bird and camera trap will vary with size class and could range from 1–5 metres from an optimum detection point depending on the species. Pierce and Pobprasert (2007) located their camera traps 2.5-5 metres from nests in trees at a height of 0-5 metres above ground level.

Survey duration

Winarni et al (2009) deployed camera traps for 28 days per replicate when they surveyed pheasants. Battery limitations constrained the study conducted by Pierce and Pobprasert (2007) to one week. Camera traps were deployed for 30 days to survey rufous scrub birds (P. Redpath, personal communication, 2012).

9. Discussion

Camera trapping is increasingly adopted worldwide as a wildlife research and monitoring tool. New devices such as thermal imaging equipment (Focardi et al 2001) are further pushing the boundaries of technology and equipment in this field. An obvious advantage of camera traps compared to other survey techniques is the potential long-term cost saving opportunities (De Bondi et al 2010; Meek 2010). Rovero and Marshall (2009) estimated that excluding the cost of purchasing cameras, camera trapping was nine times cheaper than standard trapping. The initial outlay for cameras and the equipment can be considerable at the onset, but similar costs are necessary for trapping surveys. Replacing sand pads with camera traps results in clear long-term savings when monitoring the performance of a baiting (predator control) campaign - no machine time or soil costs, fewer visits and less staff - not to mention that poor weather can no longer delay camera trapping programs.

An investigation to compare the results of predator monitoring techniques has been commenced on known canid populations (Ballard et al unpublished data). The results of this investigation will help guide whether camera trapping can be used as an alternative to sand padding to monitor canid population trends. Moreover, the use of camera trapping as a prey monitoring tool may help improve the rigour and costs of expensive surveys to measure the success or failure of pest control programs.

Although the role and value of using camera traps for wildlife surveys and monitoring is yet to be fully realised and tested in Australia, there are clear benefits when species are challenging to survey or when the identification of individuals is not necessary. If you need to estimate abundance of species that cannot be individually identified by photograph, you need complex data designs, collection and analysis (Kays and Slauson 2008; Rowcliffe et al 2008; Karanth et al 2011; O'Connell and Bailey 2011; Rowcliffe et al 2011). The key issues to resolve are:

- the sample size of cameras needed per species
- site to obtain a useful metric on abundance
- the asymptote for each species being studied
- the survey design
- what constitutes an event
- the analysis method
- the camera settings best suited to detection and analysis.

Problematically the attraction and adoption of camera traps as a tool can be misguided. They are a ‘funky’ tool for field workers and property owners and managers, but they can easily become an expensive toy that is bought prematurely, resulting in the purchase of the ‘wrong tool for the job’. The variety of camera traps and the considerable array of settings available between brands and models need to be considered carefully to ensure that the best camera traps are purchased.

This document aimed to provide novice users as well as scientists a guide to camera trapping. We also addressed the need for standards and consistency in how we use camera traps for wildlife management and research. We have emphasised that:

- camera trap functionality must be understood.
- calibration of cameras must be assessed periodically.
- sampling precision must be adequate (in most cases we don't have this information).
- sampling season must be standardised.

This document will be regularly updated as new research is published to help refine the methods used for wildlife purposes. We have summarised survey methods and settings as a quick reference guide for specific surveys (Table 6). We have also provided useful tips and websites in the following.

9.1. Tips and Hints

1. Put black electrical tape over the front of white flash cameras to reduce white wash on small mammals at close set-up range.
2. Put bark and leaf on the front of cameras to reduce any sound the cameras make and reduce animals detecting the frequency.
3. Putting a laser pointer on the camera can assist with focusing your detection zone.
4. Format your cards to each camera and always keep that card for that camera - check the formatting each time.
5. Never mix charged and uncharged batteries together in the device to avoid battery melt down and a reversal in polarity.
6. As a rule of thumb, the life of the camera should be expected to be about the time of the warranty.
7. Under US$200, cameras are best considered 'throw-away' items as they are generally not designed for repair.
8. When using rechargeable batteries, make sure that all the batteries are charged to an equivalent level.
9. Highly reflective sites, hot air, rain and high humidity can render the PIR sensors unreliable and even inoperable. Caveats apply to surveys in these conditions. It can be inappropriate to compare data from surveys under significantly different conditions as camera trap detection is significantly affected.
10. Some NiMH hybrid batteries will discharge quickly in the heat so be aware of their temperature limits.
11. Lithium batteries have the best performance in a range of temperatures.
12. If you are having trouble with getting close to animals but not wanting to put the camera close, use some cameras that have a custom 2 x telephoto lens.

13. Buy dummy camera housings to use in security boxes prior to deployment of real cameras.
14. Rechargeable batteries have a limited number of charges but the life should be a minimum of two years.
15. Think of a camera trap as an SLR camera. If you place your camera in the shade of a tree, the reduced light will make the resolution of the animal blurrier than when the camera is in open light. In practice try to set cameras in unshaded, low-light sites where possible.
16. Setting cameras to night mode (fast shutter) can help reduce blurring, but remember the illumination may decrease in range.
17. Green plastic can be cut into a filter-sized piece and stuck onto the flash to dissipate the intensity of the flash output.
18. Still images can be cut from video clips using Codex K-Lite 7.8.
19. To fix seals, INNOTEC aquarium glue can be useful.
20. Dual sets (two cameras) can increase detections.
21. Don't walk straight to a possible camera trap site in the snow - walk past and then back to the site to avoid influencing behaviour of animals to walk at the camera.

9.2. Useful Websites

1. Trail Campro from the US www.trailcampro.com/2009trailcamerashootout.aspx
2. Australian re-branded Pixcontroller supplier Automated Outdoor Animal Monitoring www.tracksnap.com/tech_support.html
3. Professional Trapping Supplies in Queensland www.traps.com.au
4. Faunatech in Australia www.faunatech.com.au/products/surveillance.html
5. Reconyx website in the US www.reconyx.com
6. Atrium biodiversity information system and CAPTURE developers www.atrium-biodiversity.org/tools/camerabase
7. Outdoor Cameras Australia outdoorcameras.com.au
8. Wildlife Monitoring in Australia www.wildlifemonitoring.com.au
9. Chasing Game www.chasingame.com
10. Trail cameras Australia www.trailcameras.com.au
11. CAMLock boxes www.camlockbox.com

Table 6. A summary of camera trap settings and methods based on existing published research or described by the authors of this document. Identification of animals is a primary consideration in selecting camera trap settings. There are few occasions where a recommendation should be considered to be absolute, but the range of settings used in surveys will vary considerably between individuals, cameras and requirements and have not been listed in this table (eg PIR settings, stills/video).

Taxon		ID	Passive (P) or Active (A)	Min. images per trigger	IR/WF	Delay	Time lapse	Positioning (H or V)	Horizontal height (cm)	Distance from focal point (cm)	Vertical height (cm)	Spacing (m)	Allocation (Grid or Transect)	Min. deployment time (day)
CARNIVORES	Small	Easy	A	5	IR or WF	Y or N	N (Y)	H or V	20	150	100	10	G or T	12
CARNIVORES	Small	Difficult	A	5	WF	Y or N	N (Y)	H or V	20	150	100	10	G or T	12
CARNIVORES	Medium	Easy	P or A	3	IR or WF	Y or N	N (Y)	H or V	20-50	150	150	20	G or T	12
CARNIVORES	Medium	Difficult	P or A	3	WF	Y or N	N (Y)	H or V	20-50	150	150	20	G or T	12
CARNIVORES	Large	Easy	P	3	IR	Y or N	N (Y)	H	50-90	500	300	500	T	12
CARNIVORES	Large	Difficult	P	5	IR	Y or N	N (Y)	H	50-90	500	300	500	T	12
HERBIVORES/OMNIVORES	Small	Easy	A	5	IR or WF	Y or N	N (Y)	H or V	20	150	100	10	G or T	12
HERBIVORES/OMNIVORES	Small	Difficult	A	5	WF	Y or N	N (Y)	H or V	20	150	100	10	G or T	12
HERBIVORES/OMNIVORES	Medium	Easy	A	3	IR or WF	Y or N	N (Y)	H or V	20-50	150	150	20	G or T	12
HERBIVORES/OMNIVORES	Medium	Difficult	A	5	WF	Y or N	N (Y)	H or V	20-50	150	150	20	G or T	12
HERBIVORES/OMNIVORES	Large	Easy	A	3	IR or WF	Y or N	N (Y)	H	50-90	200	300	20	G or T	12
HERBIVORES/OMNIVORES	Large	Difficult	A	5	IR or WF	Y or N	N (Y)	H	50-90	200	300	20	G or T	12
INSECTS			P or A	5	WF	Y	Y	H or V	NA	100	NA	?	G or T	?
REPTILES			P	3	WF	Y or N	Y (N)	H or V	20	100	100	?	G or T	?
AMPHIBIANS			P OR A	3	WF	Y	Y	H or V	20	100	100	?	G or T	?

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Appendix 1 - State legislation pertinent to the taking, storage and use of camera trap photos

State/Territory	Act Name	Website	Interpretation
Commonwealth JBT/IOT	Surveillance Devices Act 2004	http://www.comlaw.gov.au/Details/C2010C00363	Remote cameras would certainly fit the definition of an optical surveillance device in this Act. However, the intent of using the devices for wildlife monitoring is not relevant under this law.
	Privacy Act 1988	http://www.comlaw.gov.au/Series/C2004A03712	This Act is not relevant to remote camera trapping per se.
ACT/JBT	Workplace Privacy Act 2011	http://www.legislation.act.gov.au/a/2011-4/default.asp	This Act is primarily aimed at protecting the rights of workers in their workplace where detection devices are used for the purpose of human monitoring. Although remote cameras would be classified as an optical surveillance device, the deployment of a remote camera for wildlife monitoring would not be relevant if the intent remains for the purpose of wildlife monitoring.
NSW	Workplace Surveillance Act 2005	http://www.austlii.edu.au/au/legis/nsw/consol_act/wsa2005245	
	Surveillance Devices Act 2007	http://www.austlii.edu.au/au/legis/nsw/consol_act/sda2007210	
	Privacy and Personal Information Protection Act 1998	http://www.legislation.nsw.gov.au/viewtop/inforce/act+133+1998+first+0+N	This Act provides protection for people in regards to the use of their personal information.
SA	Listening and Surveillance Devices Act 1972	http://www.legislation.sa.gov.au/LZ/C/A/Listening%20and%20Surveillance%20Devices%20Act%201972.aspx	This Act would classify a remote camera as a visual surveillance device although the Act is designed for human detection.

State/Territory	Act Name	Website	Interpretation
VIC	Information Privacy Act 2000	http://www.austlii.edu.au/au/legis/vic/consol_act/ipa2000231/	This Act provides security that while at home or work an individual's rights to privacy are not being contravened. This Act makes provision for the preparation of codes of practice. Images of an individual may be considered personal information under this Act, which affects the storage and management of such data.
	Surveillance Devices Act 1999	http://www.austlii.edu.au/au/legis/vic/consol_act/sda1999210/	This Act defines remote cameras as an optical surveillance device although the Act is designed to protect individuals from privacy matters.
	Charter of Human Rights and Responsibilities 2006	http://www.austlii.edu.au/au/legis/vic/consol_act/cohrara2006433	Although this Act is not relevant to remote cameras, aspects of image capture will be.
WA/IOT	Surveillance Devices Act 1988	http://www.austlii.com/au/legis/wa/consol_act//sda1998210	Remote cameras would classify as an optical surveillance device under this Act. However, the Act remains silent if the deployment is for the wildlife monitoring purposes.
QLD	Invasion of Privacy Act 1971	http://www.austlii.edu.au/au/legis/qld/consol_act/iopa1971222	This Act is not relevant as it refers to spoken information, not visual.
	Surveillance Devices Act 2004	http://www.austlii.edu.au/au/legis/cth/consol_act/sda2004210/s6.html	
TAS	Police Powers (Surveillance Devices Bill 2006)	http://www.parliament.tas.gov.au/bills/Bills2006/pdf/34_of_2006.pdf	This Act describes the use of optical surveillance devices that would include remote cameras. However, this law has no relevance to wildlife survey methods and is specific to human monitoring under the necessity of a warrant.
NT	Surveillance Devices Act 2007	http://www.austlii.edu.au/au/legis/nt/consol_act/sda210/index.html	The Act defines optical surveillance devices that would include remote cameras. However, the Act is specific to crime detection.

Appendix 2 - Checklists of equipment and set up for field surveys

Checklist 1 – before going into the field

1. ☐ GPS
2. ☐ Dry wipe or chalk boards and marker pens/chalk
3. ☐ Flagging tape
4. ☐ Hip chain
5. ☐ Bait devices (eg tea infusers or cowl to protect the bait)
6. ☐ Bait and lures
7. ☐ Locks with Keys
8. ☐ Tripods and posts (pickets or droppers etc) if being used
9. ☐ Battery checking device (eg multi-metre)
10. ☐ Camera manuals
11. ☐ Batteries and chargers
12. ☐ US to Australia plug converter (because some chargers come only with US plugs)
13. ☐ Spare memory cards (Note: each remote camera brand can use different cards)
14. ☐ USB cables if necessary
15. ☐ Additional rope, Velcro, tie wire or cords for fixing cameras
16. ☐ Image viewing device for setting up and checking during deployment (eg laptop or Cuddeviewer)
17. ☐ Tools (eg hammer, saw, knife, secateurs, hedge pruners, machete, pliers, rubber gloves etc)
18. ☐ Desiccant packs to reduce humidity inside cameras in wet conditions
19. ☐ Lens wipes
20. ☐ Silicone gel or Vaseline for rubber grommet maintenance
21. ☐ Door wedges for setting camera angles against trees

Checklist 2 - Setting up in the Field

1. ☐ Read the instruction manual for your cameras and be familiar with their nuances.
2. ☐ Minimise scent on cameras and at sites for species such as foxes and wild dogs that are deterred by human scent.

3. ☐ Check the camera is taking and storing photos before deployment.
4. ☐ Make sure all batteries are charged before deployment.
5. ☐ Position the camera facing south or north if possible and in shade to prevent false triggers, shots into the sun or overexposed photos due to the sunlight and reflection. Avoid rock outcrops and shadows in the field of view.
6. ☐ Aim the camera at a 45-degree angle to the path of the animal.

   This will increase the chance of detecting animals as they approach the camera and avoid missing them where trigger speeds are not quick enough to respond to a 90 degree-to-trail facing camera. A 45-degree angle also reduces the blind spot some cameras have in the middle of the lens when animals are approaching from directly in front. If using a bait station, aim camera exactly on the food source and in the centre of the camera's field of view. DO NOT set cameras along logs if identification is paramount. For instance, you will need clear images to identify small rodents.
7. ☐ Make sure that the aim of the camera is appropriate for the detection of the subject. If it is too close to the animal, this may result in blurry or washed-out images. If it is too far away, the flash may not be bright enough to produce a clear image. A rule of thumb for larger animals is to aim to capture the subject between 4-5 metres from the camera. For smaller animals you will need to experiment with shorter distances (eg 1-3 m). Trials in northern NSW have successfully captured images of small rodents at 1-1.5 m from the subject using Pixcontroller, Reconyx and Cuddeback cameras (Meek unpublished data 2010).
8. ☐ The height to set the camera on a tree, post or tripod depends on what is available and what is being photographed. For small mammals you will need to place the camera at 20 cm from ground level. Larger animals may require a height setting of >100 cm.
9. ☐ The camera should ideally be set parallel to the ground although this may depend on the aims of the investigation. Use wedges behind the device to aim the camera properly. Cuddeviewers and other computers can be used to check camera fields of view.
10. ☐ To ensure that the camera is not triggered by false subjects, ensure that vegetation that can move in the wind is removed from the field of view. It is also advisable to set the camera on firm trees or posts so that they are not swaying in the wind and taking false photos.
11. ☐ Check camera settings to ensure they fulfil the objective of the investigation.
12. ☐ Use the test mode (if available) to check and verify motion detector's range. If not, take a photo and upload the image to check the settings are correct.
13. ☐ Using your dry-erase board, make note of all necessary site data (eg site name, code, date, officer, camera number if used). You may also want to write down the settings.
14. ☐ Record data on datasheets including a GPS point.
15. ☐ CHECK YOU HAVE ARMED THE CAMERA BEFORE YOU LEAVE!!

Appendix 3 – Camera Trapping data sheet

SITE CODE		**DATE SET**	**DATE RETRIEVED**	
OBSERVER(S)		**LOCATION**		
LOCATION DESCRIPTION				
MGA COORDINATES	**Easting**		**Northing**	
BROAD HABITAT TYPE	**Rainforest**	**Sclerophyll**	**Woodland**	
	☐ Subtropical ☐ Dry ☐ Temperate	☐ Wet Sclerophyll ☐ Dry Sclerophyll ☐ Swamp Sclerophyll ☐ Heath ☐ Grassland ☐ Sedge	☐ Shrub Woodland ☐ Heath Woodland ☐ Tall Woodland ☐ Grassland	
GENERAL HABITAT DESCRIPTION				
CAMERA TYPE	**CAMERA CODE(S)**		**LOCK KEY #**	
CAMERA DIRECTION	**CAMERA HEIGHT**		**DISTANCE TO LURE**	
CAMERA SETTINGS			**BAIT TYPE**	
BATTERY POWER DEVICE		**BATTERY POWER CAMERA (If separate)**		
CAMERA DETECTING WHEN MANUALLY TRIGGERED?	☐ Yes ☐ No	**BATTERY REPLACEMENT DATE**		
CARD REPLACEMENT DATE		**NUMBER OF IMAGES**		
CENSUS 1 WEATHER	Date	Measurement time	Temperature: Dry Wet	Relative Humidity (%)
WEATHER CONDITIONS WHEN CAMERA SET				
WEATHER CONDITIONS WHEN CAMERA RETRIEVED				
CENSUS 2 WEATHER	Date	Measure time	Temperature: Dry Wet	Relative Humidity (%)
WEATHER CONDITIONS WHEN CAMERA SET				
WEATHER CONDITIONS WHEN CAMERA RETRIEVED				

CAMERA TRAPPING CONT'D

COMMENTS AND ADDITIONAL INFORMATION (Camera performance)

Poor external battery performance ☐ Yes ☐ No ....

Poor camera battery performance ☐ Yes ☐ No ....

No or few images ☐ Yes ☐ No ....

Camera programming faults ☐ Yes ☐ No ....

Numerous false triggers ☐ Yes ☐ No ....

Other problems:

PESTSMART

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