Animal pests: camera trap distance sampling for monitoring deer and goat populations

Version 1.0

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Contents

Department of Conservation
Te Papa Atawhai

Synopsis

This is a best-practice guide to follow when using motion-sensitive cameras and distance sampling methodology to measure deer and goat population size or population density (i.e. the number of animals per unit area).

Images recorded by motion-sensitive cameras deployed in deer and goat habitat can also provide evidence of invasion or eradication (using occupancy models) or relative abundance (using a camera trap catch index). In cases where presence/absence or index information is sufficient for management, the extra time and effort to implement the distance sampling methods described here are unlikely to be justified.

Assumptions

We recommend using the point transect distance sampling model of Howe et al. (2017) to estimate the densities of deer and goats at each camera location. These estimates are then extrapolated to estimate animal numbers in the survey area. The method makes the following assumptions.

- Cameras are deployed independently of animal locations.
- Images are identifiable to species.
- Deer and goats do not exhibit consistent avoidance of cameras.
- Cameras capture images for as long as an individual is present to trigger the camera.
- Cameras are deployed at an appropriate height to capture images when the distance to the animal is close to zero (i.e. so the animal cannot pass below the camera's field of view (FOV)).
- A distance class can be assigned to each animal observation (e.g. by reference to markers deployed at pre-set distances from each camera).
- Sufficient target species images can be gathered to allow a mathematical 'detection function' to be fitted to the observational data.

Advantages

- Cameras can monitor deer and goats across a wide range of habitat types, including dense-canopy forests where other count methods are ineffective.
- Distance sampling provides an estimate of animal numbers rather than an index of relative abundance.
- Cameras and distance markers can be deployed by relatively unskilled personnel.
- Cameras provide additional demographic information (i.e. age and sex ratios).

- Images are date- and time-stamped, so cameras can be left unattended for weeks or months to increase the cumulative detection rate for minimal additional survey cost.
- AI image recognition can help automate the processing of large batches of camera images.

Disadvantages

- Compared to camera trap catch indices or presence/absence methods, distance sampling requires more effort in the field (to deploy distance markers) and larger sample sizes (to achieve sufficient precision).
- Use of cameras requires pre- and post-field checks, battery-charging procedures, SD-card download procedures, and a budget for repairs and replacements.
- Cameras are vulnerable to weather damage, breakage, and theft (particularly in areas with frequent human activity).
- The requirement that camera placement be independent of animal locations and movement patterns is more stringent than for index methods.
- Detection of animals 10 m or more from the cameras is necessary, which limits the use of the method in habitats with dense understorey or steep terrain.
- Analytical methods for distance-based data are relatively complex.

Suitability for inventory

The effort and expense to implement the distance sampling methods described in this document are unlikely to be justified for inventory surveys.

Suitability for monitoring

- The effort and expense to implement distance sampling methods are unlikely to be justified for annual trend monitoring, which will usually be achieved more efficiently using relative abundance indices.
- Provided the distance sampling survey is adequately powered, the method is suitable for comparisons of ungulate abundance between different areas.
- Distance sampling is suitable for assessing animal population changes resulting from management actions, particularly in situations where a before–after control–impact (BACI) survey design is impractical. If a BACI design is feasible, using a relative density index method may be more cost-effective.

Skills

Those responsible for the survey design must:

- understand, and budget for, cameras with appropriate specifications for the planned survey
- recognise the importance of deploying cameras independently of deer and goat locations and movement patterns.

Field crews must:

- have a good knowledge of camera functions and settings, and be able to trouble-shoot minor camera faults
- consistently follow the required protocol for the location and deployment of the cameras and distance markers
- manage health and safety risks associated with the travel to and from the camera deployment sites when deploying and servicing cameras.

Those responsible for analysis must be:

- familiar with the standard procedures for image review and data storage
- able to recognise all relevant species when reviewing images
- familiar with the availability and use of AI software to assist in the processing of animal images
- able to access appropriate statistical support for the distance-based data analysis.

Resources

Distance sampling camera monitoring requires a training component to ensure field crews are competent in placing and activating cameras and distance markers, including finding and marking camera locations using GPS waypoints.

The method requires the following resources for field staff:

- an appropriate number of cameras meeting the required specifications (see 'Full details of technique and best practice' below), each with a unique camera ID (electronically entered during the camera set-up and marked on a durable, sticky label placed inside the camera)
- four 1.2 m length marker stakes per camera, each topped with reflective tape
- at least two SD cards (minimum 16 GB) per camera
- rechargeable or non-rechargeable batteries suited to the model(s) of camera and type of survey (note that some camera models will not accept all battery types, e.g. Reconyx Hyperfire 2 cameras are not rated to take alkaline batteries)
- additional sets of batteries and SD cards for swapping-in during field checks of the cameras

- the manufacturer's operating manual for the model(s) of camera to be deployed

- spare cameras as replacements for deployed cameras that develop faults

- a sturdy ball mount and/or mounting strap for each camera (mounting straps can provide a more secure attachment, provided a tree or post of suitable diameter and angle is available; some ball mounts can be moved by possums, so new models need to be assessed before deployment)

- a GPS receiver pre-programmed with coordinates for camera locations

- a paper map with camera locations as backup for the GPS

- 5 cm-square wooden stakes, or metal waratahs, for sites lacking suitable trees or posts (waratahs require pre-drilled holes for bolting on the ball mounts)

- mallets or waratah rammers for driving and removing the stakes or waratahs

- screwdrivers (hand or electric) and 50 mm square-drive wood screws ('treated pine screws') for attaching camera mounts to a tree or wooden stake (treated screws are resistant to locking over time due to hardening sap; nails or staples should not be used to mount cameras because they do not provide reliable attachment, and their removal can damage brackets and trees)

- bolts, hex nuts, and spanners for attaching ball mounts to waratahs

- barbed wire for deterring cattle interference (optional)

- lockable cables (e.g. Master Lock python cable) for cameras deployed at public sites where there is a risk of theft (optional)

- camera lockboxes to protect against kea damage and/or human interference (optional)

- plastic cable ties to prevent camera door latches being opened by possums and kea

- side-cutters for removing cable ties

- a fold-up saw, loppers or heavy-duty secateurs (and hedge shears in grassy areas) for clearing obstructing vegetation

- robust cases and padding for protected storage of cameras and mounts during transport to and from the field site

- backpacks for transporting cameras in the field

- small, clear, resealable plastic bags (62 × 75 mm, or similar) for storing and labelling cards retrieved from cameras, plus a container to transport retrieved and replacement (i.e. blank) SD cards

- small, sticky labels for inserting notes into/onto cameras

- field notebooks (preferably waterproof), pencils, and marker pens (alternatively, phones or tablets with a suitable app installed)

- a cloth, wipes, or paper towel for cleaning camera door seals

- flagging tape

- the required personal protective equipment (PPE):
  - hi-viz vest

- appropriate footwear
- emergency communication device (e.g. Garmin In-Reach)
- personal locator beacon
- waterproof parka and thermal clothing appropriate for the location and time of year
- EpiPen in summer and autumn for areas with high wasp populations
- additional PPE where appropriate:
  - personal first aid kit
  - sunhat
  - sunscreen
  - canvas chaps
  - gloves
  - additional PPE required by landowners (e.g. forest radios in some production forests).

Office staff require:

- suitable chargers, if rechargeable batteries are used, preferably with a discharge function to extend the number of times batteries can be cycled
- computers with SD card readers
- dedicated internal or external hard drives, or a budget for cloud storage
- image-viewing software, and in future AI image-classification software and a high-specification computer for image analysis, including a graphics card with a minimum of 8 GB VRAM.

Minimum attributes

DOC staff must complete a 'Standard inventory and monitoring project plan' (docCM-146272) for each study/operation.

The prescribed number of cameras in the project plan must be installed at or near the predetermined locations for the prescribed period using the standard protocol (see 'Full details of technique and best practice' below). Any deviations from the plan or protocol, and the reasons for these, must be documented.

The aim should be to establish, and retrieve, the entire pool of cameras promptly (within a few days at most). If this is not possible, then all cameras should be installed by a nominal 'start date', and all retrieved on or after a nominal 'end date'.

In the field, during installation and at each re-check of cameras, record data in a field notebook or using a suitable app. These data will then be transcribed to a field datasheet (hardcopy or

electronic) at the end of each day. The datasheet may include data from multiple days and observers.

Minimum data to record:

- survey location, block, dates of trip (record once at the top of each datasheet or spreadsheet)
- site ID and camera ID (cameras will need to be changed or replaced for various reasons, so site ID should be an independent attribute from camera ID)
- observer (field crew's names and initials)
- site name and GPS location of the camera (record the latter when first installed, and thereafter if shifted by 10 m or more)
- date camera site visited
- task: install / service / replace / remove
- camera status: working / not working
- service notes: new batteries / new SD card / realigned (i.e. angle of mount) / moved (to new line of sight) / vegetation cleared; add a note about any damage or faults observed
- assign a new camera number for replaced cameras (in app/notebook, record 'Replaced CamA with CamB' and place a label inside the new camera stating 'Replaces CamA')
- habitat variables of interest
- weather: dry or wet (note that opening cameras during wet weather can cause damage and reduce battery life – this should be avoided if possible).

Data storage

- In the field, store each retrieved SD card in a small Ziploc bag along with a waterproof label recording camera ID, the date the SD card was removed, and 'working' or 'not working' depending on the status of the camera.
- If a camera needs replacing, place a temporary sticky note 'replaces CamA' inside the replacement camera so that the sequence of cameras at that site can be tracked. Thereafter, SD card labels will record the camera's ID as 'CamA_B'.
- At the end of the day, reconcile the number of SD cards retrieved against the number of cameras on the field datasheet. If there are more SD cards than the records indicate should be present, correct the datasheet. If any SD cards are missing, record in the field notebook that these cameras need to be revisited to swap out their SD cards.
- Place reconciled SD cards in a storage box labelled 'Not downloaded'; the box itself is labelled with survey location, trip dates, and the name of the field trip leader.
- On returning from the field, each completed field datasheet should either be scanned and forwarded to the survey administrator as a pdf, or the data entered into an appropriate spreadsheet. The paper field sheet is then filed.

- Hard copies of any notes on deviations from the project plan or standard protocols are scanned and stored with the electronic field datasheets, and the hardcopies filed.

- Data in spreadsheets should be arranged as 'column variables' corresponding to each field on the datasheet (survey location, date, camera ID, task, etc.), with rows representing each occasion on which a given camera was visited.

- Soon thereafter, copy all images on the SD cards into new folders on a hard drive using the 'move' command (this clears the SD card as the images transfer and provides confirmation that all files successfully transferred to the hard drive). The SD card should then be stored in a box labelled 'Cleared cards'.

- Label the root hard drive folder (if internal drive) or the drive itself (if external drive) with survey location and dates.

- Within the root folder, create individual folders, labelled by camera ID.

- Within each camera folder, create subfolders labelled by the date plus 'working' or 'not working' for each visit to the camera site.

- A clear naming protocol for when cameras are replaced is required to prevent confusion and to keep all data from the one camera site together (e.g. 'CAM61_101' indicates the original camera #61 has been replaced by camera #101).

- Once all images have been uploaded to the drive, create a backup. Depending on organisational policies, backup data can be stored on an external hard drive, an internal hard drive on another computer, in the cloud, or on a company server.

Analysis, interpretation, and reporting

- Review the images from each camera at each camera check. For cameras recorded as 'working', record each visit by a species of interest, together with the date, time, duration, and number of visitors, in a database. See the 'Full details of technique and best practice' section for how 'working / not working' and 'visits' are defined. After the final data record, add an 'End of period' service record.

- For cameras recorded as 'not working' when checked, enter the date and time of the last recorded image, regardless of whether the image was an animal or not. (This allows for later calculation of the minimum number of days the camera was operational.) After that data record, add a 'Camera not working' service record.

- A decision to analyse data from 'not working' cameras will be made based on the length of time the camera was operating. For example, data might be excluded from analysis if the camera (and any replacement) was operational for less than an agreed-on percentage of the survey period (e.g. 80%).

- Analytical methods are described in more detail in the 'Full details of technique and best practice' section and will probably require support from a biometrician.

Full details of technique and best practice

Setting a clear objective

Clearly state the objective of the monitoring programme. Good management objectives are 'SMART' – that is, they are specific, measurable, achievable, relevant, and time-bound. It should be clear from the objective why distance sampling, rather than a density index or presence/absence method, is required.

Survey timing

- Deer and goats are less mobile during winter months, so monitoring from June to August will result in lower visitation rates than from November to March.

- The spring vegetation flush and the autumn rut are periods when animal activity levels and habitat preference can change rapidly. In comparison with index methods, distance sampling methodology will compensate to some extent for these seasonal changes.

Survey design

Study block location and size

Delineate the boundary of the study block using GIS or a mapping application. Study block location and size will depend on the objective: if a discrete management operation is to be monitored, the management unit boundary will usually define the study area. Where there is flexibility in choosing boundaries, large areas bounded by geographic features that reduce animal movement (ridges, rivers, etc.) are preferable. Densities of hunted deer populations in New Zealand forests are typically in the range of two to seven per 100 hectares, with seasonal home ranges of up to several hundred hectares (Nugent and Forsyth 2021). Consequently, monitoring more than just a few dozen individuals while minimising edge effects will require study areas of > 5,000 ha (the larger the better).

Determining camera locations

To avoid bias in the resulting population estimates, random or systematic approaches are required for camera locations. A spatially balanced sampling design such as that adopted by Ramsey et al. (2019) is recommended. Spatially balanced sampling is preferable to simple random or stratified sampling because it improves coverage of the environmental space by selecting samples that minimise spatial autocorrelation among sampled units. This improves efficiency by ensuring each sampled unit provides as much unique information about the environmental space as possible (Foster et al. 2017). Robertson et al. (2025) describe methods for assigning spatially balanced samples.

As an example, Ramsey et al. (2019) intersected a habitat suitability map for their species of interest (hog deer) with the boundaries of the breeding population. The resulting area (i.e. the

sampling frame) was divided into 2 km × 2 km cells that could be sampled. A spatially balanced random sample of 50 cells was then selected, with the probability of a cell being sampled weighted by the cell's habitat suitability value.

Generate an 'oversample', consisting of additional sites over and above the sample size required for a study. The oversample is used if a potential camera location is found to be unusable (e.g. unsafe to access or with insufficient line of sight to deploy distance markers). Unusable sites are discarded and a replacement site selected from the oversample.

Camera placement

In advance of fieldwork, record the GPS coordinates of the target location for each camera. While in the field, navigate to each camera's pre-assigned GPS point and assess its suitability based on visibility out to at least 10 m from the camera with no safety risk. If the point is unsuitable, search for a better location within 50 m of the original point. If no such point can be found, record the assigned GPS location as being 'unsuitable' and select and record an alternative GPS coordinate from the oversample list described above.

Sampling intensity

Deer and goats utilise the landscape unevenly, favouring some areas and avoiding others. Camera surveys need to deploy enough cameras for enough time to produce abundance indices with acceptable accuracy and precision. The expected abundance of the target species needs to be considered: low-density populations will require more intensive sampling to obtain useful abundance indices.

Until DOC field trials are complete it is not possible to provide specific guidance on how many cameras should be deployed and for what duration. Howe et al. (2017) provide general guidance on achieving an appropriate balance between number of locations versus increasing per-camera deployment period. Briefly, increasing the deployment period increases the number of observations, which will allow better estimation of the detection functions for each location. Cameras need to be deployed for long enough to capture a reasonable number of detections, but extended deployment periods will provide diminishing returns in terms of improving density estimate precision.

Density estimates can be strongly influenced by the variation in encounter rates between cameras. The best way to reduce this variability and improve density estimate precision is to add additional camera locations.

Camera specifications

Cameras with 'black' or 'no glo' flash (wavelength = 940 nm) are recommended, because these have a similar disturbance rate to cameras operating without a flash (Henrich et al. 2020). White flash (wavelength < 700 nm) and standard infrared (IR) flash (about 850 nm) alter the behaviour of

red deer and some other wildlife, although it is unclear whether these flashes significantly affect visitation rates.

Other recommended specifications are:

- trigger speed: < 1 s
- recovery time: < 1.5 s
- passive infrared (PIR) detector coverage: same as FOV
- detection distance: > 20 m
- image resolution: 3 megapixels (higher resolution is not necessary to identify deer/goats and will slow the camera's recovery time, as more data needs to be written to the card)
- battery life: 20,000 images or 1 year
- attachment points need to be sturdy and sufficient to resist rough handling by possums.

The camera's optical FOV and the PIR sensor FOV need to be recorded, especially if more than one camera model is being used for monitoring. If this information is not available from the manufacturer's specification sheets it can be estimated by taking photos of targets of known dimensions at known distances.

Camera settings

- Set camera ID (this must match the sticky label inside the camera) and site ID.
- Set time, date, and time format (use 24 hr).
- Set image data strip to 'On' (to record date, time, camera ID, and site ID).
- Set record mode to take still pictures (rather than video) on detection of motion.
- Set aspect ratio to 16:9 (wide).
- Set sensitivity to 'High'.
- Set image resolution to 'Medium' (3–5 megapixels).
- Set schedule to 'Day and night' (or '24 hr', depending on camera model).
- Set multi-shot to 5.
- Set picture delay to rapid fire, none, or the minimum available.
- Quiet period: set to no interval before next trigger (or else minimal interval available). One of the assumptions of the distance sampling technique is that the camera continues to fire while the animal is present.
- Set temperature to Celsius.
- Enable a lock code if available (this renders the camera useless if stolen).
- Select the correct battery type (alkaline, lithium, rechargeable).

Camera mounting and setup

- Install the camera on a waratah or suitable tree, at 1.5 m height and oriented to avoid recording the rising or setting sun.
- Avoid installing on slender trees that might sway in the wind and cause false triggers.
- Drive waratahs in firmly with a mallet or waratah rammer.
- Mount cameras using nylon straps – two straps linked end to end can be used for larger trees, with a short stick wedged horizontally behind the top of the camera to achieve a suitable downwards angle.
- Alternatively, mount using a ball-joint mounting bracket attached to a waratah with hex nuts and bolts (Fig. 1), or to a tree using two square-drive treated pine screws.
- Insert fresh/recharged batteries – be aware that some camera models have restrictions on the type of battery that can be used.
- If a 16 GB SD card (or larger) is not pre-installed, insert a blank card. Ensure the camera is turned off before inserting or removing the SD card.
- Check that the door seal is clean, dry, and fully closed.
- Use the 'Erase Data' or 'Format' function to ensure no old data remains on the card.
- Orient the camera's lens between south-east and south-west (the aim is to avoid direct sun impinging on the PIR sensor, which can cause false triggers).
- Angle the camera so that the ground 10 m from the camera is at the centre of the captured FOV (on flat ground this will be a 20° angle from horizontal). Avoid angling the camera in a way that could allow a nearby deer or goat to pass under its line of sight without triggering the camera.
- Use the 'Walk-test' to ensure the camera triggers when a large animal walks through the target zone and that the distance markers (see next section) will be recorded clearly. Walk bent-over across the line of sight out to at least 10 m, checking that the LED flashes.
- If there is a risk of interference by cattle, install a 'halo' of barbed wire around the camera to deter them.
- When ready, arm the camera, cable-tie the door latch closed if possum interference is a concern, and fit the cable lock if being used.
- Ensure the camera takes one or more images of you (to provide later confirmation that the camera is turned on and has the correct time and date settings).

Figure 1. A waratah-mounted trail camera on a spur above the bush edge, deployed at Timaru Creek Recreation Reserve, Otago. (Photo credit: Grant Morriss)

Distance marker setup

- Place distance markers at 2.5, 5, 7.5, and 10 m from each camera, clearing any vegetation as necessary.

- Each 1.2 m stake should be driven in to achieve a 0.8–1.0 m final height.

- Ensure reflective tape is attached to each marker to ensure good visibility at night (Fig. 2).

- Take a test photo to ensure that no vegetation obstructs the FOV out to the 10 m distance marker.

Figure 2. Camera trap images of plastic markers with reflective tape deployed at 2.5 m intervals from the camera. (Source: Ramsey et al. 2019)

Camera and battery care

- It is highly recommended that cameras be configured, and SD cards and batteries installed, before travelling to the field. This helps minimise the time that cameras are open in damp field conditions.

- Store and transport cameras in sturdy padded boxes that protect each camera. For example, cameras can be transported using 100 mm low-density foam sheets with custom cutouts for each camera; three layers of these sheets can be stacked in a 68 L heavy-duty fish bin.

- Whenever possible, avoid installing and servicing cameras in wet weather. In wet or humid conditions, the camera should be open as briefly as possible to minimise ingress of moisture.

- Door seals need to be checked for damage and cleaned or replaced before deployment and given a wipe with a clean cloth at each service.
- Once cameras are returned from the field, they should be opened and allowed to fully dry (for at least 24 hr) before being stored.
- Remove batteries when storing cameras for an extended period.
- Rechargeable batteries should be fully discharged prior to charging and recharged before storage. Therefore, chargers with a discharge function must be used. If batteries have been in storage for several months, an additional discharge and recharge cycle is recommended before placing them in the camera. Do not store rechargeable batteries in a discharged state.
- Chargers with a 'capacity' reader are recommended so that old batteries that no longer hold a full charge can be retired or set aside for short-duration use. Batteries with low capacity can sometimes be rejuvenated with several discharge/recharge cycles.

Data analysis

Only general guidance is provided here. A biometrician should be consulted during development of the distance monitoring project to discuss survey design, and in many cases will be needed to undertake the analyses once the camera data have been gathered.

Image analysis

- Remove 'false trigger' images (e.g. from windblown vegetation) from the data set. If high rates of false triggering are encountered, AI animal detection software can speed up this task.
- It may also be appropriate to remove daily periods of inactivity from image sets (see Howe et al. 2017 for an example).
- Classify the animal images from each camera by species, and for images of deer and goats assign sex and age class (juvenile/adult) when possible.
- For each deer or goat image, record the animal's distance class (e.g. 5.0–7.5 m) using the plastic markers as distance guides.
- The raw data for analysis consist of a record for each animal image that records the date, time, camera ID, site ID, species, sex, age class, and distance class.
- If an image contains more than one individual of the target species, a separate data record for each individual needs to be generated.

Statistical analysis

The point transect distance sampling model of Howe et al. (2017) to estimate the densities of deer at each camera location is recommended. Ramsey et al. (2019) provide a case study of the use of this analytical approach.

Briefly, this method assumes that cameras are deployed independently of animal locations at a location k for a period of time T_k, and images continue to be captured for as long as an individual animal is present to trigger the camera. Images are obtained at a predetermined set of instants, t units of time apart. Temporal effort at each camera is then calculated as T_k/t.

Howe et al. (2017) suggest that a useful range for t is 0.25 to 3 s, with values at the lower end being more suitable for fast-moving or rarer species. If the camera covers a horizontal angle of view of θ radians, then the fraction of the circle observed by the camera FOV is $\theta/2\pi$. Hence, the data consist of a series of snapshot instants taken t units of time apart, with overall sampling effort at each location k equal to $(\theta T_k)/2\pi t$ (Howe et al. 2017). An estimate of density $(\widehat{D}_k)$ is obtained using standard point transect methods (Buckland et al. 2006):

$$\widehat{D}_k = \frac{n_k}{\pi w^2 \, e_k \hat{p}_k}$$

where:

- n_k is the number of observations of deer at location k
- w is the maximum observation distance from the camera (truncation distance)
- $\hat{p}_k$ is the probability of detecting an individual that is within w distance from the camera
- e_k is the overall sampling effort $(\theta T_k)/2\pi t$.

The detection probability within the area covered by the camera $\hat{p}_k$ is estimated from the detection function (e.g. Fig. 3), which models how detection probability declines with distance from the camera using the observed distance class information recorded for each individual deer (Buckland et al. 1993). The detection function can take several forms (e.g. the half-normal and the hazard rate), and the fit of these functions can be improved using adjustment terms (Miller et al. 2019). Relative fit of alternative functions can be assessed with the Akaike information criterion (AIC) (Burnham and Anderson 1998). Once a suitable detection function is found, the function with respect to distance is integrated to give the marginal or 'average' probability of detection $\hat{p}_k$.
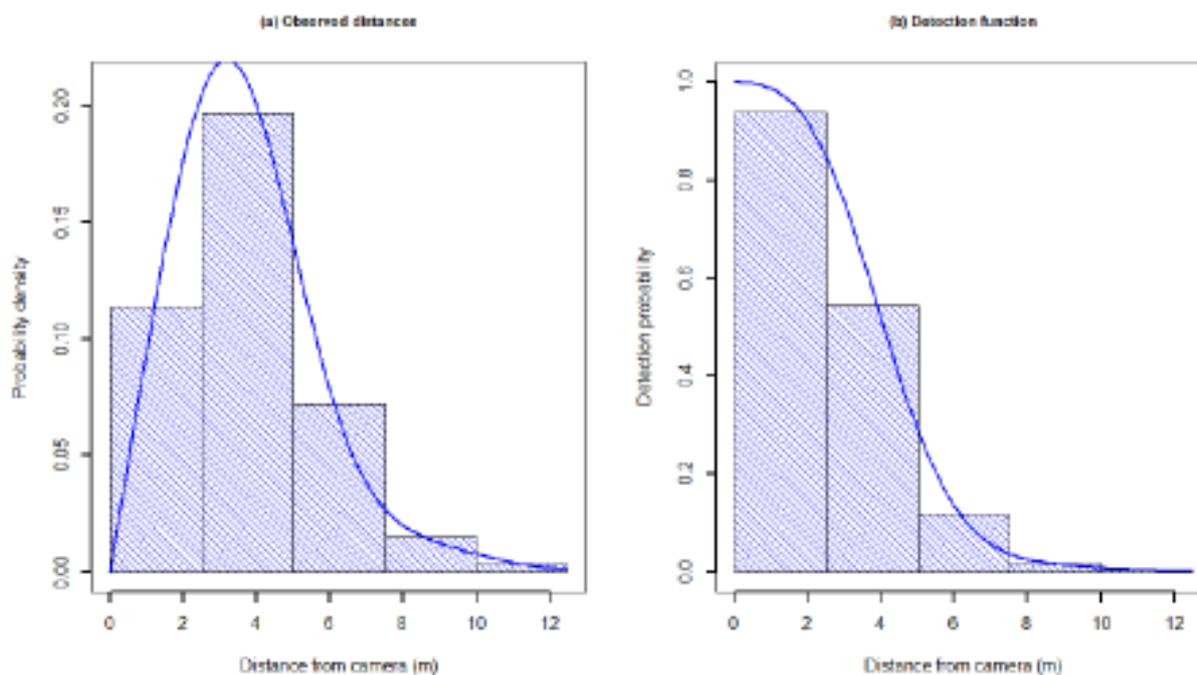
Figure 3. The distribution of observed distances of hog deer detections (left) and a fitted half-normal detection function (right) for data collected by 50 cameras deployed for a month in coastal scrubland in Victoria, Australia. (Source: Ramsey et al. 2019)

If detection probability varies across the camera's horizontal FOV, then the image set can be filtered by the angle of the animal to the camera and the camera FOV adjusted accordingly. For example, if the outer edges of the camera's FOV have low detection probability, those images can be excluded and the images for a smaller 'effective' FOV used for the analysis.

In some landscapes, strong gradients in animal abundance may be present within the study area. Since the recommended survey design consists of spatially referenced samples from camera traps, spatial variation in animal abundance can be incorporated into the analysis using methods such as density surface modelling (DSM; Miller et al. 2013). DSM is a spatial model that seeks to construct a relationship between spatially varying abundance and corresponding environmental variables, allowing for prediction of animal abundance over the entire study region rather than just the areas sampled. An example of this approach, which requires evaluation of any predictive relationships between the counts of deer and environmental variables, is provided by Ramsey et al. (2019).

References and further reading

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Appendix A

The following Department of Conservation documents are referred to in this method:

docCM-146272   Standard inventory and monitoring project plan (v1.1)

New Zealand Government