



Ecological Field Monitoring Protocols Manual

Using the Ecological Monitoring System Australia

Camera Trapping Module



Citation

Laws M, Potter T, McCallum K, Cox B, Bignall J, Peacock D, O'Neill S, Sparrow B. (2023) Camera Trapping Module. In 'Ecological Field Monitoring Protocols Manual using the Ecological Monitoring System Australia'. (Eds S O'Neill, K Irvine, A Tokmakoff, B Sparrow). TERN, Adelaide.

Version

Readers are advised that all modules of the Ecological Field Monitoring Protocols Manual regularly undergo revision. Readers should check the website tern.org.au/emsa-protocols-manual/ to ensure they are viewing the current version.

Version 2

Last updated: 17 April 2024

Acknowledgements and contributors

This publication is the result of a body of work funded by the Australian Government Department of Climate Change, Energy, the Environment and Water to develop standardised ecological monitoring standards.

Key components of this module were developed, written, and field tested by the TERN Ecosystem Surveillance team based at The University of Adelaide. In addition to the authors, the following team members made contributions to the project: Ellen Kilpatrick, Kate Matthews, Rhys Morgan, and Carly Steen. Technical components, including the development of the accompanying app, were developed by the team led by Andrew Tokmakoff, including Luke Derby, Matthew Barty, Jin Zhou, Ho Hai Huy Vo, Walid Al Naim, Muhammad Khan, and Michael Doroch. Aspects of the protocols that have been built on by this project are the result of the extensive and ongoing body of work conducted by the TERN Ecosystem Surveillance team, as part of TERN's field-based ecosystem monitoring program. A full list of team members who have contributed is available on the TERN eSupport Services [website](#).

TERN is funded by the National Collaborative Research Infrastructure Strategy.

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The information contained in this document comprises information and instructions for implementing ecological monitoring field surveys. The reader is advised that TERN has made best efforts to ensure instructions are comprehensive enough to fulfil the tasks required to the standards required at the time of publication. All field surveys must be carefully planned to ensure the safety of personnel is paramount and that the required scientific permits and wildlife licences are obtained from the appropriate jurisdictions and conditions strictly adhered to. Such requirements may go above and beyond those listed in this manual. TERN, including the project personnel, are excluded from all liability to any person for the consequences, including but not limited to all losses, damages, costs, expenses, and any other compensation arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

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Main front cover photograph: Reconyx camera trap deployed in Deep Creek National Park, South Australia.

Version control

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The version history of this module is identified below. The version history of the Ecological Field Monitoring Protocols Manual, the methods and data implications, both historical, current and future interpretations of data, are available from the TERN website. Enquiries should be directed to tern@uq.edu.au.

Version	Date	Version update overview
1	21 July 2023	First published version
2	17 April 2024	Updated details for uploading camera trap array spatial data; added deployment start date step; updated details in the steps to repeat steps in the deployment protocol; updated details for the deployment ID; updated details in the deployment end date step in the retrieval protocol.

About the Ecological Field Monitoring Protocols Manual

This module is one of many that form the *Ecological Field Monitoring Protocols Manual* using the *Ecological Monitoring System Australia* (EMSA), available at tern.org.au/emsa-protocols-manual/. EMSA has been developed by the Terrestrial Ecosystem Research Network (TERN) in collaboration with the Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEE) to support the National Landcare Program (NLP). The protocols included in the modules build on previous work by numerous ecologists throughout the country (acknowledged in the text) and have been refined with the help of Australia's natural resource management (NRM) community. They provide users with a clear set of protocols to measure and monitor most Australian ecosystems quantitatively and repeatably to enable the reliable quantification of environmental change.

The system addresses many limitations evident in previous NRM programs that have made this change quantification difficult. These included measuring or estimating environmental occurrences with disparate and often incompatible methods, particularly over a range of geographic scales, along with previous inefficiencies in data provision and analysis. The EMSA protocols presented in the modules provide clear and proven methods (built upon previous method/s where appropriate) to accurately measure environmental change for many variables of interest in Australian terrestrial environments. The modules are supported by a toolset to collect and deliver data to the Australian Government's Biodiversity Data Repository, which will see various management, policy and research outcomes informed by the data collected.

The current set of 24 modules is not an exhaustive list, and TERN and DCCEE may develop additional modules in the future as gaps are identified. We intend these modules and the supporting Monitor app to be widely accessible, with little assumed knowledge, using methods that NRM practitioners and ecologists can easily adopt. To support the uptake of the protocols, we are also developing a series of education and guidance materials and an in-person training course. We anticipate that users outside of the NLP may be interested in utilising these protocols. The team plans to make a version available in the near future that will be independent of the NRM project management system - the monitoring, evaluation, reporting and improvement tool (MERIT), to enable that widespread use.

We acknowledge, value and respect the experiences, perspectives and cultures of Indigenous Australians. We recognise the importance of combining Indigenous and western environmental knowledge systems to improve ecological monitoring in Australia. The EMSA protocols are designed to be implemented alongside First Nations protocols, procedures and policies, and we look forward to working in partnership with Indigenous land managers on future versions of these protocols.

The protocols detailed here are freely available for widespread use by acknowledging their source. The protocols will be refined over time, so we encourage you to download the latest version before using them. We look forward to continuously improving these protocols in the same way as we utilise an adaptive management framework on the environments we monitor. We know that the data collected and supported by this program will enable analyses in novel ways and at previously impossible scales. We thank you for joining us on that journey and look forward to working with you to implement the EMSA system to benefit all Australians.

We also welcome you to provide feedback to tern@adelaide.edu.au

A handwritten signature in black ink, appearing to read "Ben Sparrow".

Ben Sparrow

Associate Professor and Program Lead, TERN Ecosystem Surveillance



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1 Module overview

1.1 Available protocols

This module includes three complementary camera trapping protocols, each of which collects all associated metadata in a standardised manner in the Monitor app:

1. Camera trap deployment – camera traps deployed at points of interest or in an array or Fauna Plot.
2. Camera trap re-equipping – camera trap batteries and SD cards replaced to extend deployment.
3. Camera trap retrieval – camera traps retrieved at the end of the deployment period.

The deployment protocol can be used to simply deploy camera traps at one or more features of interest, such as a waterpoint or trail, as well as in an array (i.e. grid or transect), or in Fauna Plots in conjunction with a general vertebrate fauna survey (e.g. Gillespie et al. 2015). Camera traps may also be deployed using a combination of these approaches to improve the probability of detecting a species or maximise the species inventory when undertaking fauna monitoring within a project area.

Camera traps are often deployed at bait stations to attract fauna into the detection zone, which increases the likelihood of detection (Gillespie *et al.* 2015). As such, the deployment protocol provides an option for passive (without lure or bait) and active (with lure or bait) survey designs, including monitoring a bait station, carcass or palatable plant. This allows the protocol to be tailored to monitor vertebrate pest species, including feral cats, wild dogs, foxes, feral pigs, deer, rabbits, goats and camels.

The deployment protocol includes the procedures and guidelines for broadly locating camera trap points in the field, micro-siting the exact camera trap point locations to optimise fauna detections, site preparation, installing bait stations, and recording all associated metadata (e.g. survey type, camera trap make, model and settings, camera trap location and orientation, focal point, target species if applicable, bait station details, deployment period) in a standardised manner directly into the Monitor app.

The module covers pre-field survey tasks, including camera trap, SD card and battery preparation (see Appendix 1), as well as study design and planning considerations to maximise species detection and identification (see Appendix 2).

Complete lists of data collection fields are provided in the Monitor app, as well as the TERN Linked Data [website](#). Data standards are based on the Camera Trap Metadata Standard developed by Forrester et al. (2016), an open data standard for storing and sharing camera trap data between projects, and which offers a foundation for collecting the more detailed data needed for downstream analyses. The standard captures information about study design, the type of camera trap used, and the location and species names for all detections, among others, in a standardised manner. The standard is compatible with the Federal Geographic Data Committee, the Darwin Core, the Ecological Metadata Language, and the Audubon Core metadata standards to allow data to be easily cross referenced with existing data repositories, such as DataONE (Forrester et al. 2016).

1.2 Relationship to other modules

1.2.1 Mandatory related modules

Mandatory if deploying camera traps in a fauna plot in conjunction with a general vertebrate fauna survey:

- Plot Selection and Layout Module – the Fauna Plot must be established first, and the boundaries must be defined to ensure the camera traps are deployed within the plot boundaries.

1.2.2 Optional complementary related modules

- Vertebrate Fauna Module – camera traps can be used in combination with a range of other vertebrate fauna survey methods (e.g. pitfall trapping).
- Vegetation Mapping Module – fauna habitats in the project area and Fauna Plot selection can be informed by the results of the Vegetation Mapping Module.
- Targeted Surveys Module – camera traps can be deployed as part of targeted surveys and can be used in combination with a range of other targeted measures.
- Interventions Module – camera traps can be used to detect distribution and population trends associated with interventions to conserve threatened species, as well as monitor vertebrate pest population control.
- Opportune Module – opportune records can assist with camera trap placement based on any observations (direct or signs) of target species.
- Fauna Sign-based Surveys Module – camera trapping can be used in association with sign-based surveys to help verify sign-based data and assist with abundance estimates.
- Fauna Ground Surveys Module – camera trapping can be used in association with direct ground surveys to extend the survey period (i.e. 24 hrs per day) and assist with abundance estimates and individual identification.

2 Introduction and background

The Camera Trapping Module covers the use of camera traps to monitor fauna species, including vertebrate pests, across the project area. The module includes protocols for the deployment, re-equipping and retrieval of camera traps, each of which collects all associated metadata in a standardised manner. By standardising the collection of the metadata associated with camera trap deployment and image analysis, minimum data requirements can be met, methods can be replicated and more robust comparisons of results among studies can be undertaken (Meek *et al.* 2014a). The protocols can be used to deploy camera traps at features of interest, such as a waterpoint or trail, in an array (i.e. grid, transect), or in Fauna Plots in conjunction with a general vertebrate fauna survey.

If monitoring the behaviour of fauna under a certain set of conditions, sampling fauna at a specific set of points for experimental purposes (e.g. to examine responses of fauna to differing vegetation or specific landscape parameters), or monitoring fauna at a place of activity or gathering point such as a trail intersection, water point or nest site, targeted placement of camera traps is the most effective approach. This approach allows researchers and practitioners to monitor a large area with minimal resources and to answer specific research questions. However, this approach is highly susceptible to bias and provides a limited insight into the ecology of the greater landscape as a whole (Molloy 2018).

If using a camera trap array approach, the deployment protocol allows the flexibility to monitor the community or individual species. Surveyors can select the density and number of camera traps, and the deployment period based on the aims of their project, with this information recorded in a standardised manner among projects using the app. If undertaking a general survey of the fauna across a project or study area, an array approach is the most effective. An array can be used to sample a broad area simultaneously and uniformly it provides a better sample size than the other approaches, thereby enabling a more accurate indication of species abundance over the whole survey area. For this reason, an indicated absence (where a species is not detected) from a camera trap array sample is more likely to reflect a true absence (where a species is not present) than the other approaches. If resources are limited, establishing a transect through the most representative part of the survey area and placing camera traps at pre-determined intervals along that transect, might be the best approach. However, indicated absences obtained from transect samples cannot be reliably used as an indication of true absence. It is possible to combine grid and transect approaches (Molloy 2018).

The deployment protocol allows for camera traps to be deployed in Fauna Plots as part of general vertebrate fauna surveys, with the camera traps located within the plot based on the method being used. Two examples include the Standard Operating Procedure for Camera Trapping developed by the Department of Environment, Parks and Water Security (Northern Territory Government; Gillespie *et al.* 2015), and Bush Heritage Australia's Camera Trap Guidelines (Bush Heritage Australia 2021). Both standardised methodologies were developed from extensive trialling of various camera trap survey designs and consultation with a range of expert practitioners, to optimise the effectiveness and consistency of camera traps for general vertebrate fauna surveys and monitoring.

The vast majority of camera traps deployed in Australia for vertebrate fauna research and management use passive infrared (PIR) sensors (Meek *et al.* 2012b). PIR sensors work by sensing the movement of a body in the camera trap's detection zone that is a different temperature relative to the ambient temperature and temperature of background surface and objects (i.e. temperature in motion). This automatically triggers the camera trap to capture an image, a burst of images, or video depending on the camera trap settings. Images or video, which are continually collected over the course of a deployment in response to individuals entering the detection zone, are time- and date-stamped and stored on an external SD card. The applications that camera traps can be used for are summarised in Table 1.

Table 1. Camera trap applications.

(adapted from Gillespie *et al.* 2015)

Application	Details
Simple surveillance	To document a species that may be visiting one or more locations of specific interest (e.g. waterpoints).
General biodiversity surveys	May be used in conjunction with other standardised sampling methods to systematically document the spatial patterns of vertebrate fauna biodiversity.
Targeted fauna surveys	May be used alone or in combination with other sampling methods to determine the spatial distribution of species known to be amenable to camera trapping (e.g. foxes).
Behavioural studies	Targeted surveys to assess the behaviour of fauna, such as pollinator visitation (Krauss <i>et al.</i> 2018), seed dispersal (Florescia Miguel <i>et al.</i> 2018), and activity patterns (Barata <i>et al.</i> 2018).
Population density estimates	Where an array of cameras is used to identify the spatial distribution of uniquely marked individuals of a species.
Monitoring	To document changes in the occurrence and distribution of individual species or a suite of species over time and space.
Management evaluation	To document changes in species occurrence or species composition through time and space in response to management interventions, such as vertebrate pest management (e.g. baiting).

2.1 Key definitions and terminology

Table 2. Key definitions and terms used in the Camera Trapping Module.

Term	Definition
AI	Artificial Intelligence
AIR sensor	Active Infrared sensor
Bait station	Consists of a mounted lure used in association with a camera trap to increase the probability of detecting a target species or a suite of species. Food lures are usually protected from consumption or removal in a secure container that allows airflow.
Burst/Rapid fire	Settings that allow images to be captured continuously following a trigger event.
Camera trap	A motion sensing camera that captures images/video of wildlife automatically (also referred to as remote camera, motion sensor camera, trail camera and wildlife camera).
Camera trap array	Multiple camera traps deployed in an ordered series or arrangement (e.g. grid, transect).
Camera trap point	A particular spatial location (latitude and longitude) where a camera trap is deployed during sampling.
Delay	Program function of some camera traps to set a period of time where the camera trap is inactive before or between images/video.
Deployment	The unique placement of camera traps in space and time.
Depth of field	Aperture setting and its effect on the focus of objects in the front and rear of the image. Not often adjustable in camera traps.
Detection angle	The angle formed by the direction of camera trap and the predicted path of the target taxa/species.
Detection zone	Area/s in which a camera trap is able to detect fauna temperature signal in motion.
Event	Period of time from first trigger to the last image in a sequence, where the sequence is encompassed by the extent of independent behaviour of target/s.
False negative	Failure to detect fauna when fauna is in fact present (Type II error).
False positive	Incorrectly detecting fauna when none is present (Type I error).
Field of view	Area captured in an image or video, usually between 35° and 45°.
Focal length	The distance, in millimetres, between the lens and the camera trap's image sensor when the subject is in focus. Often set to capture images of target fauna that are a metre to several metres in front of the camera trap.
Focal point	Centre of the image/video (if composed correctly) aimed at the feature of interest (e.g. trail, water point, bait station, carcass).
GPS/GNSS enabled device	A device that is capable of logging the accurate coordinates of a location using the Global Positioning System (GPS) or the Global Navigation Satellite System (GNSS)
Horizontal orientation	Camera trap orientated horizontally with a downward-facing detection zone and field of view.

Independence interval	Specified time interval between images/video or sequences to determine independence for individuals of the same species.
Low glow IR flash	Infrared flash that produces a faint red glow to capture images/video at night.
Lure	Generic term referring to an attractant used to encourage a target species or a suite of species to investigate a specific point. May be olfactory, auditory, visual or some combination of these in nature.
Monitor	Field data collection app for Ecological Monitoring System Australia. Collects data using the Biodiversity Information Standard for delivery to the Australian Biodiversity Data Repository managed by the Department of Climate Change, Energy, the Environment and Water.
NiMH	Nickel-Metal Hydride – rechargeable batteries.
No glow IR flash	Infrared flash that does not produce a red glow but is able to capture images/video at night.
PIR sensor	Passive infrared sensor
Quiet period	Specified time between triggers when activity in the sensor will not trigger the camera trap.
Red glow IR flash	Infrared flash that produces a visible red glow to capture images/video at night.
Re-equipping	The checking and replacing camera trap batteries and SD cards, and bait stations if being used, to prolong the deployment camera traps in the same location using the same settings and mode of deployment.
Retrieval	The collection of deployed camera traps.
SD card	Secure Digital card – external memory card for storing images and video captured by camera traps.
Sensor sensitivity	Program function of camera traps that reflects the sensitivity of response to motion by the PIR sensors.
Sequence	Series of still images taken in rapid succession (i.e. burst, rapid fire) but separated by a time interval less than the set independence interval and forming an animated record of a triggering event.
Temperature in motion	Movement of an object with a different temperature relative to the ambient temperature and temperature of background surface and objects.
Time lapse	Program function of some camera traps to capture images at predetermined time intervals regardless of whether the camera is triggered.
Trigger speed	Time difference (response time) between detecting fauna temperature signal in motion and capturing an image/video.
Vertical orientation	Camera trap orientated vertically with an outward-facing detection zone and field of view.
Walk test (or similar)	Program function of some camera traps to identify where a camera will respond to temperature signal in motion. Can be used to 'focus' the camera trap's detection zone.
White flash	Xenon or LED white flash that illuminates the subject at night to capture full colour images.

2.2 Rationale

The use of camera traps is popular among scientists and natural resource managers to acquire ecological data and evidence of both native and pest fauna species. Camera traps can be used to assess fauna distribution, abundance, behaviour, and community structure (Rovero *et al.* 2013; Meek *et al.* 2014b). Such widespread applications generate a profusion of data, and if metadata collection can be standardised, camera trapping has the potential to be a cornerstone of global biodiversity monitoring initiatives (Burton *et al.* 2015).

Camera traps do not require expert skills to install. They are less invasive, safer for both fauna and field personnel, and potentially more ethical than trapping and animal handling methods. They can be more widely used (and capture a wider range of fauna species) than other survey methods such as pitfall or box traps, which are tailored to animals of a specific size range (Welbourne *et al.* 2015). Despite high initial costs, camera traps are less costly than labour-intensive trapping methods in the long-term because they can be left in the field for extended periods of time (i.e. weeks–months; Dundas *et al.* 2019). Survey periods can be easily extended without having a large effect on overall cost, other than increasing image processing time and battery use (Welbourne *et al.* 2015). Camera traps are particularly useful in sampling programs in remote areas, which are typically associated with high costs and other logistical constraints (Gillespie *et al.* 2015), including difficulty in accessing broadly spaced and hazardous locations to install and regularly check live traps (Molloy 2018; Dundas *et al.* 2019). Camera traps can also capture information about several species simultaneously (Welbourne *et al.* 2015), and facilitate the identification of individuals for some pest

species such as feral cats (Denny and Dickman 2010; Hansen *et al.* 2018) and feral pigs (Broadley *et al.* 2019).

Although camera trapping shifts the labour requirements from field based to office based (Dundas *et al.* 2019), several computer processes and programs have been developed to manage camera trapping datasets and automate image processing, in particular the removal of images captured by false triggers where no animals are present (Niedballa *et al.* 2016; Norouzzadeh *et al.* 2018). Image processing can also be undertaken by junior staff and citizen scientists (e.g. DigiVol's Wildlife Spotter program; <https://volunteer.ala.org.au/wildlife-spotter>), with expert staff able to focus on confirming identifications rather than wading through thousands of images.

The methodological information reported in camera trap publications and reports can vary widely, making replication of studies and comparison of results difficult (Meek *et al.* 2014a). For this reason, the Camera Trapping Module includes clear instructions and guidelines for deploying camera traps across Australia. Attributes of camera trapping that are covered include: (i) the make and model of the camera trap used; (ii) the camera trap settings used; and (iii) the mode of deployment (e.g. camera trap height, angle, direction). The metadata associated with these attributes is collected in a standardised manner among projects using the Monitor app, which ensures the data is correct, transparent, complete and suitable for use in ecological or natural resource management reports and peer-reviewed papers.

Standardised data collection and reporting of methods and results enables greater ease of study replication, more robust comparisons among studies, facilitates national and international reviews, and leads to improved fauna research and management outcomes (Meek *et al.* 2014a). A standardised approach to camera trap metadata collection is vital given the variability in performance among camera trap makes and models, the extensive range of camera trap settings now available, and differences in how camera traps are deployed in the field. Furthermore, the increasing availability of cyber infrastructure for storing and sharing digital data (e.g. from citizen science programs, through open access and data sharing frameworks) also requires the key aspects of camera trap deployment to be clear and consistent (Meek *et al.* 2014a).

Despite the advantages of camera traps, other fauna survey methods still have advantages, so using a combination of methods incorporating camera traps may be the most appropriate approach to surveying fauna (Gillespie *et al.* 2015). Survey effectiveness and cost can be improved by surveying taxonomic groups simultaneously with multiple techniques that complement one another (Welbourne *et al.* 2015). In recognition of this, camera trapping can be undertaken in a Fauna Plot in conjunction with a general vertebrate fauna survey, or at points of interest across a project area to supplement species inventories and gain a more thorough understanding of habitat use (Gillespie *et al.* 2015).

Technological advances in camera traps are regular and can provide novel insights. For this reason, the Camera Trapping Module allows for the incorporation of technological advances, with data vocabularies able to be updated to record new camera trap makes, models and specifications as these advances occur.

3 Camera trap deployment protocol

3.1 Field collection

3.1.1 Pre-requisites

To ensure the integrity and quality of the data collected, camera traps must be in proper functioning order. Adequate care and maintenance of the required equipment is essential and close attention must be paid when preparing and calibrating the camera traps before they are deployed in the field.

The following tasks need to be undertaken before commencing a deployment field survey:

- Camera trap identification, firmware update and settings configuration (Appendix 1)
- SD card identification and formatting (Appendix 1)
- Batteries preparation (Appendix 1)
- Desiccant installation (humid/wet conditions; Appendix 1)
- Camera trap array development and upload (Appendix 1)
- Study design and planning considerations (Appendix 2).

3.1.2 Time requirements

Survey time requirements will vary depending on the number and experience of personnel, the number of camera traps being deployed, whether additional equipment is being used (e.g. bait stations, drift fence), the level of site preparation required at each camera trap point, the size of the project area, and the level of difficulty in traversing the project area.

As a general guide:

- Allow one week prior to the field survey to prepare camera traps, SD cards, batteries and camera trap arrays.
- Allow 10–30 minutes at each camera trap point, depending if installing a bait station or carcass.
- Allow travel time between camera trap points.
- Consider the deployment period.

3.1.3 Personnel requirements

Personnel number and skills:

- Camera trap deployment is best conducted with two personnel, one setting up the camera traps, and the other recording the data directly into the app.
- The surveyor deploying the camera traps should be familiar with and experienced in the operation and settings of the camera traps. If surveyors are not confident, time should be dedicated to practising, using instruction manuals, and seeking advice before conducting this protocol.
- For large project areas and camera trap arrays, camera trap deployment is best conducted with two or more teams in separate vehicles.
- The use of camera traps involves interference with wildlife. Therefore, scientific permits and wildlife ethics approvals are likely to be required, so always check with your local authority. Access permissions are required.

3.1.4 Equipment

General deployment equipment:

- Mobile device (tablet/phone) with the Monitor app pre-loaded
- GNSS receiver capable of achieving <30 cm accuracy (e.g. Trimble R1 or DA2), hand-held GPS, or device built-in GPS (least preferred)
- Camera traps (same make and model)
- Batteries – as many as required per camera trap for all camera traps
- 1 x SD card per camera trap
- 1 x mounting post per camera trap (e.g. star dropper)
- Mounting apparatuses (e.g. cable ties, tie wire, mounting straps)
- Anti-theft devices and keys (e.g. cable lock straps, padlocks, security boxes)
- Chocks to angle camera traps to features (e.g. small wooden offcuts)
- Steel post driver or mash hammer
- Pocket tape measure
- Protractor
- Compass
- Inclinator
- Site preparation equipment (e.g. gloves, secateurs, pruning saw, rake, shovel)
- Hand-held digital camera, SD card image viewer or USB-C/Lightning to SD card reader
- Rechargeable battery chargers
- Flagging tape.

Project dependent equipment:

- 1 x bait or lure per bait station
- 1 x ventilated bait container per bait station
- 1 x small olfactory lure container per bait station
- 1 x mounting post per bait station
- Dust or granular insecticide for ants
- 1 x carcass per camera trap point
- 2 x metal stakes and tie wire per carcass
- Angle brackets (90°) and fasteners (horizontal camera trap orientation)
- Drift fences (directing species towards the detection zone)
- Cork tiles (thermal contrast between tile and species)
- 1 x desiccant packet per camera trap (humid/wet conditions).

3.1.5 Instructions and procedures

1. The camera traps should have been prepared and calibrated prior to the field survey. If not, refer to the pre-field survey tasks (Appendix 1) to install batteries, SD cards and desiccant packets (for humid/wet conditions), and configure the settings for each camera trap before continuing.
2. If deploying camera traps in an array, ensure the proposed array has been uploaded to your device (csv file with 'Name', 'Latitude' and 'Longitude' columns, with latitude and longitude in decimal degrees; see Appendix 1).

3. If deploying camera traps within a Fauna Plot, ensure the Plot Selection and Layout Module has been completed to establish the Fauna Plot and mark out the plot boundaries and trapping configuration.
4. Select the Camera Trapping Module in the Monitor app.
5. Select Camera Trap Deployment.
6. Record a *survey label*. This is a descriptor to distinguish the camera trap deployment for subsequent re-equipping and retrieval (e.g. June 30 array deployment).
7. Select the *survey type* from the following drop-down list (you can only complete one type of survey at a time):
 - Camera trap point
 - Camera trap array – grid
 - Camera trap array – transect
 - Fauna plot.
8. The *start date time* of the deployment survey will be automatically recorded. Update if required.
9. If a camera trap array *survey type* is selected, load the *array planned points* into the app by picking the relevant csv file (with 'Name', 'Latitude' and 'Longitude' columns, with latitude and longitude in decimal degrees).
10. Traverse your project area and locate a proposed camera trap point, whether at a feature of interest, as part of an array or within a Fauna Plot. Approach it with the required equipment. Use the mapping interface to locate *array planned points*.
11. Select the *add camera trap point* button.
12. Record a *camera trap point ID* that is suitable for your project (e.g. CTP001). Consider you are planning to deploy a paired camera trap at the camera trap point (e.g. CTP001A and CTP001B). Consider the name of any permanent camera trap points that are being used.
13. Record the *deployment start date*. The app will automatically record a *deployment ID* using the *camera trap point ID* and *deployment start date* (e.g. CTP001-2023-06-30 15:00:00). The *deployment start date* is also used to calculate the *deployment period* upon retrieval.
14. If a camera trap array *survey type* is selected, the app will prompt you to record the *distance to closest camera trap point* in metres (m). The initial entry will be automatically populated for subsequent deployments, and can be updated if the minimum distance between points changes. Select the *mark closest camera trap point* button in order to distinguish camera trap points that have deployed camera traps among the array on the mapping interface.
15. If the camera trap array – transect *survey type* is selected, the app will prompt you to record the *transect number*. This will be automatically set to '1'. However, you can update this if you are deploying camera traps along multiple transects.
16. If the fauna plot *survey type* is selected, the app will prompt you to select which *fauna plot* you are surveying in from a drop-down list of established fauna plots.
17. If targeting a specific taxa or species, record the *target taxa* and *target species* from the drop-down lists. Multiple taxa and/or species can be added.
18. Scan the immediate area to ensure it is suitable to secure a camera trap mounting post with the focal point in a southerly direction. If it is not suitable to secure a mounting post or there are issues with the detection zone and field of view, move to the nearest suitable area.
19. Use a steel post driver or mash hammer to secure a camera trap mounting post into the ground in a northerly direction from your desired focal point. Ensure the post remains tall enough so the top of the mounted camera trap is a suitable height for your project needs. If there is a large tree trunk or stem in a suitable position this can be used. Ensure the post is secure or the tree trunk or stem is large enough to prevent false triggers from camera movement. Record the *camera trap mount* from the drop-down list (e.g. 'Star dropper', 'Tree').

20. When standing directly at the camera trap mounting post, press the *record camera trap point location* button.
21. Record the *feature* that will be the focal point of the camera trap from the drop-down list or input a custom value (e.g. trail, waterpoint, bait station, carcass, palatable plant). Record the *distance to feature* in metres (m), a *feature photo* and any *feature comments*. If relevant, record the *carcass species*, *plant species* or *sign species*. Multiple features can be recorded (e.g. trail and bait station).
22. If using a bait station, install this first so you have a focal point when setting up the camera trap. Use a steel post driver or mash hammer to secure a mounting post into the ground. Ensure the post remains tall enough so the bait container is a suitable height above the ground for your project needs. Ensure the post is secure enough that it cannot be easily removed by animals. Record the *bait station mount*. If using a bait, place the bait in the bait container and secure to the post using a mounting apparatus. If using an olfactory lure, place the required amount inside a small container and carefully place this into the mounted bait container. If using an audio or visual lure, secure it to the post using a mounting apparatus. Record the *lure height* in centimetres (cm), *lure type* and *lure variety* used from the drop-down list or manual entry. Where ants may be a problem, spread dust or granular insecticide for ants around the base of the bait station.
23. If using a carcass, install this first so you have a focal point when setting up the camera trap. Use a mash hammer to secure the two metal stakes to the ground. Do this at a distance that will allow you to secure the carcass to the stakes using wire around the neck and hind achilles tendon.
24. If required for your project, install drift fences to direct species towards the detection zone, and/or cork tiles to create a sufficient thermal contrast between the tile, which is heated by the sun, and the species.
25. Before mounting the camera trap, open the housing and check and record the *camera trap number* and *SD card number*.
26. Record the camera trap information, including *make*, *model*, *manufacture year* (same model may vary between years), *illumination*, *activation mechanism* (e.g. 'PIR') and *trigger speed* in seconds. Once the data is entered for the first camera trap you configure, your previous selections will automatically appear for each subsequent camera trap you deploy during the current survey.
27. Switch the camera trap on and navigate to the settings menu to check that the following camera trap settings have been configured to suit your project, recording each in the app as you progress:
 - *media type* (i.e. image and/or video)
 - *images per trigger* (for images)
 - *image interval* in seconds (for images)
 - *video length* in minutes and seconds (for videos)
 - *sensor sensitivity*
 - *quiet period* in minutes and seconds
 - *aspect ratio*
 - *image quality* in megapixels (for images)
 - *video resolution* (for videos)
 - *day/night recording*
 - *night mode shutter speed* in seconds
 - *time format*
 - *date and time*
 - *unit of temperature*
 - *battery type*
 - *user label*
 - *time lapse (on/off)*

- *time lapse interval* in minutes and seconds (if time lapse turned on)
- *time lapse schedule start* and *end* (if time lapse turned on; multiple can be recorded).

The app will only display the fields relevant to the *media type* selected. Once the data is entered for the first camera trap you configure, your previous selections will automatically appear for each subsequent camera trap you deploy during the current survey. If you wish to retain the same settings, you will just need to update the *camera trap number* and *SD card number* in the app, and *user label* in the camera trap and in the app. Close the camera trap housing.

28. Using a mounting apparatus and anti-theft devices if necessary, mount the camera trap so that it is at a height to suit your project needs and facing the focal point. It should be facing south wherever possible (otherwise in a southerly direction). Use chocks to angle the camera so it captures the feature in the middle of the field of view. If required for your project, use an angle bracket to orientate the camera trap horizontally (i.e. downward-facing detection zone and field of view).
29. Record the *camera trap height* in centimetres (cm), from the surface of the ground to the camera lens.
30. Record the *camera trap angle from vertical* (0–90°). If using an angle bracket to orientate the camera trap horizontally, record the angle as '90°'.
31. Record the *camera trap direction* relative to north (0–360°) and the *detection angle* (°) relative to the predicted path of the target taxa/species.
32. Record the *slope* and *aspect*. If the area is flat, record '0°' for both. See the guidelines for setting camera traps on sloped ground.
33. Ensure that the sensor screen and camera lens are clean.
34. Check that there are no obstacles in front of the sensor, flash unit or camera lens (e.g. branches, mounting straps, flagging tape).
35. If required, undertake site preparation to prevent false triggers, maximise species identification and reduce fire risk to equipment. Clear all vegetation (low hanging vegetation, grass, sticks, leaves, etc.) between the camera trap and feature. Clear vegetation at least 1 m behind the feature and at least 1 m around the camera trap (to mitigate fire damage). Consider the field of view of the sensor and clear vegetation at least 1.5 m either side of the feature.
36. Record a *camera trap photo*.
37. Test if the camera trap is positioned correctly using one of the following methods:
 - **Walk test (if available):** open the camera trap. Switch it on and navigate to the *walk test* function. Close the camera trap. Test the field of view by moving your hand around the focal point while watching for the red light on the camera trap to indicate when are within the field of view. Adjust the camera trap and repeat the exercise as necessary.
 - **Trigger the camera trap:** open the camera trap. Switch it on and arm the camera trap. Close the camera trap. Trigger the camera trap by moving your hand around the focal point. If you can review the test images on your camera trap do so. If not, switch off the camera trap, remove the SD card and view the images using a hand-held digital camera, SD card image viewer or on your device using an SD card reader. Adjust the camera trap and repeat the exercise as necessary. Delete the images before arming the camera trap.
38. Switch on and arm the camera trap. Close the camera trap ensuring the rubber seal is clean and waterproof.
39. Position yourself or arm or leg in the detection zone to trigger a capture sequence, which is used to indicate the start of the sampling period.
40. Record the *habitat (major vegetation group)* (optional).
41. Record any additional *deployment comments* (optional).
42. Select the *save camera trap point* button.

43. Use flagging tape in a nearby tree to mark the location for easy camera trap re-equipping or retrieval. Ensure the flagging tape is not in the field of view of the camera trap. If there is a security risk, do not mark the location of the camera trap, it can be located using its coordinates.
44. Repeat steps 10–43 for each proposed camera trap point for the selected *survey type*.
45. Once all camera traps for the selected *survey type* have been deployed, complete the camera trap deployment component. The end date time of the deployment survey will be automatically recorded. Update if required. Check the data summary before queuing the collection for submission.
46. Repeat Steps 4–45 for a different *survey type* (creating a new collection for each) if required.

3.1.6 Additional guidelines

The following points are adapted from Gillespie *et al.* (2015), Molloy (2018) and TEAM Network (2011).

Traversing the project area

- Disturbance of the project area should be minimised by using existing tracks and trails or establishing temporary access routes that can be used simultaneously to undertake multiple modules.
- Some camera trap points may need to be traversed to on foot.

Camera trap deployment

- Look for features of interests, where fauna activity is likely to be high (e.g. water points, trail intersections).
- Look for signs of animal paths, or natural openings through the area, such as adjacent to rock ledges or creek beds; also place camera traps in areas with contrasting vegetation structures, such as densely vegetated versus open areas.
- Opportune observations may also give an indication of areas that could be targeted.
- Avoid deploying camera traps in areas where there is a risk of inundation during the deployment period.
- Deploy camera traps so that they are orientated south to prevent glare and sun damage to the camera lens and sensor, and to reduce false triggers from the rising and setting of the sun.
- There is evidence of overheating and malfunction of camera trap batteries on days where daytime temperatures exceed 40°C. Depending on the location and time of year, shade may need to be provided to protect the back of the camera trap from sun exposure (Dundas *et al.* 2019).
- If possible, try to deploy camera traps so they are on an angle relative to animal paths.
- In sloped terrain, camera traps should be angled and parallel to the ground to ensure detection.
- Level camera trap points are preferable as they provide undistorted and unobstructed view of subjects, particularly smaller animals. Downward slopes increase the size of blind zones (although this can be partially rectified by angling the camera trap downward) and upward slopes reduce the photographed area and proved a greater opportunity for concealment by increasing the effect of on ground structures.
- If camera traps are deployed in a Fauna Plot while ground trapping is being undertaken, take care to avoid ground trapping near detection zones to prevent false triggers.
- Refer to the relevant camera trap make and model user manuals for guidance in the operation and functionality of the camera traps.
- Check that the housing of each camera trap is properly closed to prevent moisture damaging the electronics.
- All camera traps used in a survey should all be set up with the same settings. Refer to Appendix 2 for a summary of informed camera trap settings for different taxa.

- An angle bracket can be used to orientate the camera trap horizontally (i.e. downward-facing detection zone and field of view) to survey small mammals and reptiles (e.g. Dundas *et al.* 2019; Moore *et al.* 2020b).
- Where camera trap points are in a regular grid or transect array, distance between points can be recorded as a single value. However, where camera trap points are randomly or irregularly located, the distance to the closest point is recorded, which allows for values such as the average, minimum and maximum distance among the points, along with a measure of the distribution of distances (e.g. standard deviation).
- Theft and vandalism inevitably occur. Consider the risk of this in your project area and use anti-theft devices. Cable-locking camera traps or using security boxes will act as a deterrent and is advisable in areas with high human visitation or if setting camera traps along vehicle or walking tracks.
- When multiple camera traps are deployed it is advisable to use combination locks, or have locks keyed-alike, to avoid having to carry multiple keys into the field. Coil excess cable length up off the ground.
- In many cases, people who discover cameras may not disturb them, but will be curious about why they are there. Attaching a small sign to the side of each camera with a brief description of the project and some contact information is likely to satisfy curiosity and may help to limit vandalism or other interference.
- Minimise animal interference of camera traps by securing them tightly, securing the door with a cable tie, or placing the camera trap inside a metal security box. Reconyx manufacture sturdy metal cases for their cameras for additional protection if needed.

Site preparation

- Determine what vegetation may cause false triggers, such as overhanging branches, or plants nearby that may grow into the sensor field during deployment, and remove with secateurs or rake as necessary.
- If deployment will extend over a growing period, dig out perennial grass and shrub bases of the cleared area.
- Avoid piling cleared material right next to the camera trap point as this may just blow across the field of vision, triggering false images, or impede animal access.
- If in doubt regarding vegetation clearing, set the camera trap and trigger it to take a couple of photos, then view the images on the camera trap or remove the SD card and view the images using a hand-held digital camera, SD card image viewer or on your device using a SD card reader.

Installing bait stations

- Standard mammal trapping bait of peanut butter, rolled oats and honey has been successfully used in surveys targeting a wide variety of small and medium-sized native mammals, such as quolls, bandicoots, possums and rodents.
- Bait containers should be ventilated (i.e. mesh) to allow scent to escape. A suspended metal tea infuser a common option (Meek *et al.* 2012a; Andrewartha *et al.* 2021; McHugh *et al.* 2022). Alternatively, PVC pipe with a ventilated end cap and an overhanging cover is recommended to reduce dehydration and water diluting the bait in the wet conditions (Gillespie *et al.* 2015). A comparative design is the PVC Vent Cowl (Figure 21 in Meek *et al.* 2012b).
- If suitable for your project, bait stations can be secured to the ground using a large tent peg rather than attached to a bait station mounting post.
- Bait stations can also be interfered with if not secured or designed properly. Crows and some rat species are notorious for breaking into or damaging bait stations, and dingoes will readily remove bait stations that are not adequately secured.

Installing carcasses

- Camera trap points should be spaced at distances sufficient to minimise carcass scent travel between points, such that scavengers would have to actively forage and seek out carcasses rather than being able to move quickly from one camera trap point to another. A minimum distance of 1 km has been used in recent studies in Australia (Spencer and Newsome 2021; Spencer *et al.* 2021).
- Carcasses can be sourced from management culls, simulated culls, hunter kills and road kills.
- Any carcass that displays evidence of disease (e.g. heavy parasite loads) should not be used.
- Following collection, carcasses should be placed in the field without freezing within 24 hours in warm conditions and within 36 hours in cool conditions.
- Cameras should be removed, or carcass replaced, when a carcass has been reduced to skeletal remains and all edible soft tissue has been removed as the carcass loses its attraction to scavengers (Behrendorff *et al.* 2018).
- Research licences or permits may be required to obtain, relocate and monitor carcasses.
- Consider the indirect impact of carcass provision on native species before use (Spencer *et al.* 2021).

Selecting palatable plants

- Before undertaking camera trapping, determine the most palatable plants within the study area. For example, the following papers discuss plant palatability for rabbits, which are likely palatable for other species (Cooke 1988; Cooke *et al.* 2010; Bird *et al.* 2012; Cooke 2012; Mutze 2016; Mutze *et al.* 2016a, 2016b).
- The preferential foraging behaviour of the target species within the area should be established through research and observation because observing grazing impacts is the only guaranteed method of determining palatability (Bohning and Wilkie 1999). Alternatively, a cafeteria study may be conducted (Arcese *et al.* 2014). The most palatable species is likely the most noticeably browsed species in an area (McDonald and Brandle 2009) or the species lacking juvenile cohorts (Mutze *et al.* 2016b).
- A plant's chemical and physical components determine its palatability (Forsyth *et al.* 2005). Palatable species generally have high protein content, carbohydrate aroma compounds and alkaloids, low tannin content, and minimal organic acids (Raufirad *et al.* 2016).
- The palatability of plants depends on a wide range of complex factors such as available species, the abundance of species, season and stock type (Bohning and Wilkie 1999). Climate, topography, soil moisture, past grazing use and plant growth stage should be considered because they influence some plant species' chemical composition and palatability (Raufirad *et al.* 2016).
- Where a palatable plant neighbours an unpalatable plant, the palatable plant is vulnerable to herbivory (Rautio *et al.* 2012). Where herbivores selectively graze, the camera should be positioned on a palatable plant neighbouring less or non-palatable plant species.
- The selection of palatable plant species should depend on the target pest species:
 - Goats are less selective, a consequence of adaptations that neutralise tannins and their ability to stand on their hind legs (McDonald and Brandle 2009). As a result, goats prefer the species most prevalent in the landscape (Raufirad *et al.* 2016).
 - Deer preference depends on the ecosystem – in a temperate forest, select species with lower leaf fibre content (Forsyth *et al.* 2005), and in a grassland, preference species with a greater specific leaf area (Lloyd *et al.* 2010).
 - Rabbits prefer palatable, short-lived species such as acacias and casuarinas as opposed to less palatable, long-lived eucalypts (Cooke and McPhee 2007).

Palatable plant camera placement

- Camera traps should be positioned for the height of the browsing on palatable plants (e.g. rabbits browse up to approximately 40 cm) and positioned so they can detect this herbivory on palatable plants.
- Camera traps should be arranged to maximise visual coverage of potential foraging areas (e.g. two camera traps; Reid *et al.* 2020).
- Areas around camera traps should be cleared to roughly 25 m² (Reid *et al.* 2020).
- Where long grass is present, camera traps should be placed a minimum of 1 m above ground to reduce false triggers (Reid *et al.* 2020).
- Plants chosen should have significant dimensional characteristics and maintain a presence irrespective of seasonal conditions (McDonald and Brandle 2009).

3.2 Post-field survey tasks

Not applicable for camera trap deployment. See Section 5.2 for post-field survey tasks required after camera trap retrieval.

4 Camera trap re-equipping protocol

4.1 Field collection

4.1.1 Pre-requisites

The following tasks need to be undertaken before commencing a re-equipping field survey:

- Camera trap identification, firmware update and settings configuration (Appendix 1)
- SD card identification and formatting (Appendix 1)
- Batteries preparation (Appendix 1)
- Desiccant installation (humid/wet conditions; Appendix 1).

4.1.2 Time requirements

Survey time requirements will vary depending on the number and experience of personnel, the number of camera traps being re-equipped, whether any damaged or missing camera traps need to be replaced, whether additional equipment is being used and needs to be replaced, the level of follow-up site preparation required at each camera trap point, the size of the project area, and the level of difficulty in traversing the project area.

As a general guide:

- Allow one week prior to the field survey to prepare replacement camera traps, SD cards and batteries.
- Allow 5–20 minutes at each camera trap point, depending if replacing a bait station or carcass.
- Allow travel time between camera trap points.
- Consider the deployment period.

4.1.3 Personnel requirements

Personnel number and skills:

- Camera trap re-equipping and recording the data directly into the app can be conducted by a single surveyor. However, it is best conducted with two personnel, one re-equipping the camera traps, and the other recording the data directly into the app.
- The surveyor re-equipping the camera traps should be familiar with and experienced in the operation and settings of the camera traps. If surveyors are not confident, time should be dedicated to practising, using instruction manuals, and seeking advice before conducting this protocol.
- For large project areas and camera trap arrays, camera trap re-equipping is best conducted with two or more teams in separate vehicles.
- The use of camera traps involves interference with wildlife. Therefore, scientific permits and wildlife ethics approvals are likely to be required, so always check with your local authority. Access permissions are required.

4.1.4 Equipment

General re-equipping equipment:

- Mobile device (tablet/phone) with the Monitor app pre-loaded
- GNSS receiver capable of achieving <30 cm accuracy (e.g. Trimble R1 or DA2), hand-held GPS, or device built-in GPS (least preferred)
- Anti-theft device keys
- Replacement batteries – as many as required per camera trap for all camera traps
- 1 x replacement SD card per camera trap
- Replacement camera traps (same make and model)*
- Replacement mounting posts (e.g. star dropper)*
- Replacement mounting apparatuses (e.g. cable ties, tie wire, mounting straps)*
- Replacement anti-theft devices and keys (e.g. cable lock straps, padlocks, security boxes)*
- Replacement chocks to angle camera traps to features (e.g. small wooden offcuts)*
- Steel post driver or mash hammer
- Pocket tape measure
- Protractor
- Compass
- Inclinator
- Site preparation equipment (e.g. gloves, secateurs, pruning saw, rake, shovel)
- Hand-held digital camera, SD card image viewer or USB-C/Lightning to SD card reader
- Rechargeable battery chargers
- Flagging tape.

**Ensure a suitable number of each item is taken into the field to replace any that have been damaged or are missing/stolen.*

General re-equipping equipment:

- 1 x replacement bait or lure per bait station
- Replacement ventilated bait containers*
- Replacement small olfactory lure containers*
- Replacement bait station mounting posts*
- Dust or granular insecticide for ants
- 1 x replacement carcass per camera trap point
- Replacement metal stakes and tie wire to secure carcasses*
- Replacement angle brackets (90°) and fasteners (horizontal camera trap orientation) *
- Replacement drift fences (directing species towards detection zone) *
- Replacement cork tiles (thermal contrast between tile and species) *
- 1 x replacement desiccant packet per camera trap (humid/wet conditions).

**Ensure a suitable number of each item is taken into the field to replace any that have been damaged or are missing/stolen.*

4.1.5 Instructions and procedures

The following steps should be followed to check and replace camera trap batteries and SD cards, and bait stations if being used, to prolong the deployment of each camera trap in the same location using the same settings and mode of deployment. If retrieving a camera trap and deploying at a new camera trap point and/or with different settings or mode of deployment, refer to the camera trap retrieval protocol (Section 5) and then the camera trap deployment protocol (Section 3).

1. Replacement camera traps should have been prepared and calibrated prior to the field survey. If not, refer to the pre-field survey tasks (Appendix 1) to install batteries, SD cards and desiccant packets (for humid/wet conditions), and configure the settings for each camera trap before continuing.
2. Select the Camera Trapping Module in the Monitor app.
3. Select Camera Trap Re-equipping.
4. Select the relevant deployment *survey label* (e.g. June 30 array deployment).
5. The *start date time* of the re-equipping survey will be automatically recorded. Update if required.
6. Traverse your project area and locate a camera trap point. Approach it with the required equipment from the front to trigger a capture sequence, which is used to indicate the end of the sampling period.
7. If the camera trap is missing, search the vicinity as it may have been dislodged and shifted by fauna. If you cannot find the camera trap, you will record it as 'Missing' in step 9.
8. Select the relevant *deployment ID* from the drop-down list.
9. Record the *re-equipping date*.
10. Keeping the camera trap mounted, open the housing and turn it off to disarm it.
11. Turn the camera trap on and navigate to the *check status* function. The number of images captured, amount of space on the SD card and amount of battery power remaining will be displayed. If the display is blank, the batteries may be flat. Replace the batteries and switch the camera trap on to determine if the camera trap was not operational due to flat batteries or being damaged. Record the *operational status* from the drop-down list.
12. If the *operational status* is 'Operational', 'SD card full', 'SD card failure' or 'Batteries flat', replace the batteries, SD card and desiccant packet (for humid/wet conditions) and record the *number of images* (optional) and the *replacement battery type* and *replacement SD card number*, and then skip to Step 20, or Step 17 if using a bait station, Step 18 if using a carcass, or Step 19 if you need to replace missing drift fences or cork tiles.
13. If the *operational status* is 'Hardware failure', 'Unknown failure', 'Vandalism' or 'Missing/theft', consider the security risk and whether replacement is worthwhile. If it is, check the *camera needs replacing* checkbox.
14. Before mounting the replacement camera trap, open the housing and check and record the *replacement camera trap number*, *replacement battery type* and *replacement SD card number*.
15. Switch the replacement camera trap on and navigate to the settings menu to check that the camera trap settings have been configured to be the same as during deployment. The app will display the camera trap information and settings recorded during deployment (auto filled based on the selected *deployment ID*). Update the *date* and *time* as these will have changed, and the *user label* if changing.
16. If the camera trap mounting post is missing, use a steel post driver or mash hammer to secure a replacement camera trap mounting post into the ground at the camera trap point. This should be the same as the initial deployment. If not, update *camera trap mount*. Ensure the post remains tall enough so the top of the mounted camera trap is a suitable height for your project needs (this should be the same as the initial deployment). Ensure the post is secure to prevent false triggers from movement.
17. Using a mounting apparatus and anti-theft devices if necessary, mount the replacement camera trap. Ensure that the *camera trap height*, *camera trap angle*, *camera trap direction* and *detection angle* of

the replacement camera trap are the same as during deployment (the app will display the mode of deployment).

18. If using a bait station, replace the bait or olfactory lure in the bait container, or replace the audio or visual lure if required. Replace the bait container and mounting post if they are missing. Update *camera trap mount* if the replacement is not the same as the initial deployment. Ensure that the *lure height*, *lure type* and *lure variety* of the replacement bait station are the same as during deployment (the app will display the lure information recorded during deployment). Where ants may be a problem, spread dust or granular insecticide for ants around the base of the bait station.
19. If using a carcass, replace the carcass. Secure the carcass to the two metal stakes using wire around the neck and hind achilles tendon. Replace the stakes and wire if they are missing. The *carcass species* should be the same as the initial deployment. Update if required.
20. If using drift fences or cork tiles, replace these if they are missing.
21. Ensure that the sensor screen and camera lens are clean.
22. Check that there are no obstacles in front of the sensor, flash unit or camera lens (e.g. branches, mounting straps, flagging tape).
23. If required, undertake follow-up site preparation to prevent false triggers, maximise species identification and reduce fire risk to equipment. Clear all vegetation (low hanging vegetation, grass, sticks, leaves, etc.) between the camera trap and feature. Clear vegetation at least 1 m behind the feature and at least 1 m around the camera trap (to mitigate fire damage). Consider the field of view of the sensor and clear vegetation at least 1.5 m either side of the feature.
24. Record a *camera trap photo*.
25. Test if the camera trap is positioned correctly using one of the following methods:
 - **Walk test (if available):** open the camera trap. Switch it on and navigate to the *walk test* function. Close the camera trap. Test the field of view by moving your hand around the focal point while watching for the red light on the camera trap to indicate when are within the field of view. Adjust the camera trap and repeat the exercise as necessary.
 - **Trigger the camera trap:** open the camera trap. Switch it on and arm the camera trap. Close the camera trap. Trigger the camera trap by moving your hand around the focal point. If you can review the test images on your camera trap do so. If not, switch off the camera trap, remove the SD card and view the images using a hand-held digital camera, SD card image viewer or on your device using an SD card reader. Adjust the camera trap and repeat the exercise as necessary. Delete the images before arming the camera trap.
26. Switch on and arm the camera trap. Close the camera trap ensuring the rubber seal is clean and waterproof.
27. Position yourself or arm or leg in the detection zone to trigger a capture sequence, which is used to indicate the start of the sampling period.
28. Record any additional *re-equipping comments* regarding the re-equipping (optional), including any equipment (other than batteries, SD cards or lures) that was replaced.
29. Select the *save camera trap re-equipping* button.
30. Use flagging tape in a nearby tree to mark the location for easy camera trap re-equipping or retrieval. Ensure the flagging tape is not in the field of view of the camera trap. If there is a security risk, do not mark the location of the camera trap, it can be located using its coordinates.
31. Repeat steps 5–30 for each camera trap point for the selected *survey type*.
32. Once all camera traps for the selected *survey type* have been re-equipped, complete the camera trap re-equipping component. The end date time of the re-equipping survey will be automatically recorded. Update if required. Check the data summary before queuing the collection for submission.
33. Repeat Steps 2–32 for a different *survey type* (creating a new collection for each) if required.

4.1.6 Additional guidelines

- It is important to confirm whether or not the camera trap was operational for the whole survey period. If there is no capture sequence upon re-equipping of the camera trap it makes it impossible to know whether it was operational for the full deployment period. For example, if the last image occurs in week 3 of 4, this could reflect either no animals at the camera trap point post week 3 or a camera malfunction sometime after this capture.
- If the SD card was full, it is recommended that the SD card is replaced with one with greater storage capacity, or checking the SD card storage at a shorter period to maintain camera trap functionality.
- If the batteries were flat, it is recommended that they be checked at a shorter period to maintain camera trap functionality.
- Consider if the site preparation might have caused false triggers and undertake more clearance if necessary.
- If the camera trap was stolen or vandalised, consider the risk of this happening again and if anti-theft devices and measures will be enough to prevent this.

4.2 Post-field survey tasks

Not applicable for camera trap re-equipping. See Section 5.2 for post-field survey tasks required after camera trap retrieval.

5 Camera trap retrieval protocol

5.1 Field collection

5.1.1 Pre-requisites

There are no tasks that need to be undertaken before commencing a retrieval field survey.

5.1.2 Time requirements

Survey time requirements will vary depending on the number and experience of personnel, the number of camera traps being retrieved, the size of the project area, and the level of difficulty in traversing the project area.

As a general guide:

- Allow 5–10 minutes at each camera trap point, depending if removing a bait station or carcass.
- Allow travel time between camera trap points.

5.1.3 Personnel requirements

Personnel number and skills:

- Camera trap retrieval and recording the data directly into the app can be conducted by a single surveyor. However, it is best conducted with two personnel, one retrieving the camera traps, and the other recording the data directly into the app.
- The surveyor retrieving the camera traps should be familiar with and experienced in the operation and settings of the camera traps. If surveyors are not confident, time should be dedicated to practising, using instruction manuals, and seeking advice before conducting this protocol.
- For large project areas and camera trap arrays, camera trap retrieval is best conducted with two or more teams in separate vehicles.
- The use of camera traps involves interference with wildlife. Therefore, scientific permits and wildlife ethics approvals are likely to be required, so always check with your local authority. Access permissions are required.

5.1.4 Equipment

- Mobile device (tablet/phone) with the Monitor app pre-loaded
- GNSS receiver capable of achieving <30 cm accuracy (e.g. Trimble R1 or DA2), hand-held GPS, or device built-in GPS (least preferred)
- Anti-theft device keys.

5.1.5 Instructions and procedures

1. Select the Camera Trapping Module in the Monitor app.
2. Select Camera Trap Retrieval.
3. Select the relevant deployment *survey label* (e.g. June 30 array deployment).
4. The *start date time* of the retrieval survey will be automatically recorded. Update if required.
5. Traverse your project area and locate a camera trap point. Approach it with the required equipment from the front to trigger a capture sequence, which is used to indicate the end of the sampling period.
6. If the camera trap is missing, search the vicinity as it may have been dislodged and shifted by fauna. If you cannot find the camera trap, you will record it as 'Missing' in step 10.
7. Select the relevant *deployment ID* from the drop-down list.

8. Record the *retrieval date*. The app will automatically calculate the *deployment period* (number of camera trap nights based on the deployment date).
9. Open the camera trap and turn it off to disarm it.
10. Turn the camera trap on and navigate to the *check status* function. The number of images captured, amount of space on the SD card and amount of battery power remaining will be displayed. If the display is blank, the batteries may be flat. Replace the batteries and switch the camera trap on to determine if the camera trap was not operational due to flat batteries or being damaged. Record the *operational status* from the drop-down. Record the *number of images* (optional).
11. Switch off and close the camera trap.
12. Record any additional *retrieval comments* (optional).
13. Select the *save camera trap retrieval* button.
14. Remove the camera trap and bait container (if bait station used) from the mounting posts, and remove the mounting posts. Remove any materials used to secure the carcass (if used). Remove any flagging tape used to mark the location of the camera trap.
15. Ensure all equipment is packed appropriately for transport. Camera traps, in particular the PIR sensor, may become damaged if they are left loose in a vehicle or backpack.
16. Repeat steps 5–15 for each camera trap point for the selected *survey type*.
17. Once all camera traps for the selected *survey type* have been retrieved, complete the camera trap retrieval component. The *end date time* of the retrieval survey will be automatically recorded. Update if required. Check the data summary before queuing the collection for submission.
18. Repeat Steps 1–17 for a different *survey type* (creating a new collection for each) if required.

5.1.6 Additional guidelines

- It is important to confirm whether or not the camera trap was operational for the whole survey period. If there is no capture sequence upon retrieval of the camera trap it makes it impossible to know whether it was operational for the full deployment period. For example, if the last image occurs in week 3 of 4, this could reflect either no animals at the camera trap point post week 3 or a camera malfunction sometime after this capture.

5.2 Post-field survey tasks

5.2.1 Data curation

- When back in the office, backup the media data (images and video) from the camera trap SD cards for long-term storage and processing, to a server of your choosing.
- Media data should not be deleted from SD cards until it has been checked that they have been backed up successfully.
- It is good practice to keep an additional back-up of media data (e.g. cloud storage, external hard-drive) until electronic delivery of the receiving server.
- Once all data is backed up and checked, a good practice is to clear all SD cards, preferably by formatting. This ensures that SD cards are working correctly and prevents full cards from being reloaded into camera traps in future deployments.
- Arrange for electronic delivery of the media data to the receiving server (see the Submitting EMSA Digital Media information sheet).
- This will involve linking the project administration data and camera trap survey data to the media data via the project number, deployment number, camera trap number and SD card number.

6 Data submission

Data from the Camera trapping Module is collected in the field using the Monitor app. Data entry is completed in the app and photos are taken using the app (or later linked if taken on other devices). All data is checked for correctness and completeness in the app before it is submitted.

Once all data is finalised and marked as completed, the data is submitted from the Monitor app to the staging server by an explicit user action. If the device is offline at the time, the data will be pushed as soon as it is reconnected to a network (i.e. either back in mobile phone range or a wi-fi network). The local herbaria (or approved taxonomist) completing the field name identifications uses data curation tools to submit the taxonomic determinations to the staging server. Once field survey and taxonomic determination data reaches the staging server it is prepared in an export interface for delivery to the Biodiversity Data Repository. DCCEEW is then responsible for managing the data. In the future, it is anticipated that data curation tools will be made available to project personnel.

7 Data use and reason for collection

7.1 Data use to date

Camera trap deployment is not currently undertaken by TERN's Ecosystem Surveillance platform. For potential uses of the camera trap data collected as part of the Camera Traps Module, see [Future use of the data](#) below.

7.2 Future use of the data

Camera trap data has several potential applications, including: documenting the presence of a species within a project area or specific habitat or feature of interest in that area (DSEWPAC 2011; Cotsell and Vernes 2016); systematically documenting spatial patterns of vertebrate biodiversity (TEAM Network 2011; Gillespie *et al.* 2015; Bush Heritage Australia 2021); determining the spatial distribution of species known to be amenable to camera trapping (Meek 2018); assessing behaviour, such as pollinator visitation and activity patterns (Barata *et al.* 2018; Krauss *et al.* 2018; Potter *et al.* 2021); estimating population density by monitoring uniquely marked individuals of a species (Ramsey *et al.* 2015; Moore *et al.* 2020a); monitoring changes in the occurrence and distribution of individual species, a suite of species, or community over time (TEAM Network 2011); and evaluating management outcomes (e.g. documenting changes in the occurrence and abundance of vertebrate pest species in accordance with a lethal baiting program; Moseby and Read 2014; Meek 2018).

Camera traps are generally used as point-based sampling devices, and many analytical methods exist for the data they collect, such as photographic rates of species (Di Bitetti *et al.* 2014), occupancy models, which estimate species occurrence while accounting for imperfect detection and can reveal species–habitat associations (Tobler *et al.* 2015), capture–recapture models, which estimate abundance and detection probability from individual detection/non-detection data and are applicable to camera-trap data for individually recognizable species (Borchers *et al.* 2014), and spatial capture–recapture models, which extend the capture–recapture framework by accounting for animal movement and location relative to the trap array (Royle *et al.* 2009). Several methods have been developed to estimate abundance for species that cannot be individually identified (Bengsen *et al.* 2011; Gilbert *et al.* 2021). Finally, as well as describe activity patterns, time stamps on camera-trap records can be used to describe temporal interactions between species (Frey *et al.* 2017). Considering the usefulness of camera trapping, continued development of analytical approaches for camera-trap data can be expected (Sollmann 2018), as well as computer processes and programs to manage camera trapping datasets and automate image processing (Niedballa *et al.* 2016; Norouzzadeh *et al.* 2018).

8 References

- Andrewartha, TA, Evans, MJ, Batson, WG, Manning, AD, Price, C, Gordon, IJ, Barton, PS (2021) Outfoxing the fox: Effect of prey odor on fox behavior in a pastoral landscape. *Conservation Science and Practice* **3**, e516.
- Arcese, P, Schuster, R, Campbell, L, Barber, A, Martin, TG (2014) Deer density and plant palatability predict shrub cover, richness, diversity and aboriginal food value in a North American archipelago. *Diversity and Distributions* **20**, 1368–1378.
- Barata, IM, Griffiths, RA, Ferreira, GB (2018) Activity pattern and behavior of an endemic bromeliad frog observed through camera trapping. *Herpetological Review* **49**, 432–438.
- Behrendorff, L, Leung, LK-P, Allen, BL (2018) Utilisation of stranded marine fauna washed ashore on K'gari (Fraser Island), Australia, by dingoes. *Australian Journal of Zoology* **66**, 128–138.
- Bengsen, A, Butler, J, Masters, P (2011) Estimating and indexing feral cat population abundances using camera traps. *Wildlife Research* **38**, 732–739.
- Bengsen, AJ, Forsyth, DM, Ramsey, DS, Amos, M, Brennan, M, Pople, AR, Comte, S, Crittle, T (2022) Estimating deer density and abundance using spatial mark–resight models with camera trap data. *Journal of Mammalogy* **103**, 711–722.
- Bird, P, Mutze, G, Peacock, D, Jennings, S (2012) Damage caused by low-density exotic herbivore populations: the impact of introduced European rabbits on marsupial herbivores and *Allocasuarina* and *Bursaria* seedling survival in Australian coastal shrubland. *Biological Invasions* **14**, 743–755.
- Bohning, G, Wilkie, A (1999) Palatability scoring of forage plants in central Australia. Department of Primary Industries, Alice Springs. Available at <http://www.nt.gov.au/d/Content/File/p/Technote/TN106>.
- Borchers, D, Distiller, G, Foster, R, Harmsen, B, Milazzo, L (2014) Continuous-time spatially explicit capture–recapture models, with an application to a jaguar camera-trap survey. *Methods in Ecology and Evolution* **5**, 656–665.
- Broadley, K, Burton, AC, Avgar, T, Boutin, S (2019) Density-dependent space use affects interpretation of camera trap detection rates. *Ecology and Evolution* **9**, 14031–14041.
- Burton, AC, Neilson, E, Moreira, D, Ladle, A, Steenweg, R, Fisher, JT, Bayne, E, Boutin, S (2015) Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. *Journal of Applied Ecology* **52**, 675–685.
- Bush Heritage Australia (2021) Method: M05.100 Survey – Motion Sensor Cameras. Bush Heritage Australia, Melbourne.
- Carter, A, Luck, GW, McDonald, SP (2012) Ecology of the red fox (*Vulpes vulpes*) in an agricultural landscape. 2. Home range and movements. *Australian Mammalogy* **34**, 175–187.
- Cloyed, CS, Cappelli, LR, Tilson, DA, Crawford, JA, Dell, AI (2018) Using camera traps to assess mammal and bird assemblages in a midwestern forest. *Journal of Fish and Wildlife Management* **9**, 496–506.
- Collett, RA, Fisher, DO (2017) Time-lapse camera trapping as an alternative to pitfall trapping for estimating activity of leaf litter arthropods. *Ecology and Evolution* **7**, 7527–7533.
- Colyn, RB, Radloff, FGT, O'Riain, MJ (2018) Camera trapping mammals in the scrubland's of the Cape Floristic Kingdom—the importance of effort, spacing and trap placement. *Biodiversity and Conservation* **27**, 503–520.
- Cooke, B, Jones, R, Gong, W (2010) An economic decision model of wild rabbit *Oryctolagus cuniculus* control to conserve Australian native vegetation. *Wildlife Research* **37**, 558–565.
- Cooke, BD (1988) The effects of rabbit grazing on regeneration of sheoaks, *Allocasuarina verticillata* and saltwater ti-trees, *Melaleuca halmaturorum*, in the Coorong National Park, South Australia. *Australian Journal of Ecology* **13**, 11–20.
- Cooke, BD (2012) Rabbits: manageable environmental pests or participants in new Australian ecosystems? *Wildlife Research* **39**, 279–289.
- Cooke, BD, McPhee, SR (2007) Rabbits and Native Plant Biodiversity. A report compiled for Australian Wool Innovation and Meat and Livestock Australia as part of the Invasive Animals Co-operative Research Centre Project 7.T.6 – Biodiversity Impact of Rabbits. Invasive Animals Co-operative Research Centre, Canberra.
- Cotsell, N, Vernes, K (2016) Camera traps in the canopy: surveying wildlife at tree hollow entrances. *Pacific Conservation Biology* **22**, 48–60.
- Davies, C, Wright, W, Hogan, FE, Davies, H (2020) Detectability and activity patterns of sambar deer (*Rusa unicolor*) in Baw Baw National Park, Victoria. *Australian Mammalogy* **42**, 312–320.
- Davis, AJ, Keiter, DA, Kierepka, EM, Sloomaker, C, Piaggio, AJ, Beasley, JC, Pepin, KM (2020) A comparison of cost and quality of three methods for estimating density for wild pig (*Sus scrofa*). *Scientific Reports* **10**, 1–14.
- Davis, NE, Di Stefano, J, Whelan, J, Wright, J, Taylor, L, Coulson, G, Sitters, H (2022) Power of faecal pellet count and camera trapping indices to monitor mammalian herbivore activity. *Wildlife Research* **49**, 686–697.
- Denny, EA, Dickman, CR (2010) Review of cat ecology and management strategies in Australia. Invasive Animals Cooperative Research Centre, Canberra.
- Di Bitetti, MS, Paviolo, AJ, de Angelo, CD (2014) Camera trap photographic rates on roads vs. off roads: location does matter. *Mastozoologia Neotropical* **21**, 37–46.
- Diete, RL, Meek, PD, Dixon, KM, Dickman, CR, Leung, LK-P (2015) Best bait for your buck: bait preference for camera trapping north Australian mammals. *Australian Journal of Zoology* **63**, 376–382.
- DSEWPAC (2011) *Environment Protection and Biodiversity Conservation Act 1999* Draft Referral Guidelines for the Endangered Southern Brown Bandicoot (Eastern), *Isodon obesulus obesulus*. Department of Sustainability, Environment, Water, Population and Communities, Canberra.
- Dundas, SJ, Ruthrof, KX, Hardy, GESJ, Fleming, PA (2019) Pits or pictures: a comparative study of camera traps and pitfall trapping to survey small mammals and reptiles. *Wildlife Research* **46**, 104–113.
- Engbrecht, NJ, Lannoo, MJ (2012) Crawfish frog behavioral differences in postburned and vegetated grasslands. *Fire Ecology* **8**, 63–76.

- Fancourt, BA, Sweaney, M, Fletcher, DB (2018) More haste, less speed: pilot study suggests camera trap detection zone could be more important than trigger speed to maximise species detections. *Australian Mammalogy* **40**, 118–121.
- Florencia Miguel, M, Tabeni, S, Cona, MI, Campos, CM (2018) Secondary seed dispersal by mammals between protected and grazed semiarid woodland. *Forest Ecology and Management* **422**, 41–48.
- Forrester, T, O'Brien, T, Fegraus, E, Jansen, PA, Palmer, J, Kays, R, Ahumada, J, Stern, B, McShea, W (2016) An open standard for camera trap data. *Biodiversity Data Journal* **4**, e10197.
- Forsyth, DM, Richardson, SJ, Menchenton, K (2005) Foliar fibre predicts diet selection by invasive Red Deer *Cervus elaphus scoticus* in a temperate New Zealand forest. *Functional Ecology* **19**, 495–504.
- Forsyth, DM, Woodford, L, Moloney, PD, Hampton, JO, Woolnough, AP, Tucker, M (2014) How does a carnivore guild utilise a substantial but unpredictable anthropogenic food source? Scavenging on hunter-shot ungulate carcasses by wild dogs/dingoes, red foxes and feral cats in south-eastern Australia revealed by camera traps. *PloS ONE* **9**, e97937.
- Foster, RJ, Harmsen, BJ (2012) A critique of density estimation from camera-trap data. *The Journal of Wildlife Management* **76**, 224–236.
- Frey, S, Fisher, JT, Burton, AC, Volpe, JP (2017) Investigating animal activity patterns and temporal niche partitioning using camera-trap data: Challenges and opportunities. *Remote Sensing in Ecology and Conservation* **3**, 123–132.
- Geyle, HM, Stevens, M, Duffy, R, Greenwood, L, Nimmo, DG, Sandow, D, Thomas, B, White, J, Ritchie, EG (2020) Evaluation of camera placement for detection of free-ranging carnivores; implications for assessing population changes. *Ecological Solutions and Evidence* **1**, e12018.
- Gilbert, NA, Clare, JDJ, Stenglein, JL, Zuckerberg, B (2021) Abundance estimation of unmarked animals based on camera-trap data. *Conservation Biology* **35**, 88–100.
- Gillespie, G, Brennan, K, Gentles, T, Hill, B, Low Choy, J, Mahney, T, Stevens, A, Stokeld, D (2015) A guide for the use of remote cameras for wildlife survey in northern Australia. Charles Darwin University, Darwin.
- Gray, EL, Dennis, TE, Baker, AM (2017) Can remote infrared cameras be used to differentiate small, sympatric mammal species? A case study of the black-tailed dusky antechinus, *Antechinus arktos* and co-occurring small mammals in southeast Queensland, Australia. *PloS ONE* **12**, e0181592.
- Hansen, CM, Paterson, AM, Ross, JG, Ogilvie, SC (2018) Estimating feral cat (*Felis catus*) density in a rural to urban gradient using camera trapping. *New Zealand Journal of Zoology* **45**, 213–226.
- Harmsen, BJ, Foster, RJ, Silver, S, Ostro, L, Doncaster, CP (2010) Differential use of trails by forest mammals and the implications for camera-trap studies: a case study from Belize. *Biotropica* **42**, 126–133.
- Hoffman, AS, Heemeyer, JL, Williams, PJ, Robb, JR, Karns, DR, Kinney, VC, Engbrecht, NJ, Lannoo, MJ (2010) Strong site fidelity and a variety of imaging techniques reveal around-the-clock and extended activity patterns in Crawfish Frogs (*Lithobates areolatus*). *BioScience* **60**, 829–834.
- Hohnen, R, P. Murphy, B, A. Gates, J, Legge, S, R. Dickman, C, CZ Woinarski, J (2019) Detecting and protecting the threatened Kangaroo Island dunnart (*Sminthopsis fuliginosus aitkeni*). *Conservation Science and Practice* **1**, e4.
- Kays, R, Tilak, S, Kranstauber, B, Jansen, PA, Carbone, C, Rowcliffe, M, Fountain, T, Eggert, J, He, Z (2011) Camera traps as sensor networks for monitoring animal communities. *International Journal of Research and Reviews in Wireless Sensor Networks* **1**, 19–29.
- Kim, TK, Kim, S, Won, M, Lim, J-H, Yoon, S, Jang, K, Lee, K-H, Park, YD, Kim, HS (2021) Utilizing machine learning for detecting flowering in mid-range digital repeat photography. *Ecological Modelling* **440**, 109419.
- Krauss, SL, Roberts, DG, Phillips, RD, Edwards, C (2018) Effectiveness of camera traps for quantifying daytime and nighttime visitation by vertebrate pollinators. *Ecology and Evolution* **8**, 9304–9314.
- Lloyd, KM, Pollock, ML, Mason, NWH, Lee, WG (2010) Leaf trait–palatability relationships differ between ungulate species: evidence from cafeteria experiments using naïve tussock grasses. *New Zealand Journal of Ecology* **34**, 219–226.
- Mann, GKH, O'Riain, MJ, Parker, DM (2015) The road less travelled: assessing variation in mammal detection probabilities with camera traps in a semi-arid biodiversity hotspot. *Biodiversity and Conservation* **24**, 531–545.
- Mattioli, L, Canu, A, Passilongo, D, Scandura, M, Apollonio, M (2018) Estimation of pack density in grey wolf (*Canis lupus*) by applying spatially explicit capture-recapture models to camera trap data supported by genetic monitoring. *Frontiers in Zoology* **15**, 1–15.
- McDonald, J, Brandle, R (2009) Management of feral goats: evaluation of ecological indicators for a monitoring and evaluation framework, summary. Department for Environment and Heritage, Adelaide.
- McHugh, D, Goldingay, RL, Letnic, M (2022) Occupancy and co-occurrence patterns of endemic mammals and introduced predators across a broad geographical gradient in eastern Australia. *Biodiversity and Conservation* **31**, 989–1021.
- Meek, P (2018) Guide for camera trapping wild dogs, foxes and feral cats. NSW Department of Primary Industries, Orange, NSW.
- Meek, P, Ballard, G, Claridge, A, Kays, R, Moseby, K, O'brien, T, O'connell, A, Sanderson, J, Swann, D, Tobler, M (2014a) Recommended guiding principles for reporting on camera trapping research. *Biodiversity and Conservation* **23**, 2321–2343.
- Meek, P, Ballard, G, Fleming, P (2012a) 'An Introduction to Camera Trapping for Wildlife Surveys in Australia.' (PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre: Canberra, Australia)
- Meek, P, Fleming, P, Ballard, G, Banks, P, Claridge, A, Sanderson, J, Swann, D (2014b) 'Camera Trapping: Wildlife Management and Research.' (CSIRO Publishing: Melbourne)
- Meek, PD, Ballard, G-A, Vernes, K, Fleming, PJS (2015) The history of wildlife camera trapping as a survey tool in Australia. *Australian Mammalogy* **37**, 1–12.
- Meek, PD, Ballard, G, Fleming, P (2012b) An introduction to camera trapping for wildlife surveys in Australia. PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia.
- Meek, PD, Vernes, K (2015) Can camera trapping be used to accurately survey and monitor the Hastings River mouse (*Pseudomys oralis*)? *Australian Mammalogy* **38**, 44–51.

- Molloy, SW (2018) A Practical Guide to Using Camera Traps for Wildlife Monitoring in Natural Resource Management Projects. Edith Cowan University, Western Australia.
- Moore, HA, Champney, JL, Dunlop, JA, Valentine, LE, Nimmo, DG (2020a) Spot on: using camera traps to individually monitor one of the world's largest lizards. *Wildlife Research* **47**, 326–337.
- Moore, HA, Valentine, LE, Dunlop, JA, Nimmo, DG (2020b) The effect of camera orientation on the detectability of wildlife: a case study from north-western Australia. *Remote Sensing in Ecology and Conservation* **6**, 546–556.
- Moseby, KE, Read, JL (2014) Using camera traps to compare poison bait uptake by invasive predators and non-target species. In 'Camera Trapping: Wildlife Management and Research.' pp. 131–139. (CSIRO Publishing: Melbourne)
- Mutze, G (2016) Barking up the wrong tree? Are livestock or rabbits the greater threat to rangeland biodiversity in southern Australia? *The Rangeland Journal* **38**, 523–531.
- Mutze, G, Cooke, B, Jennings, S (2016a) Density-dependent grazing impacts of introduced European rabbits and sympatric kangaroos on Australian native pastures. *Biological Invasions* **18**, 2365–2376.
- Mutze, G, Cooke, B, Jennings, S (2016b) Estimating density-dependent impacts of European rabbits on Australian tree and shrub populations. *Australian Journal of Botany* **64**, 142–152.
- Niedballa, J, Sollmann, R, Courtiol, A, Wilting, A (2016) camtrapR: an R package for efficient camera trap data management. *Methods in Ecology and Evolution* **7**, 1457–1462.
- Norouzzadeh, MS, Nguyen, A, Kosmala, M, Swanson, A, Palmer, MS, Packer, C, Clune, J (2018) Automatically identifying, counting, and describing wild animals in camera-trap images with deep learning. *Proceedings of the National Academy of Sciences* **115**, E5716–E5725.
- Pagnucco, KS, Paszkowski, CA, Scrimgeour, GJ (2011) Using cameras to monitor tunnel use by long-toed salamanders (*Ambystoma macrodactylum*): an informative, cost-efficient technique. *Herpetological Conservation and Biology* **6**, 277–286.
- Paull, DJ, Claridge, AW, Barry, SC (2011) There's no accounting for taste: bait attractants and infrared digital cameras for detecting small to medium ground-dwelling mammals. *Wildlife Research* **38**, 188–195.
- Potter, TI, Greenville, AC, Dickman, CR (2021) Night of the hunter: using cameras to quantify nocturnal activity in desert spiders. *PeerJ* **9**, e10684.
- Ramsey, DSL, Caley, PA, Robley, A (2015) Estimating population density from presence-absence data using a spatially explicit model. *The Journal of Wildlife Management* **79**, 491–499.
- Raufirad, V, Azadi, H, Ebrahimi, A, Bagheri, S (2016) Determining Rangeland Species Palatability: Application of Principal Component Analysis. *Rangelands* **38**, 105–112.
- Rautio, P, Bergvall, U, Tuomi, J, Kesti, K, Leimar, O (2012) Food Selection by Herbivores and Neighbourhood Effects in the Evolution of Plant Defences. *Annales Zoologici Fennici* **49**, 45–57.
- Reconyx (2018) HyperFire 2 User Manual. Reconyx, Holmen, Wisconsin.
- Rees, JD, Crowther, MS, Kingsford, RT, Letnic, M (2020) Direct and indirect effects of carrion subsidies in an arid rangeland: Carrion has positive effects on facultative scavengers and negative effects on a small songbird. *Journal of Arid Environments* **179**, 104174.
- Reid, AM, Murphy, BP, Vigilante, T, Wunambal Gaambera Aboriginal Corporation, Bowman, DMJS (2020) Distribution and abundance of large herbivores in a northern Australian tropical savanna: A multi-scale approach. *Austral Ecology* **45**, 529–547.
- Rovero, F, Zimmermann, F, Berzi, D, Meek, P (2013) "Which camera trap type and how many do I need?" A review of camera features and study designs for a range of wildlife research applications. *Hystrix, the Italian Journal of Mammalogy* **24**, 148–156.
- Rowcliffe, JM, Field, J, Turvey, ST, Carbone, C (2008) Estimating animal density using camera traps without the need for individual recognition. *Journal of Applied Ecology* **45**, 1228–1236.
- Royle, JA, Karanth, KU, Gopalaswamy, AM, Kumar, NS (2009) Bayesian inference in camera trapping studies for a class of spatial capture-recapture models. *Ecology* **90**, 3233–3244.
- Ruykys, L, Carter, A (2019) Removal and eradication of introduced species in a fenced reserve: Quantifying effort, costs and results. *Ecological Management & Restoration* **20**, 239–249.
- Seidlitz, A, Bryant, KA, Armstrong, NJ, Calver, M, Wayne, AF (2021) Optimising camera trap height and model increases detection and individual identification rates for a small mammal, the numbat (*Myrmecobius fasciatus*). *Australian Mammalogy* **43**, 226–234.
- Silveira, L, Jacomo, AT, Diniz-Filho, JAF (2003) Camera trap, line transect census and track surveys: a comparative evaluation. *Biological Conservation* **114**, 351–355.
- Silvester, R, Shine, R, Oldroyd, B, Greenlees, M (2017) The ecological impact of commercial beehives on invasive cane toads (*Rhinella marina*) in eastern Australia. *Biological Invasions* **19**, 1097–1106.
- Sollmann, R (2018) A gentle introduction to camera-trap data analysis. *African Journal of Ecology* **56**, 740–749.
- Spencer, E, Newsome, T (2021) Dingoes dining with death. *Australian Zoologist* **41**, 433–451.
- Spencer, EE, Dickman, CR, Greenville, A, Crowther, MS, Kutt, A, Newsome, TM (2021) Carcasses attract invasive species and increase artificial nest predation in a desert environment. *Global Ecology and Conservation* **27**, e01588.
- Srbek-Araujo, AC, Chiarello, AG (2013) Influence of camera-trap sampling design on mammal species capture rates and community structures in southeastern Brazil. *Biota Neotropica* **13**, 51–62.
- Stokeld, D, Frank, AS, Hill, B, Choy, JL, Mahney, T, Stevens, A, Young, S, Rangers, D, Rangers, W, Gillespie, GR (2015) Multiple cameras required to reliably detect feral cats in northern Australian tropical savanna: an evaluation of sampling design when using camera traps. *Wildlife Research* **42**, 642–649.
- TEAM Network (2011) Terrestrial Vertebrate Protocol Implementation Manual, v. 3.1. Tropical Ecology, Assessment and Monitoring Network, Center for Applied Biodiversity Science, Conservation International, Arlington, VA, USA.
- Tobler, MW, Carrillo-Percastegui, SE, Leite Pitman, R, Mares, R, Powell, G (2008) An evaluation of camera traps for inventorying large-and medium-sized terrestrial rainforest mammals. *Animal Conservation* **11**, 169–178.

- Tobler, MW, Zúñiga Hartley, A, Carrillo-Percegué, SE, Powell, GVN (2015) Spatiotemporal hierarchical modelling of species richness and occupancy using camera trap data. *Journal of Applied Ecology* **52**, 413–421.
- Trolle, M, Kéry, M (2005) Camera-trap study of ocelot and other secretive mammals in the northern Pantanal. *Mammalia* **69**, 405–412.
- Welbourne, DJ, Claridge, AW, Paull, DJ, Ford, F (2019) Improving terrestrial squamate surveys with camera-trap programming and hardware modifications. *Animals* **9**, 388.
- Welbourne, DJ, MacGregor, C, Paull, D, Lindenmayer, DB (2015) The effectiveness and cost of camera traps for surveying small reptiles and critical weight range mammals: a comparison with labour-intensive complementary methods. *Wildlife Research* **42**, 414–425.
- Williams, BL, Holtfreter, RW, Ditchkoff, SS, Grand, JB (2011) Efficiency of time-lapse intervals and simple baits for camera surveys of wild pigs. *The Journal of Wildlife Management* **75**, 655–659.

9 Appendices

Appendix 1. Pre-field survey tasks

Camera trap identification

Before camera traps are deployed in the field they need to be allocated and marked with an identification number. Camera traps should also be registered in an equipment management database (e.g. spreadsheet) to keep track of their location (e.g. in storage, assigned to project #), current firmware, and operational status (e.g. functional, damaged; TEAM Network 2011).

1. Clearly mark the camera trap externally with a unique identification number (e.g. 01, 02, 03) using a permanent, water-resistant marker.
2. Open the camera trap and mark it internally with the same unique identification number as marked externally.
3. Retrieve the serial number of the camera trap from the white sticker underneath the control panel.
4. Record the *camera trap number* and *camera trap serial number* in an equipment management database. Other data you may wish to record includes the camera trap *make*, *model*, *purchase date*, *firmware*, *operational status* and *current location*.
5. Repeat steps 1–4 for each camera trap.

Camera trap firmware update

Camera trap manufacturers regularly provide firmware updates for their camera traps. Ensure you check the relevant website for updates and instructions for updating before each field survey or camera trap redeployment. As an example, the steps to update the firmware on Reconyx camera traps are provided below (Bush Heritage Australia 2021).

1. Navigate to the *support* tab and *firmware updates* link on the [Reconyx website](#) to access the most recent firmware update. Updates are provided on an approximately annual basis.
2. Check the list of Reconyx camera trap models for the relevant update. HC500, HC550, HC600 and PC850 models generally all have the same update.
3. Upload the firmware update onto an empty SD card.
4. Insert the SD card into your Reconyx camera trap.
5. Switch on your Reconyx camera trap and firmware updates will automatically occur.
6. Reconyx firmware updates since 2016 have maintained the current camera trap settings. Check or set camera trap settings after firmware updates are completed.
7. Repeat steps 4–6 for all remaining Reconyx camera traps.

Camera trap settings configuration

Configure your camera trap settings before going into the field. Refer to the user manual for your camera trap make and model for instructions to navigate the control panel.

1. Open the camera trap and insert a spare set of batteries to configure the settings.
2. Switch the camera trap on and navigate to the control menu based on the user manual for your camera trap.
3. Select a pre-programmed settings option, or program customised settings (see following steps).
4. Set the *media type* (i.e. image and/or video).
5. For images, set the number of *images per trigger*.
6. For images, set the *image interval* in seconds.

7. For videos, set the *video length* in minutes and seconds.
8. Set the *sensor sensitivity*.
9. Set the *quiet period* in minutes and seconds.
10. Set the *aspect ratio*.
11. For images, set the *image quality* in megapixels.
12. For videos, set the *video resolution*.
13. Set *time lapse (on/off)*. If turned on, set the *time lapse interval* in minutes and seconds, and *time lapse schedules*.
14. Set *day/night recording*.
15. Set the *night mode shutter speed* in seconds.
16. Set the *time format*.
17. Set the *date* and *time*.
18. Set the *unit of temperature*.
19. Set the *user label* (i.e. relevant project, camera and/or camera trap point code).
20. Set the *battery type* to match the batteries that will be used during the survey.
21. Repeat steps 1–20 for each camera trap.

SD card identification

Before SD cards are used in camera traps that are deployed in the field, they need to be allocated and marked with an identification number. Similar to camera traps, SD cards should also be registered in an equipment management database to keep track of their location (e.g. in storage, assigned to project #, assigned to camera #) and operational status (e.g. functional, damaged; TEAM Network 2011).

1. Clearly mark the SD card externally with a unique identification number (e.g. 01, 02, 03) using a permanent, water resistant marker.
2. Retrieve the serial number of the SD card from the back of the SD card.
3. Record the *SD card number* and *SD card serial number* of each SD card in an equipment management database. Other data you may wish to record includes the SD card *brand*, *type* (SD, SDHC, SDHX), *purchase date*, *storage capacity*, *format* (e.g. FAT32), *format date*, and *current location*.
4. Repeat steps 1–3 for each SD card.

SD card formatting

Formatting an SD card effectively erases all the card data, giving you a fresh, empty folder structure to work with. After you have backed up your SD card after each field survey, you should format each SD card before the next field survey. This will ensure data from different surveys is not mixed up. Furthermore, regular formatting of SD cards can lower the risk of corrupt files.

1. Ensure your data from the previous field survey is backed up.
2. Insert the SD card into your computer's SD card reader (or use an external SD card reader).
3. For Windows, you should see your SD card under the list of available drives. Right-click on the drive and select *format*. Under *file system* select 'FAT32' if the SD card is 32 GB or smaller. If the SD card is 64 GB or greater, select 'ExFAT' then click on *start*. Select *ok* to ignore the warning that the data on the drive will be erased and begin formatting the SD card.
4. For Mac, open disk utility and select the SD card on the left side of the window. Click on the *erase* tab and then click on the *format* drop-down menu. Select 'MS-DOS (FAT)' if the SD card is 32 GB or smaller. If the SD card is 64 GB or greater, select 'ExFAT'. Click *erase*. Your Mac will delete the contents of your SD card and format it.

5. Record the SD card *format* and *format date* of each SD card in an equipment management database.
6. Insert the formatted SD card into a camera trap so it is ready for the survey.
7. Repeat steps 1–6 for each SD card.

Batteries preparation

Each camera trap can require up to 12 AA batteries depending on the make and model. Batteries should be selected after consulting the user manual of the camera traps you are using and consideration of your study requirements. The three most common battery types used are rechargeable nickel-metal hydride (NiMH), lithium and alkaline.

1. If using rechargeable NiMH batteries and charging the batteries for the first time, or the first time for a given field season, put them in a discharging-recharging cycle (conditioning cycle) at least 48 hours before leaving for the field. This ensures that the battery memory is properly set and prolongs the life of the rechargeable battery. Refer to the battery charger for instructions to put the batteries into a condition cycle. Only use battery chargers that have this specification. Depending on the number of camera traps you have, multiple large battery chargers may be required to be used in parallel to prepare for the field.
2. If not charging the rechargeable NiMH batteries for the first time, discharge them first and recharge them for at least 24 hours before leaving for the field survey.
3. Once the rechargeable NiMH batteries are finished charging, check they have adequate voltage using a voltmeter. Rechargeable batteries will show a lower voltage than their posted voltage of 1.5 V, but this is normal for these battery types (between 1.25 and 1.3 V).
4. Try not to charge the rechargeable NiMH batteries more than 2–3 days before taking them into the field.
5. Within 1–2 days of the field survey, insert new lithium or alkaline, or charged NiMH batteries into each camera trap so they are ready for the survey. Do not mix battery types.
6. Do not use the rechargeable NiMH batteries prepared for the field survey to configure the camera trap settings (see above). Use a spare set of batteries.

Desiccant installation

If the camera traps are being deployed in humid or wet conditions, desiccant (silica gel) can be placed inside the camera trap housings to help protect the electronics from moisture.

1. Open the camera trap housing and place a packet of desiccant inside.
2. Close the camera trap housing.
3. Repeat steps 1–2 for each camera trap.

Camera trap array development and upload

1. Review ecological information for the target taxa/species to inform the number, spacing and shape of the camera trap array. GIS spatial data layers (e.g. vegetation mapping, access tracks, landform), along with any other information relevant to the project, are also useful in determining an array.
2. Upload a csv file of the proposed array to your mobile device, with 'Name', 'Latitude' and 'Longitude' columns, and with latitude and longitude in decimal degrees.

Appendix 2. Study design and planning considerations

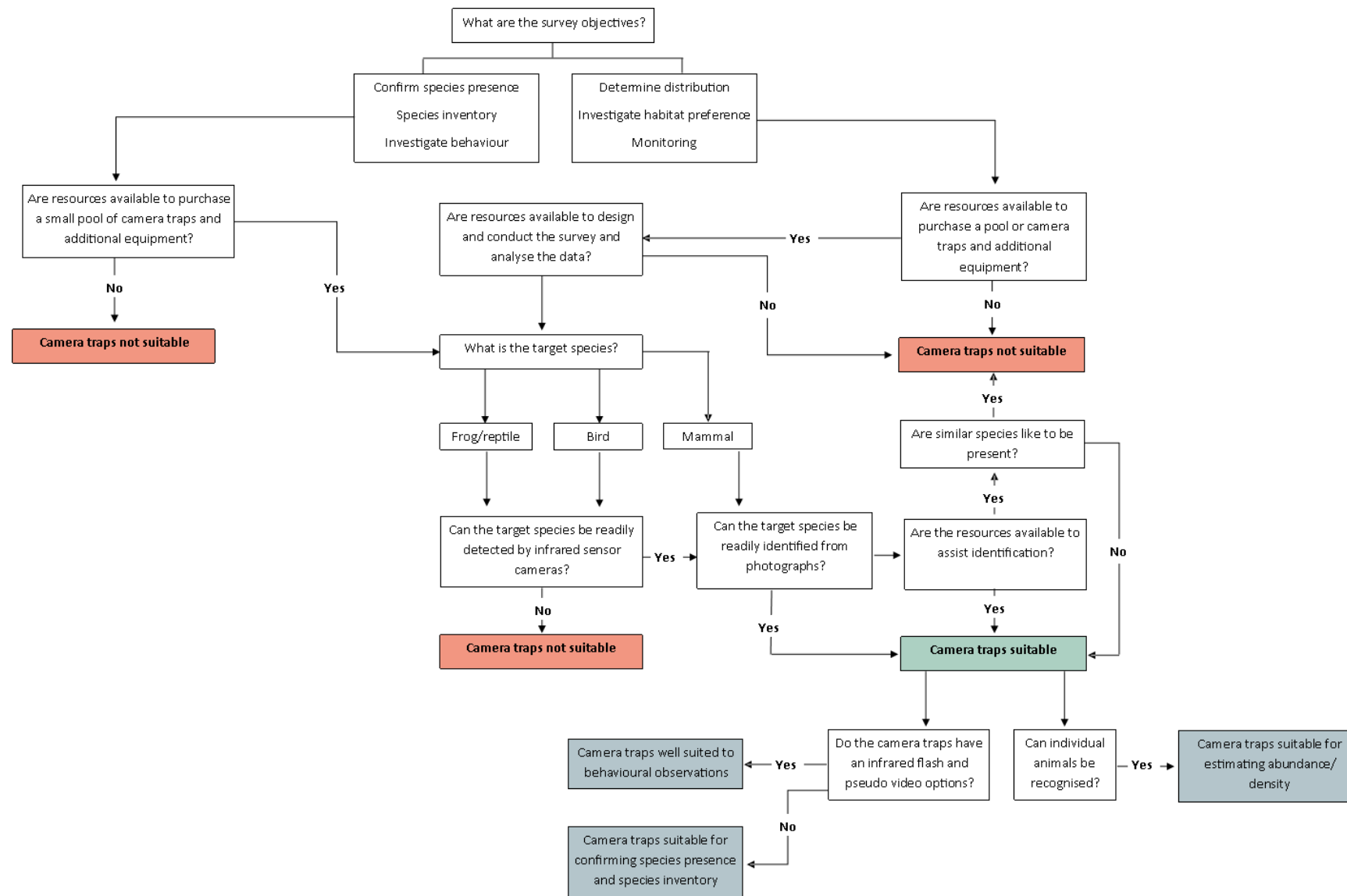
Proper attention must be given to the design of camera trapping studies, including the target species, the make and model of the camera trap used, the camera settings used, the mode of camera trap deployment, and what data is collected and how it will be analysed. Poorly designed surveys often result in data which cannot be used to answer the question of interest (Gillespie *et al.* 2015). A clear and defined statement of the study objectives and why camera traps are the best survey tool to achieve these objectives is therefore an important component of camera trapping studies. The study design and methodology should align with the clearly defined objectives (Meek *et al.* 2014a).

Study design and planning considerations for camera trapping surveys are detailed in the sections below, and cover:

- A camera trap decision key
- Quick reference deployment guidelines
- Factors affecting detection
- Target species
- Camera trap selection
- Camera trap point selection and preparation
- Mode of deployment
- Camera trap settings
- Lures
- The number and density of camera traps
- Camera trap arrays
- Deployment period
- SD cards
- Batteries
- Storage and transport
- Permits and ethics.

Camera trap decision key

The following decision key (below) will help you determine whether or not camera traps are suitable to use and for what purpose, based on the objectives of your survey, the available resources and the target species (Gillespie *et al.* 2015).



Camera trap decision key

Use to determine whether or not camera traps are suitable to use and for what purpose, based on the objectives of your survey, the available resources and the target species (adapted from Gillespie et al. 2015).

Quick reference deployment guidelines

The quick reference deployment guidelines (see table below) provide informed deployment recommendations for various taxa (e.g. small, medium-sized and large mammals, invasive predators, reptiles), including for the following aspects of camera trap deployment:

- Camera trap selection
- Camera trap point selection and preparation
- Mode of deployment
- Camera trap settings
- Lures
- The number and density of camera trap points
- Deployment period.

Each of these aspects is discussed more broadly in the sections below.

Quick reference camera trap deployment guidelines.

Deployment guidelines for various Australian taxa based on those used in relevant studies and those recommended in relevant guidelines (shown in bold).

Taxa	Target species	Camera trap specifications used/ recommended	Mode of deployment	Camera trap settings	Lures	Camera trap point number and density	Deployment period	Reference
Small mammals	▪ <i>Antechinus arktos</i> ▪ <i>A. stuartii</i> ▪ <i>Rattus fuscipes</i> ▪ <i>Melomys cervinipes</i>	▪ PIR sensor ▪ No sound ▪ IR no glow flash ▪ Image + video mode	▪ 35 cm above ground ▪ Orientated horizontally with camera facing downwards toward bait station on ground	▪ 10 min image interval ▪ 1 image per trigger ▪ 20 s video per trigger	▪ Peanut butter, oats, bacon ▪ Single application (2 s spray) of FeralMone	▪ 11 total ▪ Randomly assigned to stations set 50 m apart along four 200 m parallel transects, each 20 m apart	▪ Five consecutive deployments ▪ 11–16 days	(Gray <i>et al.</i> 2017)
	▪ Dasyurids	▪ PIR sensor ▪ IR low glow flash ▪ 0.2 s trigger speed	▪ 70 cm above ground ▪ Orientated horizontally with camera facing downwards toward cork tile marked with 5 x 5 cm grid on ground ▪ Drift fence 5 m either side of cork tile	▪ 5 images per trigger	▪ Passive (no lure)	▪ 32 total ▪ 2 per each of 16 sites ▪ 20 m apart	▪ 16 weeks	(Dundas <i>et al.</i> 2019)
	▪ <i>Sminthopsis fuliginosus aitkeni</i>	▪ PIR sensor ▪ No sound ▪ IR no glow flash ▪ 0.2 s trigger speed	▪ 30 cm above ground ▪ Angled at 45° toward base of drift fence 1 m away	▪ 1 s image interval ▪ No delay ▪ 3 images per trigger	▪ Passive (no lure)	▪ 210 and 252 total ▪ 6 per site ▪ 2 per each of three drift fences ▪ 35 sites during first survey ▪ 42 sites during second survey	▪ 3 days and nights	(Hohnen <i>et al.</i> 2019)

Taxa	Target species	Camera trap specifications used/ recommended	Mode of deployment	Camera trap settings	Lures	Camera trap point number and density	Deployment period	Reference
Medium-sized mammals	▪ <i>Isoodon obesulus</i> ▪ <i>Isoodon obesulus</i>		▪ 50 cm above ground ▪ Angled toward bait station 1–3 m away		▪ Standard mammal mix ▪ Truffle oil optional	▪ Affected area ≤10 ha: 1/ha ▪ Affected area >10 ≤30 ha: 1 per 2 ha ▪ Affected area >30 ha: 1 per 5 ha	▪ Minimum of 2 weeks ▪ Two deployments at least 1 month apart ▪ At least one deployment following significant rainfall	(DSEWPAC 2011)
Medium-sized mammals	▪ <i>Dasyurus hallucatus</i> (camera trap angle did not impact detection) ▪ <i>Petrogale rothschildi</i> (horizontal camera trap angle more effective for detection)	▪ PIR sensor ▪ No sound ▪ IR no glow flash ▪ 0.2 s trigger speed	▪ Paired camera traps ▪ First 1.5 above ground orientated horizontally with camera facing downwards toward bait station on ground ▪ Second 50 cm above ground, 2.5 m north of first, orientated vertically with angle of 10° towards bait station on ground	▪ 1 s image interval ▪ 5 images per trigger ▪ High sensitivity	▪ Canned fish	▪ 92 total ▪ 2 per site (paired) ▪ 2 sites >300 m apart in each of 23 landscapes	▪ 28 weeks	(Moore <i>et al.</i> 2020b)
Large mammals	▪ Macropods	▪ PIR sensor ▪ IR low glow flash ▪ 0.2 s trigger speed	▪ 1 m above ground ▪ Orientated vertically toward potential foraging areas	▪ 1 s image interval ▪ 1 min quiet period ▪ 3 images per trigger ▪ Medium/high sensitivity	▪ Passive (no lure)	▪ 55 total ▪ 5 per each of eleven sites	▪ 4–42 weeks	(Reid <i>et al.</i> 2020)
	▪ <i>Macropus giganteus</i> ▪ <i>Wallabia bicolor</i> ▪ <i>Vombatus ursinus</i> ▪ <i>Axis porcinus</i>	▪ PIR sensor ▪ No sound ▪ IR no glow flash ▪ 0.2 s trigger speed	▪ 50 cm above ground ▪ Orientated vertically to focus on point 6 m away and 20 cm above ground (core body zone of smallest species)	▪ No delay ▪ 3 images per trigger ▪ High sensitivity	▪ Passive (no lure)	▪ 36 total ▪ 1 per each of 36 sites	▪ 14 weeks	(Davis <i>et al.</i> 2022)

Taxa	Target species	Camera trap specifications used/ recommended	Mode of deployment	Camera trap settings	Lures	Camera trap point number and density	Deployment period	Reference
Small, medium-sized and large mammals	Wide range of mammal species	- PIR sensor - White flash 0.2 s trigger speed	70 cm above ground - Angled toward bait station 30 cm above ground, 1.5 or 2.5 m away - Variety of micro-habitats in and around fauna monitoring plot	1 s image interval - No delay 3 images per trigger - High sensitivity	Standard mammal mix	5 per fauna monitoring plot - Single camera trap at centre of plot and four placed 50 m from centre in diamond configuration	- Minimum of 5 weeks - Encompassing ground trapping at beginning or end of deployment	(Gillespie <i>et al.</i> 2015)
Vertebrate pests	- Wild dogs - Foxes - Feral cats	- PIR sensor - No sound - IR no glow flash 0.2 s trigger speed	50 cm above ground - Orientated vertically 30 cm from edge of track - Orientated 23° to track - Detection point 4–6 m away in middle of track	- RapidFire (2 frames/s) - No delay 10 images per trigger - High sensitivity - Night mode: fast shutter or high quality	Passive (no lure)	- Minimum of 20–30 1 km apart along tracks	Minimum of 4 weeks	(Meek 2018)
	Rabbits			Slow trigger speed		6 per 100 ha	5 days before and after control	(Fancourt <i>et al.</i> 2018; Ruykys and Carter 2019)
	Feral deer		- Point-based - Grid arrays 3 m above ground - Orientated south			30 0.5–1 km apart	90 days	(Davies <i>et al.</i> 2020; Bengsen <i>et al.</i> 2022)
	Feral pigs		20–50 cm above ground - Orientation south - In areas with signs of pig activity			20 per 1 km²	11 days	(Davis <i>et al.</i> 2020)
	Feral goats		- Point-based - At water points - Must be inconspicuous and secure	Multiple photos per trigger				

Taxa	Target species	Camera trap specifications used/ recommended	Mode of deployment	Camera trap settings	Lures	Camera trap point number and density	Deployment period	Reference
Vertebrate pests	▪ Feral horses	▪	▪ >1 m above ground ▪ Along tracks and in areas with signs of horse activity	▪	▪	▪	▪	
	▪ Feral camels	▪ Devices that don't rely on PIR sensors to target camels diurnally	▪ Point-based ▪ At waterholes ▪ Grid arrays	▪	▪	▪	▪	
Reptiles	▪ <i>Varanus giganteus</i>	▪ PIR sensor ▪ No sound ▪ IR no glow flash ▪ 0.2 s trigger speed	▪ 1.5 m above ground ▪ Orientated horizontally with camera facing downwards towards bait station on ground	▪ 1 s image interval ▪ No delay ▪ 5 images per trigger ▪ High sensitivity	▪ Canned fish	▪ 115 total ▪ 5 per each of 23 landscapes, 1 km in diameter ▪ >200 m apart	▪ 21–35 weeks ▪ Bait replenished twice after 10 and 20 weeks	(Moore <i>et al.</i> 2020a)
	▪ Varanids (vertical camera trap angle more effective for detection)	▪ PIR sensor ▪ No sound ▪ IR no glow flash ▪ 0.2 s trigger speed	▪ Paired camera traps ▪ First 1.5 above ground orientated horizontally with camera facing downwards toward bait station on ground ▪ Second 2.5 m north of first, 50 cm above ground, orientated vertically with angle of 10° towards bait station on ground	▪ 1 s image interval ▪ 5 images per trigger ▪ High sensitivity	▪ Canned fish	▪ 92 total ▪ 2 per site (paired) ▪ 2 sites >300 m apart in each of 23 landscapes	▪ 28 weeks	(Moore <i>et al.</i> 2020b)

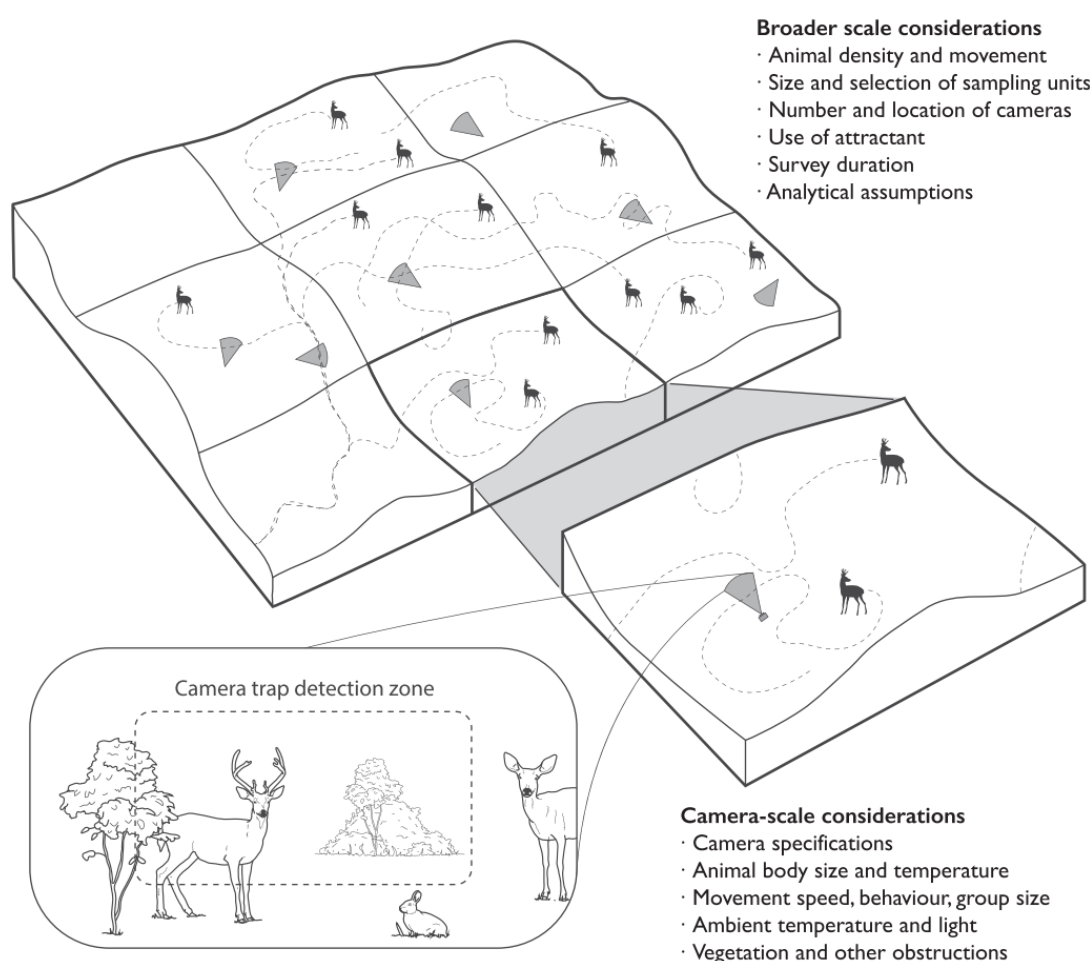
Taxa	Target species	Camera trap specifications used/ recommended	Mode of deployment	Camera trap settings	Lures	Camera trap point number and density	Deployment period	Reference
Reptiles	- Snakes - Lizards	- PIR sensor - No sound - IR no glow flash 0.2 s trigger speed	70 cm above ground - Orientated horizontally with camera facing downwards toward cork tile and bait station on ground - Drift fence 3 m either side of cork tile	- No delay 10 images per trigger - High sensitivity - Time lapse (1 min)	Standard mammal mix	40 total 4 per each of ten 100 m transects - At 20, 40, 60 and 80 m along each transect	6 weeks	(Welbourne <i>et al.</i> 2019)
	Small reptiles	- PIR sensor - No sound - IR no glow flash 0.2 s trigger speed	70 cm above ground - Orientated horizontally with camera facing downwards toward cork tile and bait station on ground - Drift fence 3 m either side of cork tile	- No delay 10 images per trigger - High sensitivity	Standard mammal mix	36 total 2 per each of eighteen 100 m transects across study area 50 m apart on each transect	4 weeks	(Welbourne <i>et al.</i> 2015)
Birds	Birds	IR or white flash	20 cm above ground for terrestrial species - Above nest orientated horizontally with camera facing downwards to nest or level with top of nest and orientated vertically 1–5 m from feature depending on species	- No delay 3–5 images per trigger - High sensitivity	Passive (no lure)		4 weeks	(Meek <i>et al.</i> 2012b)

Taxa	Target species	Camera trap specifications used/ recommended	Mode of deployment	Camera trap settings	Lures	Camera trap point number and density	Deployment period	Reference
Birds	Honeyeaters	- PIR sensor - IR low glow flash 0.2 s trigger speed	- Various heights above ground up to 1.5 m - Same height as inflorescence 60 cm away - Orientated vertically at inflorescence	- RapidFire (2 frames/s) - No delay 10 images per trigger - High sensitivity	Inflorescences	12 total 9 plants monitored in 1 ha	16 weeks	(Krauss <i>et al.</i> 2018)
Amphibians	Amphibians	- IR or white flash - Time lapse	1–1.5 m above ground - Angled at feature to detect target species	Time lapse	Passive (no lure)		2–4 weeks	(Meek <i>et al.</i> 2012b)
	Cane toads	- PIR sensor - IR no glow flash	1.5 m above ground - Angled at 45° toward beehive 1.5 m from beehive	20 s video during night-time (longest available) 60 s video during daytime	Beehives	12 total 6 per each of two apiaries	2 weeks	(Silvester <i>et al.</i> 2017)
Invertebrates	Lycosids	Time lapse	50 cm above ground - Angled at 45° and horizontally with camera facing downwards toward ground	- No delay - High sensitivity - Time lapse (5 min)	Passive (no lure)	24 total 12 angled at 45° 12 angled vertically 20 m apart along four 100 m transects, each 100 m apart	14 weeks	(Potter <i>et al.</i> 2021)
	Litter arthropods	Time lapse	25 cm above ground - Orientated horizontally with camera facing downwards toward pitfall trap - Ruler on ground on one side of field of view	Time lapse (15 s, 30 s, 1 min, 15 min)	Passive (no lure)	25 total 5 at Site 1 20 at Sites 2–5	1 week (Site 1) 2 weeks (Sites 2–5)	(Collett and Fisher 2017)

Factors affecting detection

Like any fauna survey methodology, camera trap surveys must address common sources of sampling error to reliably assess animal populations. This includes imperfect detection – where individuals or species present within a sampling area are not always detected. Camera trap surveys, which sample mobile species, must consider imperfect detection at the camera trap scale, where fauna passing through the relatively small camera trap detection zone fail to be detected, and at the study area scale, where fauna using the study area that the camera trap is assumed to sample fail to be detected (see figure below; Burton *et al.* 2015).

The probability of detection (i.e. the probability that a species will be detected during a survey if it is present within the study area; Gillespie *et al.* 2015) is affected by several factors at the camera trap scale, including camera trap specifications, mode of deployment, animal body size and temperature, animal speed of movement, behaviour and group size, ambient temperature and light, and vegetation and other obstructions, as well as at the study area scale, including animal density and movement, the size and selection of sampling units, the number and location of cameras, the use of attractant, the deployment period, and analytical assumptions (Burton *et al.* 2015). Consideration of these factors (see below) and following the carefully planned camera trapping protocol are imperative to reduce detection bias in camera trap field data collection. However, researchers will need to consider analytical approaches to contend with imperfect detection when undertaking downstream analyses (e.g. capture-mark-recapture methods, random encounter models).



Factors affecting camera trap detection.

*The detection of fauna by camera traps is affected by ecological and observational processes occurring at the broader, landscape scale and local, camera trap detection zone scale (Burton *et al.* 2015).*

Target species

The target species, suites of species, or community of interest should be clearly identified when planning camera trap surveys. This is because the study design, camera trap model, camera trap point selection, mode of deployment, camera trap settings, use and type of lure, number and density of cameras, and deployment period should be tailored to the target fauna to maximise detection probability (Harmsen *et al.* 2010; Rovero *et al.* 2013; Diete *et al.* 2015; Fancourt *et al.* 2018; Moore *et al.* 2020a). Consideration should be given to the size, behaviour, diagnostic characteristics, home range and mode of body temperature regulation of the target fauna.

Deployment recommendations for various Australian taxa (e.g. small, medium-sized and large mammals, invasive predators, reptiles) are summarised in the *Quick reference deployment guidelines* above. Furthermore, deployment recommendations for different species, relating to each of the factors mentioned above, are discussed in the corresponding sections below.

Camera trap selection

The make and model of the camera traps used in a survey have important consequences for species detectability and the interpretation and repeatability of results. There are numerous manufacturers (e.g. Reconyx, Pixcontroller, Buckeye, Cuddeback, Bushnell, Scoutguard) that typically have multiple camera trap models available. These makes and models vary in their cost, trigger speed, detection zone, sensor sensitivity, how they detect fauna (e.g. PIR or AIR sensors), how they illuminate the scene at night (e.g. white or infrared flash), and battery life, among others (see table below). Websites such as [TrailCamPro.com](https://www.trailcampro.com) provide comparative performance statistics as well specifications for many popular models (Meek *et al.* 2014a). The camera trap features that should be evaluated when selecting a camera trap model are summarised in the table below. Only a single model of camera trap should be used in a study because performance is likely to vary among models.

Recording the make and model (including the manufacturing year for models that are updated frequently but keep the same name) of the camera traps used in a study ensures repeatability of the methods and comparability of the results, both among projects and monitoring surveys within the same project. Data of the remaining camera trap features summarised in the table below should also be collected with the camera trap make, model and year as these features are not always apparent.

There are many examples where a poor choice in camera traps can negatively affect data and outcomes. For example, images captured with infrared flash are monochrome and of relatively low resolution compared to those taken with a white light flash. If using camera traps to survey small mammals, models with white flash will likely be required to capture the characteristic features required to distinguish similar-looking sympatric species with an acceptable level of precision (Meek and Vernes 2015). The possibility that the species of interest might be disturbed by a white light flash or the noises made by cameras and subsequently avoid the camera is also an important consideration (Gillespie *et al.* 2015). Furthermore, studies of animal refuge use (e.g. burrows, tree hollows) may be better carried out using camera traps with an AIR sensor, rather than a PIR sensor, and choosing a camera trap with a small detection zone and a slow trigger response may be unsuccessful in detecting small and fast-moving animals at close range (Meek *et al.* 2014a).

Reconyx Hyperfire camera traps are the most widely used camera trap for wildlife research (Meek *et al.* 2012b; Meek *et al.* 2015; Meek 2018). Protocols that specify the use of Reconyx camera traps in Australia include the *Standard Operating Procedure for Camera Trapping in Northern Australia* developed by the Department of Environment, Parks and Water Security (Northern Territory Government; Gillespie *et al.* 2015), and Bush Heritage Australia's *Camera Trap Guidelines* (Bush Heritage Australia 2021). Both protocols use Reconyx HC550 or PC850 camera for data consistency and comparability. These models have similar specifications and setting options, as well as LED white flash capability, which importantly allows colour

images to be captured during the day and night, and significantly improves species identification capability (Gillespie *et al.* 2015). Internationally, the *Terrestrial Vertebrate (formerly Camera Trap) Monitoring Protocol* requires the use of Reconyx camera traps, particularly the HC500 or PC800 models, depending on the site's climate (PC800 models used in humid climates). This is due to their rapid response time, infrared flash, multi-fire capabilities and unique design for field conditions (TEAM Network 2011).

Summary of the camera trap features that should be evaluated when selecting a camera trap model (Rovero *et al.* 2013).

Feature	Summary
Sensor (PIR or AIR)	Most camera traps have passive infrared (PIR) sensor, which detect a differential in temperature and motion between a subject and the background temperature. When ambient temperature falls within the body temperature range of most mammals (31.5–36.5° C), PIR camera traps can be unreliable. PIR sensors can also be triggered by the movement of pockets of hot air or by the motion of warm vegetation in the detection zone. This problem can be limited by avoiding pointing the camera trap directly to a background that is under sun incidence. Active infrared (AIR) sensors, which respond to a break in an infrared beam between two units spaced apart, are not widely used but may, for example, be suitable for studies of animal use of burrows or tree hollows.
Trigger speed	A fundamental feature of camera traps, if not the critical feature. Fast trigger speeds are necessary to capture fast moving targets. Fast trigger speeds may be less necessary if using a bait station as fauna generally stay in the detection zone for longer.
Flash type (white or infrared)	Camera traps with white flash are critical to capture sharp and colour images at night as well as during the day. This is fundamental in studies that require individual recognition or for faunal inventories, as colour images aid identification. Currently, classic Xenon white flashes produce sharper images than white LED flashes due to their greater power and flash duration. Camera traps with infrared flash use arrays of LEDs that emit infrared light. The images captured are often in grey-scale or may have a reddish-pink tinge. Infrared flashes tend to be less obvious to fauna, use less energy and tend to have quicker trigger speeds than white flashes. Recently, no-glow (also called "black") infrared flashes have been introduced to minimise the red glow emitted by standard infrared LEDs which is seen by animals. A limited number of PIR camera trap models (e.g. Spypoint, Bolymedia) have dual flashes (Xenon and infrared).
Detection zone	Critical feature that varies widely among current models (15.8–324.1 m; Meek <i>et al.</i> 2012b). Camera traps with a narrow detection zone (i.e. smaller than the field of view) usually have fast trigger speeds and will take the photo when the animal is well within the field of view. The detection zone can be increased to some extent by moving the camera trap further away from the target, which can compensate for slow trigger speeds.
Number of photos taken, recovery time, and video	Capability to capture bursts of images in rapid sequence (i.e. fast recovery time) may be important for improved species identification (as chances of obtaining a good image within a burst will be increased), recording individuals within family groups and packs, and analysis of passing sequences to derive day range, which is a critical parameter in the Random Encounter Model (REM; Rowcliffe <i>et al.</i> 2008). At night, Xenon white flash cameras are unable to take photo bursts or videos due to the flash recharge time, which can take ≥ 30 seconds, a limitation that is overcome by LED white flash camera traps. Rapid image sequences and video can be useful for behavioural studies or specific research needs. However, data handling is more time consuming, SD cards are filled quicker and power consumption is greater, hence videos are not recommended when photographs alone provide sufficient data.
PIR sensitivity	Regulates the sensor responsiveness to the target by changing the heat sensitivity threshold. High sensitivity is generally better to detect small-sized animals. However, this will increase chance of false triggers caused by warm, moving vegetation.
Flash intensity	A number of camera trap models allow flash intensity to be adjusted automatically to the distance to the subject. Some models enable the amount of light generated by the white flash to be adjusted for two to three distance settings. However, the flash of most models is programmed for maximum distance and illumination.
Power autonomy	Studies in remote areas and/or with long deployment periods require high power autonomy. Camera traps with white flash generally consume more battery power than those with infrared flash. The three most common battery types used by camera traps are AA Lithium, Nickel Metal Hydride (NiMH) and Alkaline, which are discussed in the Batteries section. Despite the higher initial costs, rechargeable NiMH batteries are recommended as long as camera trap performances are not altered. A number of camera models (e.g. Spypoint, Bolymedia, Uway) mount an input jack for external batteries or small solar panels so higher capacity, lead-acid batteries can be used to prolong deployment.
Image resolution, sharpness and clarity	Most camera traps capture medium-to-high resolution images and video. However, the sharpness and clarity of colour images, needed to identify individuals and species, are also critical features. For images captured at night, only those taken with a white Xenon flash are clear and sharp enough to identify naturally marked individuals. Image resolution and clarity is often critical when targeting small animals, especially where sympatric species coexist with similar morphological features.

Camera housing and sealing	Housing, camouflage and water and insect proof qualities of camera traps is extremely important, especially where extreme weather conditions are experienced (e.g. snow, rainfall and humidity). In addition, ability to protect cameras with metal cases and lock them is critical against theft and/or damage by large animals. Housing should allow easy attachment of the unit to the support or tree used and allow access to replace batteries and SD cards when attached to the support. Housing should ideally have a tripod stud on the rear and underside to attach mounting brackets.
Camera programming and setting	Should be as simple as possible, to allow researchers and practitioners with varying degree of experience to set camera traps consistently and without errors. The option of programming the operation time, to avoid unnecessary images, may be useful for example when only nocturnal species are targeted. Setting camera traps to take an image at regular intervals in time (i.e. time lapse), either at pre-designated intervals or regular intervals following a motion detection, may be useful to decrease data load while confirming presence or examine temporal activity of invertebrates (Williams <i>et al.</i> 2011; Potter <i>et al.</i> 2021).

Cost is a key factor in determining camera trap selection. A suitable number of units are needed for robust scientific research, and the cost of different camera traps, as well as your budget and objectives will influence selection. One must consider the trade-off between fewer higher cost devices, with greater data, durability and security, and a greater number of low-cost devices. If the features of a low-cost unit are sufficient to meet your data objectives, this may be the best option, particularly if you require a high number of camera traps for robustness. The risk of theft and damage must also be considered during camera trap selection. Widely used Reconyx camera traps (see above) have a high cost per unit relative to most other makes. However, this is greatly offset by their climatic durability, reliability, sensitivity and flexible programming (Gillespie *et al.* 2015).

Camera trap specifications used or recommended for various Australian taxa (e.g. small, medium-sized and large mammals, invasive predators, reptiles) are summarised in the [Quick reference deployment guidelines](#).

Camera trap point selection and preparation

When choosing the exact location for a camera trap, careful attention to camera trap placement and site preparation can improve detection, facilitate species identification and significantly reduce the incidence of false triggers. When considering camera trap placement look for signs of fauna (e.g. tracks, scats) and features likely to be used or visited by fauna (e.g. animal trails, fallen logs, drainage lines, narrow gullies, edges of dense vegetation, paths to water). Consider the target species or suite of species and their travel habits, the likely path of travel, the sensor's range and field of view, and the terrain. Select the location that is likely to detect your target species or yield the greatest number of images of a suite of species, depending on the aims of your project (TEAM Network 2011).

An ideal location is a flat or gently sloping area that is relatively clear of shrubs and ground vegetation but is shaded by trees or rock over-hangs. If deploying camera traps in a rocky or densely vegetated habitat, think carefully how fauna might access the point; if access is limited then this will influence the detection probability (Gillespie *et al.* 2015).

Set the 'stage' for the camera trap. Occasionally, terrain or vegetation can obstruct the detection zone. Remove vegetation as needed (considering windy conditions), to maximise detection within the field of view of the camera trap and to minimise false triggers. Try to keep the stage as natural as possible, taking care not to disturb the area too much or create obstructions of cleared vegetation (TEAM Network 2011).

If using bait stations or carcasses, it may be best to remove all vegetation around them to ensure an uninterrupted view of fauna and prevent false triggers. The vegetation around the base of the camera trap mount, or tree to which the camera trap is attached to, should also be reduced to minimise the risk of fire damage to camera traps (Gillespie *et al.* 2015).

Mode of deployment

How a camera trap is deployed in the field (i.e. its height, angle, direction) can greatly improve detection probability and reduce false triggers. The detection zone of the PIR sensor in most camera traps is a wedge-

shaped, horizontal band (or bands) spreading outwards from the front of the sensor. As a result, the detection zone increases in size with increasing distance from the sensor (see the figure below). Setting camera traps so that the sensor is at different heights above the ground and at different distances to the focal area allows different sized fauna species to be targeted (see the figure below).

Setting camera traps close to the ground (i.e. 15–20 cm) and angled horizontally to the ground, or higher and angled so that they point towards the ground, will record the greatest size range of animals, as sensors will be triggered by both smaller animals and the legs of larger animals. The camera trap's field of view is more expansive vertically and generally wider than the sensor's detection zone, so although only the legs of an animal may trigger the sensor the photograph will contain more of the animal. Detection zone area varies widely among camera trap models (see Meek *et al.* 2012). Camera traps with a narrow detection zone (i.e. smaller than the camera field of view) usually have fast trigger speeds and will take the photo when the animal is well within the field of view (Gillespie *et al.* 2015).

When targeting large animals such as kangaroos, camera traps should be set so that the sensor is at the height of the animal's shoulder (e.g. approximately 1 m above the ground). This will reduce the number of images of smaller non-target species, as these animals will be underneath the detection zone (see the figure below). A maximum distance of 5 m between the camera trap and the focal point (e.g. a trail along which an animal may be travelling) should allow adequate illumination and reduce the likelihood of animals being obscured by vegetation (Gillespie *et al.* 2015).

For medium-sized animals (e.g. quolls, bandicoots, possums), the camera trap should be set so that the sensor is approximately 50 cm above the ground. A distance of 3 m between the camera and the target area (e.g. bait station) will ensure the animal is in the foreground of the photograph and is clearly illuminated by the flash (Gillespie *et al.* 2015). For example, for bandicoots, camera traps are deployed approximately 50 cm above ground level in locations with evidence of recent diggings or suitable habitat, with inaccessible bait stations with rolled oats, honey and peanut butter (5:1:2 ratio; truffle oil optional at 20 ml/kg) bait attractant set up 1–3 m in front of each camera trap. Vegetation is removed to ground level between the camera trap and bait station and within 1 m around the bait station if necessary (DSEWPAC 2011).

For small mammals, studies have found that a sensor height of approximately 20–30 cm above the ground, or downward facing camera traps increase detection (Welbourne *et al.* 2015; Gray *et al.* 2017; Dundas *et al.* 2019; Seidlitz *et al.* 2021). When targeting small mammals set the remote camera close to the target area (e.g. 1.5 m between the camera and bait station). Although small mammals are detected by remote cameras targeting medium-sized mammals, setting the camera close to the target area will capture the fine detail required for identifying certain small mammal species (Gillespie *et al.* 2015).

Tracks and roads have been shown to facilitate movement of introduced predators such as feral cats and foxes (Carter *et al.* 2012), and consequently, placing camera traps along them will increase the probability of detection (Meek 2018). Indeed, on-road detectability using camera traps was estimated to be seven times higher for cats and three times higher for foxes than off-road detectability. Furthermore, targeting camera trap survey effort on-road yielded the greatest power for detecting declines in both species (Geyle *et al.* 2020), which is useful for monitoring the success of lethal baiting programs. For feral cats, foxes and wild dogs, camera traps should be placed 30 cm from a road or track edge, 50 cm above the ground, set parallel to the ground (although this may vary depending on topography), oriented 23° to the road or track and facing away from the sun's path (facing south and in shade is optimal). The detection point should be 4–6 m from the camera trap in the middle of the road or track. Rock outcrops, reflective surfaces and shadows in the field of view should be avoided, as well as vegetation close enough that it can blow into the field of view (Meek 2018).

Setting camera traps to optimise detection of a wide range of species requires a balanced approach; there is no one size fits all. One option is to maximise the sensor sensitivity and the picture frame; set the camera



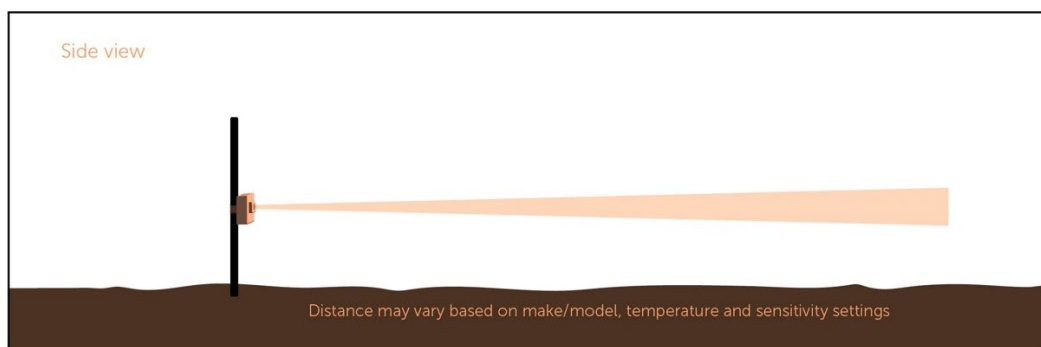
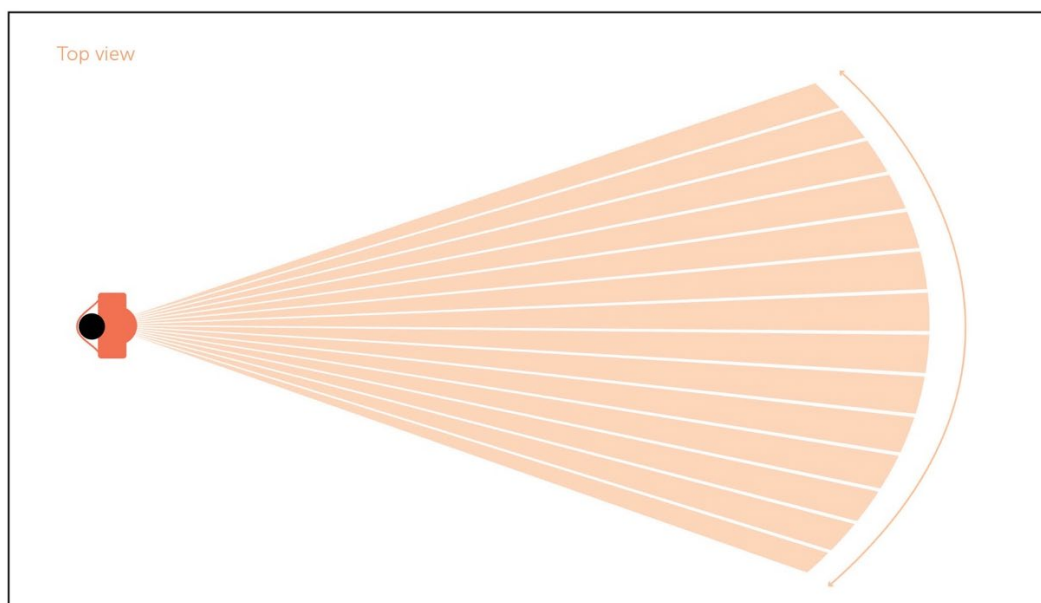
up so that it is angled down towards a feature or bait station such that the field of view covers an area of ground from the foreground of the feature or bait station within 1.5 m of the camera trap to several metres beyond the feature or bait station. For single camera trap deployments, the bait station to camera distance should be 2.5 m. However, by deploying multiple cameras at a site, variable setups can also be incorporated, such as varying the bait station distance from 1.5 – 2.5 m (Gillespie *et al.* 2015).

The majority of camera traps work by sensing objects that move and are a different temperature relative to the background surface and objects. They are therefore most suited to detecting mammals and to a lesser extent birds (i.e. endotherms; TEAM Network 2011; Cloyed *et al.* 2018), but are generally less sensitive at detecting reptiles and amphibians (i.e. ectotherms; Gillespie *et al.* 2015). However, camera traps positioned facing downwards have successfully monitored reptiles using bait stations to attract species to the detection zone, drift fences to direct species towards the detection zone, and cork tiles to create a sufficient thermal contrast between the tile, which is heated by the sun, and the species (Welbourne *et al.* 2015; Moore *et al.* 2020a). More recently, this approach was refined by reducing the focal length of Reconyx camera traps to avoid blurry images for when they are angled vertically towards the ground, 70 cm above the ground. This allowed small, similar looking sympatric species to be differentiated (Welbourne *et al.* 2019). Reconyx can alter the focal length of their professional series of camera traps at the time of purchase, but it is also possible for practitioners to adjust this themselves, as demonstrated by Welbourne *et al.* (2019).

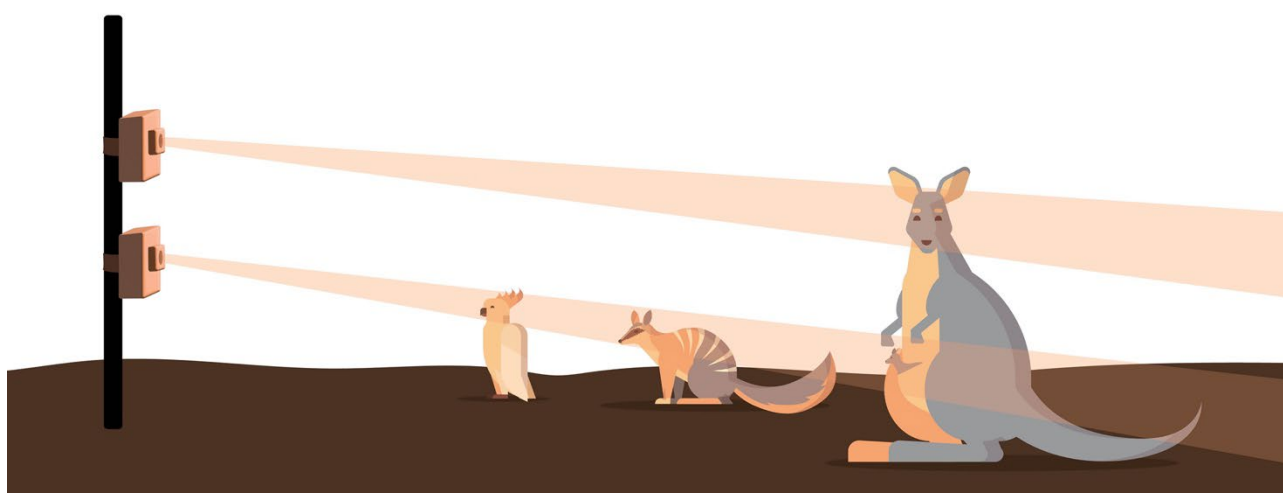
For amphibians, camera traps deployed close to and focused on microhabitats have been successfully used to monitor movements, activity patterns and behaviour when capturing time lapse images (Hoffman *et al.* 2010; Pagnucco *et al.* 2011; Engbrecht and Lannoo 2012; Barata *et al.* 2018). Similarly, camera traps deployed 50 cm above the ground and angled at 45° and vertically towards the ground have been successful at detecting invertebrates when capturing time lapse images (Potter *et al.* 2021).

Camera traps should be orientated facing south to prevent false triggers from sun glare and shadowing, and minimise sun damage to the camera lens and sensor. If using a tree to mount a camera trap, select a solid tree that will not move in the wind (diameter greater than 20 cm), with a relatively straight trunk and with a clear area to the south to direct the camera trap (Gillespie *et al.* 2015).

Mode of deployment used or recommended for various Australian taxa (e.g. small, medium-sized and large mammals, invasive predators, reptiles) are summarised in the [Quick reference deployment guidelines](#).



PIR sensor detection zone (adapted from; Reconyx 2018).



Detection of different sized fauna from camera traps mounted at different heights (adapted from Gillespie *et al.* 2015).

Camera trap settings

Three adjustable settings are common to many camera traps that can be used to ensure animals are captured, false triggers are minimised, and camera traps remain operational for the duration of a deployment: (i) motion sensor sensitivity; (ii) activation time; and (iii) camera delay (Gillespie *et al.* 2015).

Adjusting the sensitivity of the PIR sensor changes the heat sensitivity threshold, either being more or less responsive to the temperature differential between an animal and the background environment required to trigger the camera. As this heat difference is larger in cold temperatures, PIR sensors are more sensitive in temperate environments or during cooler seasons. High sensitivity is typically better to detect small-sized mammals. Lowering the sensitivity may reduce false triggers. However, by reducing the sensitivity there is a risk that some animals may not trigger the camera, especially in warm environments (e.g. many parts of northern Australia), where there is less difference between an animal's body temperature and that of its surroundings. For cameras with SD cards that have the capacity to retain large numbers of images on a single set of batteries, large numbers of false triggers are less problematic and the maximum sensitivity setting is recommended to avoid missing animals (Gillespie *et al.* 2015). However, the data storage and processing implications of this need to be considered.

Activation time settings allow camera traps to be set to operate continuously, only at night, or only during the day. Some camera traps can also be programmed to operate between particular times (e.g. 0500–0800 hours). When targeting species that are strictly nocturnal, setting the camera trap for night operation only will eliminate many false trigger events during the day and reduce the number of images of non-target species. Reliable knowledge of the activity patterns of the target species aid in determining whether this is an appropriate setting for nocturnal animals that may also be active at dawn and dusk (Gillespie *et al.* 2015).

Many camera traps include a feature that allows for a pause (e.g. 15, 30 seconds, 1 minute, 5 minutes) between successive triggers, which is important for determining the independence of captures. This will reduce the number of photographs taken of the same animal (e.g. if animals linger for long periods at bait stations), and may be useful in areas where there are very high levels of animal activity, especially of non-target species (e.g. where macropods are common). The appropriate length of the delay will depend largely on the target species; a minimal delay will maximise the chances of obtaining multiple photographs of rare or cryptic species, or group with distinctive marking (e.g. goats), which can help to determine the size of group. A longer delay would be appropriate when targeting slower moving animals (Gillespie *et al.* 2015).

Trigger speed (i.e. the speed with which a camera trap captures an image relative to when the sensor detects the animal) can be adjusted in some camera trap models. If available, this function can be useful for optimising detection of different species that may move through the field of view at different speeds, without the need for purchasing different camera trap models with different trigger speeds. Multiple trigger options in some camera traps, such as Reconyx, allow programming of camera traps to capture several images in quick succession each time the camera trap is triggered. This capability increases the likelihood of multiple images of the same animal, aiding in accurate species identification. The flash range is adjustable in some camera traps via the shutter speed setting (e.g. Reconyx). A slow shutter increases the flash range but also increases the potential for a blurry image. A fast shutter reduces flash range but results in a cleaner image. For smaller and faster moving animals, a faster shutter is recommended (Gillespie *et al.* 2015).

Time lapse settings allow programming the camera trap to take photos at predetermined time intervals, without being triggered. This function may be useful for recording the presence of species that do not readily trigger infra-red sensors, such as amphibians and invertebrates (Hoffman *et al.* 2010; Pagnucco *et al.* 2011; Engbrecht and Lannoo 2012; Barata *et al.* 2018; Potter *et al.* 2021), or for monitoring ecological processes, such as plant phenology (Kim *et al.* 2021). For amphibians, camera traps set to capture time lapse images, or a combination of sensor triggered and time lapse images have been successfully used to monitor movements (Pagnucco *et al.* 2011), and describe activity patterns and behaviour (Hoffman *et al.*

2010; Engbrecht and Lannoo 2012), including for a rare and elusive micro-endemic frog species strictly dependent on bromeliads (Barata *et al.* 2018).

Most camera traps can be set to capture video when they are triggered, which may be useful in behavioural studies (Hoffman *et al.* 2010; Krauss *et al.* 2018), distinguishing sympatric species (Gray *et al.* 2017), or individual identification in mark-recapture studies (Mattioli *et al.* 2018).

Camera trap settings used or recommended for various Australian taxa (e.g. small, medium-sized and large mammals, invasive predators, reptiles) are summarised in the [Quick reference deployment guidelines](#).

Lures

Camera trap surveys often use lures to attract fauna into the detection zone of camera traps, thereby maximising the likelihood of detection. This is particularly important when targeting wide ranging species that occur at low densities and species that do not use predictable travel routes or habitats where camera traps can be deployed. Without the attractive effects of a lure, the likelihood that such species will happen to pass by the camera trap and be detected may be very low (Gillespie *et al.* 2015).

Lures can be edible (i.e. baits, which may also have an attractive scent), olfactory (i.e. scent), auditory (i.e. sound) or visual. Common lures used to attract vertebrate pest species such as foxes and feral cats include fresh and dried meat baits, auditory lures (e.g. Feline Audio Phonic, Westcare Industries, Perth, WA, Australia), and scent lures (e.g. fox urine; Catastrophic, a proprietary product developed by Outfoxed Pest Control, Melbourne, VIC, Australia) (Stokeld *et al.* 2015). Visual lures, such as flashing lights and shiny compact disks, which can be used to appeal to the hunting instincts of predators and increase visitation to bait stations, are often used in association with other types of lures (Bengsen *et al.* 2011).

When using baits, the choice of bait depends on the food preferences of the species being targeted. When targeting carnivores, meat baits have generally been used in Australia, including chunks of raw chicken, kangaroo, rabbit or fish (e.g. pilchards, tuna log, perforated tins of cat food) and fish oil. However, meat and fish can putrefy very quickly, which may in fact act as a deterrent to some species. A standard mammal trapping bait mix of peanut butter, rolled oats and honey has been successfully used in surveys targeting a wide variety of small- and medium-sized native mammals, such as quolls, bandicoots, possums and rodents (Gillespie *et al.* 2015). A number of manufactured, lethal baits are commercially available for vertebrate pest management (e.g. FOXOFF®, FOXECUTE®, DOGABAIT®, CUROSITY®, Animal Control Technologies (Australia), Somerton, VIC, Australia), and these may serve as lures for camera trap studies targeting these species.

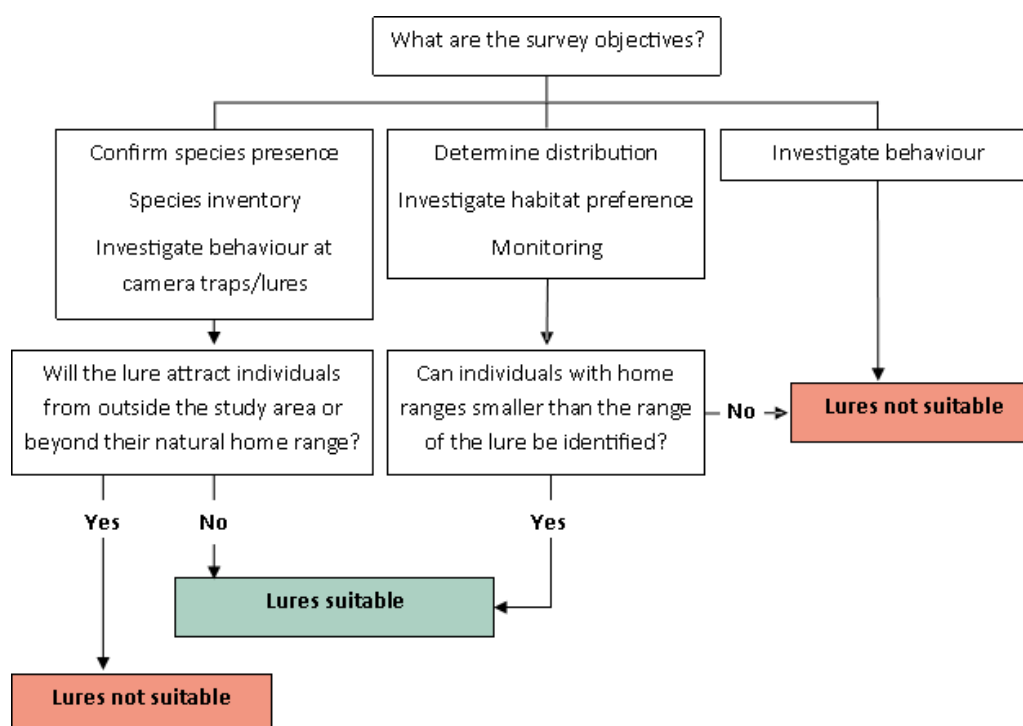
Placing baits and olfactory lures inside containers that allow airflow (e.g. small cages, tea infusers, perforated PVC pipes) suspended above the ground will protect them from removal by target and non-target species, and ensure that their attractiveness persists for as long as possible. Species including corvids, rodents, dingoes, and ants can interfere severely with baits. Attaching the bait container to a pole (e.g. star dropper, wooden stake) secures it and provides greater flexibility in positioning of the bait in relation to the camera trap. Ants can be deterred by spreading dust or granular insecticide for ants around the base of the pole (Gillespie *et al.* 2015).

The Department of Environment, Parks and Water Security (Northern Territory Government) has devised a bait container that is suitable for most baits and deployments and can be quickly constructed from readily available materials. The bait container is constructed using a short (80 mm) length of 50 mm PVC pipe with a wire-mesh ventilated end cap, an overhanging cover on the top and slit-ventilated bottom cap. The plumbing descriptions for the end caps are 'vent water/insect proof PVC 50 mm' for the top and 'vent insect proof PVC 50 mm' for the bottom (Gillespie *et al.* 2015).

The aims of your study need to be carefully considered when deciding if lures will be used to attract fauna to camera traps. Detection rates and the species detected can vary considerably between camera traps deployed with and without lures. The use of lures may cause differential behavioural responses of individuals within and between species. Some individuals or species may become 'trap happy', while others may avoid the camera traps. This can be problematic if accurate or representative population demographic (assumes equal detectability) or spatial and temporal habitat use information is required (Meek *et al.* 2014a). A decision key to help you determine whether or not lures are suitable to use for your project is provided in the figure below.

Where lures are used, sufficient detail of the type of lure (edible, olfactory, audio, visual), variety of lure, how far and at what height the lure is placed from the camera trap, if and how the lure is protected from consumption or removal by target and non-target animals, and how long the lure is deployed for must be recorded (Meek *et al.* 2014a).

Lures used or recommended for various Australian taxa (e.g. small, medium-sized and large mammals, invasive predators, reptiles) are summarised in the [Quick reference deployment guidelines](#).



Lure use decision key. Use to help determine whether or not lures are suitable for use.

Carcasses

Carrion, or decaying animal flesh, is a key component and driver of ecosystem structure and functioning that supports a range of vertebrate, invertebrate and microbial species. Considering vertebrate species, many that scavenge animal remains also function as predators. Therefore, carcasses that attract scavengers may increase the predation risk to local fauna communities in proximity to the carcasses, particularly in environments of low productivity, where human activity increases carcass provision (e.g. culling), and if the scavengers are invasive predators (Spencer *et al.* 2021).

Camera traps can be used to monitor carcasses for a number of reasons. These include determining how carcasses affect overall and predator-specific nest predation (Spencer *et al.* 2021), improving understanding of wild dog scavenging ecology (Spencer and Newsome 2021), testing the direct and indirect effects of

carcass subsidies from simulated culls (Rees *et al.* 2020), and investigating scavenger utilisation of hunter-shot deer and stranded marine fauna (Forsyth *et al.* 2014; Behrendorff *et al.* 2018).

If carcasses are required for your camera trapping study they can be sourced from management culls, hunting kills or road kills. Alternatively, a camera trap may be placed at a carcass encountered in your study area (Behrendorff *et al.* 2018). If obtaining and placing carcasses, camera trap points should be spaced at distances sufficient to minimise carcass scent traveling between points, such that scavengers would have to actively forage and seek out carcasses rather than being able to move quickly from one camera trap point to another. A minimum distance of 1 km has been used in recent studies in Australia. The carcasses, in particular smaller carcasses, should be secured to the ground so they cannot be removed out of the camera trap's field of view (Spencer *et al.* 2021). When all edible soft tissue has been removed from a carcass and it has been reduced to skeletal remains, camera traps should be removed, or the carcass replaced, as the carcass loses its attraction to scavengers (Behrendorff *et al.* 2018; Spencer and Newsome 2021). The indirect impact of carcass provision on native species must be considered before use (Spencer *et al.* 2021).

Monitoring herbivory of palatable plants

Camera traps can be focused on palatable plants to monitor browse species and their impacts, including both native fauna and introduced pests. It is important determine the most palatable plant species and the preferential foraging behaviour of target species within the study area. These two factors often align and the most palatable species is also the most noticeably browsed species or the species lacking juvenile cohorts (McDonald and Brandle 2009; Mutze *et al.* 2016b).

Selecting a palatable plant species as a feature to focus a camera trap on depends on the target browse species. For example, feral rabbits prefer palatable, short-lived species such as acacias and casuarinas as opposed to less palatable, long-lived eucalypts (Cooke and McPhee 2007), and feral deer prefer species with lower leaf-fibre content in temperate forests and species with a greater specific leaf area in grasslands (Forsyth *et al.* 2005; Lloyd *et al.* 2010). Feral goats are less selective, based on adaptations that neutralise tannins and their ability to stand on their hind legs (McDonald and Brandle 2009), and often prefer the most prevalent species in the landscape (Raufirad *et al.* 2016).

Camera traps should be positioned based on the height of the target browse species (e.g. feral rabbits browse up to approximately 40 cm), and can be arranged to maximise visual coverage of potential foraging areas (e.g. paired camera traps at each camera trap point; Reid *et al.* 2020). The level of site preparation to reduce false triggers needs to be balanced with limiting disturbance to the potential foraging area. Where long grass is present, a simple solution is to place the camera trap at least 1 m above the ground to prevent false triggers (Reid *et al.* 2020).

Number and density of camera trap points

The number of camera trap points, whether single or multiple camera traps are allocated per point, the distance between camera traps, the spatial coverage of a camera trap, and the total survey area are all important considerations for camera trapping studies. An adequate number of camera trap points is required to ensure the sampling effort can reliably detect an effect relative to the total survey area. When determining this number, the desired levels of accuracy and precision must be considered comparative to other influential factors, such as the increasing cost of deployment with each camera trap and the heterogeneity of the study area (Meek *et al.* 2014a). The table below outlines a rudimentary guide to the minimum number of camera trap points with a single camera trap for occupancy surveys based on how common or rare and detectable a species is (Gillespie *et al.* 2015).

The daily detection probability of the camera traps and the number of repeat surveys that are carried out at each camera trap point (i.e. the number of camera trap nights) should also be considered when determining the number of camera trap points. In general, surveying more camera trap points a greater number of times using the camera trap settings and deployment mode with the highest probability of

detection, will maximise the precision of the estimate of the rate of occupancy. However, there are usually conflicts and trade-offs between these three aims. For example, if limited numbers of camera traps are available for use on a particular project, then carrying out many days of survey at each camera trap point will limit the total number of points that can be surveyed over the course of a survey season. The expected precision associated with a particular sampling program can be calculated if reasonable estimates regarding the occupancy rate amongst the sampled camera trap points and probability of detection are available prior to the survey. This information may be available from a previous study of the same species, from pilot studies, or from expert opinion (Gillespie *et al.* 2015).

The distance between camera trap points, or camera trap spacing, will vary depending on the ecology of the target species and needs to be scaled accordingly to ensure independence of observations at adjacent camera trap points. The home ranges of target species should be considered and reported. More widely spaced camera traps will be appropriate for wide-ranging animals with large home ranges, while closer spacing is generally more suitable for species with smaller home ranges (Gillespie *et al.* 2015). Where camera trap points are in a regular grid or transect, distance between cameras can be recorded as a single value. However, where camera trap points are randomly or irregularly located, as in the targeted protocol, the average, minimum and maximum distance among the points along with a measure of the distribution of distances (e.g. standard deviation) should be recorded. The survey area can be defined by calculating the areas enclosed by either the concave or convex perimeter of camera trap points (Meek *et al.* 2014a).

Where multiple species are being surveyed, detection bias needs to be considered as it is difficult to achieve an optimal camera trap spacing for a suite of species, and you are likely to end up with increased detection probability for some species and decreased detection probability for others (Harmsen *et al.* 2010; Foster and Harmsen 2012; Mann *et al.* 2015). Studies assessing the species richness of terrestrial mammals vary considerably in camera trap spacing, including <1 km (Trolle and Kéry 2005; Di Bitetti *et al.* 2014; Colyn *et al.* 2018), 1 km (Colyn *et al.* 2018), 1.5 km (Silveira *et al.* 2003), 2 km (Tobler *et al.* 2008; Colyn *et al.* 2018) and varied spacing between 1.75 and >5 km within the same study area (Srbek-Araujo and Chiarello 2013). Arrays of 20–30 camera traps at a density of one camera trap per 2 km² are used to monitor changes in the community of ground-dwelling, terrestrial vertebrates in tropical regions (TEAM Network 2011), whereas a robust predator monitoring program will often have at least 20–30 camera traps spaced approximately 1 km apart (Meek 2018).

Deploying more than one camera trap at each sampling location is expected to lead to an increase in the probability of detecting a species (Gillespie *et al.* 2015). Deploying multiple camera traps per point in an array may also be useful to determine occupancy, detectability and power to monitor population change of species among micro-habitats (e.g. monitoring feral cats and foxes on- and off-road; Geyle *et al.* 2020), or to assess the influence of camera trap placement relative to a grid point based on the number and type of animal signs (Colyn *et al.* 2018).

Camera trap numbers and densities used or recommended for various Australian taxa (e.g. small, medium-sized and large mammals, invasive predators, reptiles) are summarised in the [Quick reference deployment guidelines](#).

A rudimentary guide to the minimum number of camera trap points and deployment periods with a single camera trap for occupancy surveys. These values will vary depending on the ecology of the target species and habitat type (Gillespie *et al.* 2015).

Species	Minimum number of camera trap points	Minimum deployment period
Common and easy to detect	30	3 weeks
Common but hard to detect	40	7 weeks
Rare but easy to detect	150	4 weeks
Rare and hard to detect	180	7 weeks

Camera trap arrays

If you wish to undertake a general survey of the fauna across a project or study area without altering the behaviour of that fauna, deploying camera traps in a grid array is the most effective approach. Grid arrays can be used to sample a broad area simultaneously and uniformly, which provides a suitable sample size and enables an accurate indication of species abundance over the whole survey area. For this reason, an indicated absence (where a species is not detected) from a grid array sample is likely to reflect a true absence (where a species is not present). If resources are limited, establishing a transect through the most representative part of the survey area and placing camera traps at pre-determined intervals along that transect, might be the best approach. However, indicated absences obtained from transect samples cannot be reliably used as an indication of true absence. It is possible to combine grid and transect array approaches (Molloy 2018). For example, sampling transects along a network of roads and tracks across a study area.

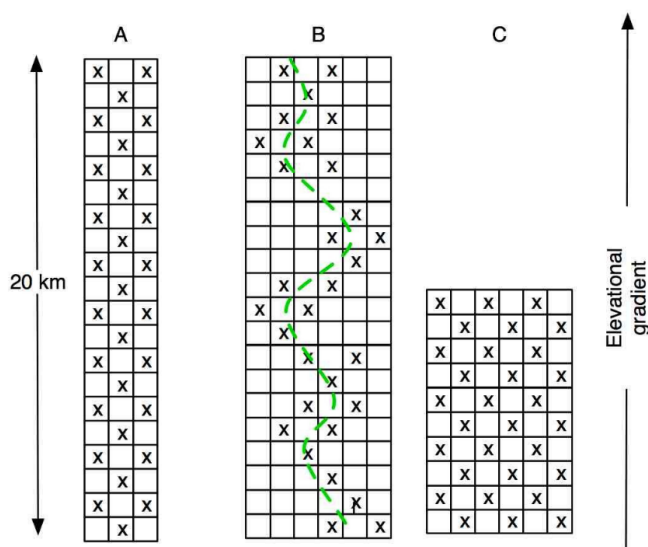
If planning to deploy camera traps in an array, it is important to review ecological information for the target species, suite of species, or community to inform the number, spacing and shape of the camera trap array (see [Number and density of cameras](#) above and the table below). Satellite imagery and GIS spatial data layers (e.g. vegetation mapping, access tracks, soil, landform, watercourses, land-use), along with any other information relevant to the project, are also critical to establish and geo-reference the array (see the figure below). Factors such as poor accessibility (e.g. few tracks, difficult terrain, dense vegetation) can limit the camera trap array design. Decisions on the camera trap array should be based on the best available biological and geographical information (see the table below). Consider the need to minimise disturbance of the project area associated with accessing each camera trap point. Identify existing tracks and trails, as well as passages that may be suitable for temporary access routes. Consider if temporary access routes are required to undertake other modules and if these can be combined with camera trap array temporary access routes. Identify areas not suitable for inclusion in the camera trap array, such as rocky outcrops (by interpreting satellite imagery), steep slopes that would prohibit traversing or sampling (using a digital elevation model), and open areas or large gaps (e.g. cleared areas; by interpreting satellite imagery).

Broad-scale locations of camera trap points (e.g. 1 km spacing) are generally established and geo-referenced through the desktop assessment process. Fine-scale camera trap locations, within close proximity (e.g. 20 m) to the broad-scale locations, are then determined in the field based on suitable camera trap placement locations to maximise detection of the target fauna. If there is a major altitudinal gradient within the project area or study area, you may consider generating multiple camera trapping grids or transects along this gradient (e.g. in three strata: low elevation, mid elevation and high elevation).

Useful GIS spatial data layers are provided in table below. The *Terrestrial Vertebrate (formerly Camera Trap) Monitoring Protocol* provides useful information to undertake camera trapping using a grid array (TEAM Network 2011). The protocol was developed from the collective experience of many field biologists with experience using camera trap arrays to estimate the abundance of a range of terrestrial mammal and bird species, with the sampling design carefully specified to maximise the probability of detecting an adequate sample species that range over large (>100 km²) and small (~1 km²) home ranges. For camera trapping using transect arrays, the *Guide for camera trapping wild dogs, foxes and feral cats* provides useful information (Meek 2018).

Camera trap array desktop assessment decision making framework.

Target fauna (species, suite of species, or community)	▪ Home range ▪ Habitat preferences ▪ Habitat use ▪ Size ▪ Speed ▪ Mode of temperature regulation ▪ Demography
GIS spatial data layers	▪ Extent of the project area ▪ Landsat image, or similar mid-level resolution satellite imagery, covering the project area ▪ Digital Elevation Model (DEM) with a spatial resolution $\leq 90\text{m}$ ▪ Administrative boundaries including property and reserve and protected area boundaries ▪ Major/minor access roads within and around the project area ▪ Existing trails system within and around the project area ▪ Major/minor rivers, creeks and drainage lines within and around the project area ▪ Existing or historical land cover and use (e.g. native vegetation, forestry, pastoralism, agriculture) ▪ Soils and/or geology ▪ Historical disturbance (e.g. land clearance, fire history) in the project area ▪ Location of any existing monitoring plots ▪ Previous survey data (e.g. flora and fauna records, vegetation/habitat mapping) ▪ Other data on hydrology, topography, landcover, etc.
Logistic Considerations	▪ Number of camera traps available ▪ Ease of access to suitable camera trap points ▪ Vehicle access ▪ Traversability ▪ Financial, resource and personnel limitations ▪ Development or intervention footprint.
Political or Legislative Considerations	▪ Animal ethics approval and reporting ▪ Scientific research permit and reporting ▪ State guidelines and constraints ▪ NRM region guidelines and constraints ▪ Ownership and tenure of the project area ▪ Protected communities and species.



Examples of potential camera trap grid arrays.

Each small square is 1 x 1 km and the 'X' represents the ideal location of a camera trap. There is one camera trap per 2 km². (A) 20 x 3 km array with camera traps placed regularly along the array. (B) Camera traps are located close to an access trail (broken green line) but placed at the predetermined density of one camera trap per 2 km². (C) 10 x 6 km array with camera traps placed regularly. Camera traps arrays are orientated along the elevational gradient (TEAM Network 2011).

Overview of potential sources for GIS spatial layers that can be utilised as part of the camera trap array generation process.

Please note that this list is not exhaustive, so it is also recommended to do a general search for any other information relevant to your project area, that is not contained below.

Name	Extent	Description	Link	Data sets
Geoscience Australia	AUS	Australian Government database for geoscience data. Includes a range of spatial and other resources.	http://www.ga.gov.au/	Hydrogeology, geophysics, surface hydrology, topography and elevation, catchments, and drainage basins.
Data.gov.au	AUS	Australian Government database including a range of spatial and other resources. Includes a range of national and state/territory specific datasets.	https://data.gov.au/	Reserves, heritage agreements, vegetation mapping, groundwater dependent ecosystems, administrative boundaries, roads and railways, topography, IBRA, threatened species and ecological communities, soils and geology.
Atlas of Living Australia	AUS	Database of species occurrence records, from multiple sources (open infrastructure).	https://www.ala.org.au/	Species occurrence records.
NVIS	AUS	Native Vegetation Information System (NVIS), Australia wide mapping from vegetation class to sub-association.	https://www.environment.gov.au/land/native-vegetation/national-vegetation-information-system/data-products	Vegetation cover shapefiles for each state and territory. Australia wide major vegetation group layer.
ARDC – Research Data Australia	AUS	Research datasets, including open access data. Mix of data types, including some spatial data.	https://researchdata.edu.au/	Some species or ecosystem specific research datasets.
CSIRO habitat condition portal	AUS	Continent-wide ecological condition data.	https://data.csiro.au/collections/collection/CICsiro:38438v2/DItrue	Habitat condition.
WA Department of Water	WA	Western Australia Department of Water and Environmental Regulation database for state wide water layers.	https://water.wa.gov.au/maps-and-data/monitoring	Groundwater, hydrogeology, catchments, dams.
Data WA	WA	Provides access to a range of WA government data. Mix of open access and restricted layers, including some datasets that require payment.	https://data.wa.gov.au/	Elevation, threatened species and habitat, offsets, native vegetation cover, threatened ecological communities, reserves, hydrology, soils.
NatureMap	WA	Biodiversity mapping portal.	https://naturemap.dbca.wa.gov.au/	Remnant vegetation, pre-European vegetation, threatened ecological communities, NRM regions, pastoral leases, climate and rainfall, infrastructure, flora and fauna records, topography.
NT Environment Data	NT	Northern Territory Government resource that provides links to web portals for a range of environmental data.	https://nt.gov.au/environment/environment-data-maps/environment-data	Provides links to native flora and fauna, vegetation, soil and water resources, weeds, geoscience data, infrastructure, administrative boundaries, cadastre, and fire.
NatureMaps	SA	South Australian Department for Environment and Water (DEW) online	https://data.environment.sa.gov.au/NatureMaps/Pages/default.aspx	Species occurrence data, vegetation cover, land use, grazing gradients, administrative

Name	Extent	Description	Link	Data sets
		mapping portal that provides access to maps and geographic information.		boundaries, cadastre, elevation, hydrology and soils, fire and heritage.
DataSA	SA	Provides access to spatial datasets for a range of South Australian Government Departments including DEW, and the Department for Infrastructure and Transport (DIT). Provides a mix of state-wide and regional datasets.	https://data.sa.gov.au/	Hydrology, aquifers, Landscapes SA boundaries, fire, reserves, land use, soils, land systems, roads and tracks, railways, built up areas, pastoral stations.
SARIG (South Australian Resources Information Gateway)	SA	Government of South Australia online mapping portal for geoscientific and geospatial data.	https://map.sarig.sa.gov.au/	Major mines and quarries, mineral projects, exploration licenses, mineral leases, property boundaries, pastoral stations, dog fence, administrative boundaries, land use zones, land management agreements, protected areas, infrastructure, soils, geology,
Data NSW	NSW	Open access NSW government data. Provides links to other departments and databases.	https://data.nsw.gov.au/	State Heritage, threatened species habitat mapping, state forest, flora reserves, <i>Phytophthora</i> , land zoning, wetlands.
SEED NSW	NSW	The Central Resource for Sharing and Enabling Environmental Data (SEED) in NSW.	https://www.seed.nsw.gov.au/	Vegetation and floristics, climate, biodiversity values, fire history and prescribed burns, soils, elevation,
NSW BioNet	NSW	Repository for biodiversity data products managed by the Department of Planning, Industry and Environment.	http://www.bionet.nsw.gov.au/	Species records, vegetation classification.
NSW Spatial Collaboration Portal	NSW	Provides a secure platform to facilitate the delivery of NSW spatial datasets. Local, state, and federal datasets.	https://portal.spatial.nsw.gov.au/portal/apps/sites/#/home/pages/nsw-data-themes	Administrative boundaries, elevation, landcover, cadastre, bushfire, transport and infrastructure, hydrology.
NSW Spatial Services	NSW	New South Wales spatial services portal that contains links to a range of state resources.	https://www.spatial.nsw.gov.au/	Links to imagery and elevation, topographic maps, and surveys (aquaculture leases, mineral leases).
eSpade	NSW	NSW soil mapping	https://www.environment.nsw.gov.au/topics/land-and-soil/information/espade	Soil landscapes, land systems, acid sulphate soils, hydrogeology and soil profiles.
ACT Open Data Portal	ACT	Geospatial Data Catalogue.	https://www.data.act.gov.au/ https://actmapi-actgov.opendata.arcgis.com/	Topography, natural resource management, heritage, land administration, hydrology, threatened fauna habitat, threatened plants, vegetation mapping, aquatic habitat, soil landscapes, wetlands.
Data Vic	VIC	Discover and access Victorian Government open data. Provides access to a range of spatial and non-spatial datasets.	https://www.data.vic.gov.au/	Fire history, planned burns, elevation, crown land, tree cover, flora and fauna records, groundwater dependent ecosystems, hydrology, vegetation cover, roads and infrastructure.

Name	Extent	Description	Link	Data sets
VicMap	VIC	Victoria's state-wide portfolio of spatial data products. Managed by the Department of Environment, Land, Water & Planning (DEWLP). Links with Data Vic.	https://www.land.vic.gov.au/maps-and-spatial/spatial-data/vicmap-catalogue	Administrative boundaries, crown land, elevation, hydrology, transport, topography, vegetation and planning.
MapShareVic	VIC	Online interactive mapping interface.	https://mapshare.vic.gov.au/mapsharevic/	Provides access to property, forest, public land, water and wetland information.
Victorian Biodiversity Atlas (VBA)	VIC	Access and upload occurrence data to the VBA. Search and map species from across the state or check for species in a specific area.	https://www.environment.vic.gov.au/biodiversity/victorian-biodiversity-atlas	Flora and fauna records.
List Data	TAS	Tasmanian Government List Data	https://www.thelist.tas.gov.au/app/content/data	Climate and environment, geology and soils, hydrology, elevation, flora and fauna, reserves, administrative boundaries, infrastructure and utilities.
Land Tasmania	TAS	Provides links to other databases that contain relevant information.	https://dpiwwe.tas.gov.au/land-tasmania/location-data-products-and-services/tasmanian-spatial-data	Links to datasets including administrative boundaries, elevation, imagery, landcover and land use, place names.
Natural Values Atlas	TAS	Tasmanian Government website that provides species occurrence data.	https://www.naturalvaluesatlas.tas.gov.au/	Flora and fauna records, conservation planning, geology, geomorphology and soils.

Deployment period

The period of time in which camera traps are deployed determines how many daily replicate samples are collected (Meek *et al.* 2014a), with datasets generally improving the longer the deployment period (Kays *et al.* 2009). This variable has been found to be a more important factor than camera trap spacing and microsite placement at grid points in providing accurate species richness estimates (Colyn *et al.* 2018). Ultimately, the optimal deployment period will depend on your target species, meaning further research should be undertaken to adequately prepare for your survey (Meek *et al.* 2012b).

A common camera trap deployment period is 2–4 weeks (Kays *et al.* 2011). However, how common or rare a species is in the landscape and the detection probability will affect decisions around the deployment period of camera traps (Gillespie *et al.* 2015). In some cases, including where the number of camera trap points sampled is more important for analysis than deployment period (Kays *et al.* 2011), or during a pilot study to confirm that traps can adequately detect certain species and allow accurate identification (Meek and Vernes 2015), camera traps may be deployed for less than 2 weeks. However, the minimum recommended deployment period of camera traps to monitor small- and medium-sized mammals in Australia is 14 nights (Paull *et al.* 2011). A deployment period of 30 nights for each of 20–30 camera traps is used to monitor changes in the community of ground-dwelling, terrestrial vertebrates in tropical regions (TEAM Network 2011). Similarly, camera traps are recommended to be deployed for a minimum period of four weeks for each of 20–30 camera traps used to monitor predators (Meek 2018).

The table in the [Number and density of camera trap points](#) section outlines a rudimentary guide to the minimum number of weeks to deploy camera traps for occupancy surveys based on how common or rare and detectable a species is (Gillespie *et al.* 2015). Whereas the table below outlines the estimated deployment periods required to achieve a detection probability >0.7 for feral cats using 2–5 camera traps placed in and around a 50 x 50 m Fauna Plot. At each plot, five camera traps were deployed in a diamond configuration, with a single camera trap in the centre and four camera traps placed 30–100 m from the centre point (Stokeld *et al.* 2015).

The maximum camera trap deployment period is also usually limited by battery life or the storage capacity of SD cards. If camera traps are not required for use at other camera trap points, then deploying camera traps for a length of time close to the expected endurance of the batteries and/or SD card storage capacity is a good strategy. This is because the cost of leaving a deployed camera trap out for a few extra days is effectively zero – no additional staff time or resources are required for a 30-day deployment for example, compared to a 10-day deployment. By maximising the length of the deployments, a greater effective number of daily replicate samples are collected at each camera trap point, and hence a longer sequence of detection and non-detection events are accumulated. Statistically, this leads to a more precise estimation of both the probability of detection and the rate of occupancy. Occupancy estimates can also be improved by increasing the number of locations surveyed (Gillespie *et al.* 2015).

Deployment periods used or recommended for various Australian taxa (e.g. small, medium-sized and large mammals, invasive predators, reptiles) are summarised in the [Quick reference deployment guidelines](#).

Deployment periods to achieve a detection probability >0.7 for feral cats using different numbers of camera traps in and around a 50 x 50 m Fauna Plot (Stokeld et al. 2015).

At each plot, five camera traps were deployed in a diamond configuration, with a single camera trap in the centre and four camera traps placed 30–100 m from the centre point.

Number of camera traps	Deployment period (weeks)	Detection probability
5	5	0.705
4	6	0.727
3	7	0.709
2	8	0.704

SD cards

A Secure Digital® (SD) card is required to store the images and videos captured by a camera trap. SD cards have various storage capacities and reading and writing speeds. Larger capacity cards can store more images and videos. Several factors will influence your required storage capacity, including deployment period, target species, site conditions, selected image quality and whether you are capturing video. Most users find that 4GB or 8GB cards are more than adequate for general use, with capacity to store between approximately 4,000 and 8,000 3.1MP images, respectively. You may want to consider a larger storage capacity if camera traps are being deployed for a long period, the risk of false triggers is high, or you are capturing video. Ensure you check the maximum capacity SD card that your camera traps will accept.

SD cards with higher speed ratings are capable of reading and writing images faster, which is particularly advantageous when capturing RapidFire image sequences. Speed Class 10 SD cards, which are capable of high reading and writing speeds with a minimum write speed of 10MB/s, are recommended. It is also recommended that you purchase two SD cards per camera trap, so they can be easily swapped when redeploying camera traps.

Batteries

Each camera trap can require up to 12 AA batteries depending on the make and model. Batteries should be selected after consulting the user manual of the camera traps you are using and consideration of your study requirements. The three most common battery types used are Nickel-Metal Hydride (NiMH), lithium and alkaline. Longer lasting batteries such as rechargeable NiMH and lithium batteries are preferred over alkaline batteries (TEAM Network 2011), which tend to discharge quicker and also suffer in extreme cold weather (Meek *et al.* 2012b).

Rechargeable and lithium batteries have similar upfront costs (excluding chargers). However, rechargeable batteries are a better long-term option and recommended for their reliability, longevity, and sustainability. In Australia, Eneloop and Eneloop Pro batteries are high quality and have been recommended by experts (Meek *et al.* 2012b). It is common practice to have two complete sets of rechargeable batteries per camera trap, which enables the seamless redeployment of camera traps within and between studies. Instructions for preparing rechargeable batteries for the field are outlined [Pre-field survey tasks](#) (TEAM Network 2011).

Storage and transport

Camera traps should be stored in a safe location and transported in sealed, padded containers to prevent accidental damage, water damage, dust damage and theft (Gillespie et al. 2015). Do not store or carry camera traps with food or any other substances that can leave an odour, as this might attract fauna to the camera trap in the field, biasing the estimates of detection probability. An open backpack frame to which the camera traps can be strapped is a practical solution to carry camera traps in the field (TEAM Network 2011).

Permits and ethics

A key feature of camera traps, in contrast to many other wildlife survey techniques, is that they are relatively non-invasive; animals don't need to be physically captured or handled as part of the survey. From an ethical and animal welfare point of view, camera traps are only minimally intrusive, with impacts on animals limited to minor disturbance caused by flashes and camera noise, and behavioural responses to baits and minor habitat disturbance. For these reasons, animal ethics approvals may still be required for implementing camera trap surveys (Gillespie *et al.* 2015).

You should contact the relevant animal ethics committee to ensure you have the required animal ethics approvals well in advance of your field survey. You will need to consider how often the animal ethics committee meets and the timeframe for approvals to be granted. It is also wise to allow time to address any queries from the committee or conditions that must be met prior to an approval being granted.

As part of its Ecological Monitoring System Australia (EMSA), the Australian Government has partnered with Australia's Terrestrial Ecosystem Research Network (TERN) in the co-design of a suite of ecological monitoring protocols and a data exchange system. The protocols build on TERN's long-established data aggregation systems and well-tested survey protocols.

The primary purpose of the standardised monitoring protocols is to support natural resource management (NRM) programs that benefit the environment, agriculture and communities, as well as making the protocols freely available for use by other environmental land managers and environmental consultants.

The Australian Government and TERN protocols ensure NRM service providers and ecologists collecting field data:

- have ready access to comprehensive instructions for each of the standardised collecting protocol modules
- are able to use mobile-based applications in the field to enter data and images
- and can easily submit and share data.

Data collected from the application of the standardised collecting protocol modules will help evaluate the current NRM program and support research on changes to Australia's ecosystems and biodiversity.

TERN acknowledges the traditional owners and their custodianship of the lands on which TERN operates. We pay our respects to their ancestors and their descendants, who continue cultural and spiritual connections to country.

