Animal pests: camera trap catch indices for deer and goats

Version 1.0

This specification was prepared by Peter Sweetapple and Graham Hickling in 2024.

Contents

Department of Conservation
Te Papa Atawhai

Synopsis

This is a best practice guide for DOC staff to follow when using motion-sensitive cameras to measure deer and goat relative abundance or presence/absence. Images recorded by motion-sensitive cameras deployed in deer and goat habitat can provide evidence of invasion or eradication (using occupancy models) or a camera trap catch index (CTCI) of the relative abundance of these two species, based on the number of images captured per unit time. In some situations, camera data can also be analysed to estimate absolute deer and goat density using camera trap distance sampling (CTDS), spatially explicit capture–recapture (SECR), random encounter modelling (REM) or random encounter and staying time (REST) modelling (references in Hickling et al. 2024). These absolute-density methods are outside of the scope of this Toolbox method.

The CTCI can be used to assess trends in deer and goat abundance over time, and for assessing the impact of management interventions. However, factors that affect deer and goat activity levels potentially confound camera-based indices, so these factors need to be controlled as much as possible through the survey design. Direct comparison of CTCIs between different management areas is not recommended because confounding factors are unlikely to be adequately controlled.

Deer and goat movement patterns vary seasonally, so camera trap surveys for trend estimation will be most reliable if annual surveys are undertaken at the same time of year. If the aim is to assess the impact of management interventions, the requirement for pre and post surveys to be done in the same season each year can be relaxed if a pre/post treatment/non-treatment design (i.e. a before–after, control–impact (BACI) design) is feasible.

It is important to recognise that a key assumption of the CTCI method—that the CTCI is linearly related to animal abundance—has not been validated under New Zealand conditions and has been problematic when tested internationally (e.g. Sollmann et al. 2013; Trolliet et al. 2014).

Assumptions

- The camera trap catch rate is positively related to deer and goat abundance.
- The animal population remains demographically closed throughout the survey period.
- The target ungulates do not exhibit any consistent avoidance of cameras.
- Ungulate photographs are identifiable to species.
- Factors affecting the probability of ungulates encountering, triggering and being identifiable on camera (= ‘detectability’) either do not vary in space and time, or vary equally on treatment and non-treatment blocks. Examples of such factors include:
  - The protocol used to select camera locations
  - Camera type and settings (e.g. the ‘sensitivity’ setting)

  - Factors that affect animal activity and visibility (e.g. weather, season, and vegetation structure)

Advantages

- Cameras can monitor deer and goats across a wide range of habitat types, including dense-canopy forests where aerial count methods are ineffective.
- Target animals do not need to be individually identifiable.
- Cameras provide species identification and additional demographic information (i.e. age and sex ratios).
- Data are gathered simultaneously for all ungulate species and other non-target species.
- Images are date and time stamped, so cameras can be left unattended for weeks or months, thereby increasing the cumulative detection rate for minimal additional survey cost (valuable in areas with low ungulate population density).
- Cameras can be deployed, and the data analysed, by relatively unskilled personnel.
- Advances in AI image recognition are beginning to automate the processing of large batches of camera images.
- The CTCI is straightforward to calculate.
- More complex analyses (e.g. abundance estimation) can be made with the same data if required.

Disadvantages

- CTCIs are unlikely to be linearly related to animal density across the entire range of deer and goat abundances that can be encountered (the linearity of the index has not been tested under New Zealand conditions).
- The CTCI is affected by animal activity levels as well as abundance. Factors that alter wild animal activity levels—such as weather, reproductive season, food supply and vegetation structure—are therefore potentially confounding when CTCIs are being compared between different areas, seasons, or years. Unexplained variance could be large unless a statistical model can be used to correct for confounding.
- Camera detection rates are limited by the field of view of the cameras and so will be lower in habitats with dense understorey.
- Short-term (i.e. within-year) assessments of management interventions require a suitable ‘non-treatment’ block nearby to enable a BACI survey design to be employed.
- Camera surveys tend to be underpowered (i.e. the number of cameras deployed may be too low to generate sufficiently precise indices).
- Sensitivity, and therefore detection rate, may vary between camera models. It is possible to account for variation in camera model sensitivity with a modelled approach, but this could be problematic in simpler analyses.

- Cameras are vulnerable to weather damage, breakage, and theft (particularly in areas with frequent human activity).
- Cameras have a finite field life, and fault rates increase as cameras age. Uneven camera age (e.g. if half the cameras are old and half are new) may result in biased indices.
- Camera surveys typically generate tens or hundreds of thousands of images, which are costly and time-consuming to process manually.
- Output data are not available until the images have been processed.
- Processing of camera images using AI technology requires further refinement to be fully fit-for-purpose.

Safety issues

There are no safety issues associated with the cameras themselves. Deployment and servicing of cameras involves exposure to the health and safety risks associated with travel to and from the camera deployment sites.

Suitability for inventory

- The high cost of cameras for an adequately powered inventory (i.e. presence/absence survey) may not be justified. In most habitats, structured or informal searches for ungulate faecal pellets, tracking, browse sign, and hair by experienced observers may be more cost-effective.
- Cameras may be suitable for ongoing surveillance of potential incursion areas, or of putative eradication areas, provided they can be left unattended (and remain functional) for many months at a time.

Suitability for monitoring

- CTCI is suitable for annual trend monitoring (provided time of year and camera locations are standardised and the cameras can be left in place for at least 2 months each year).
- Given the likelihood of confounding factors, CTCI is poorly suited for comparisons of ungulate abundance between different areas.
- CTCI is suitable for assessment of management outcomes, particularly if a BACI survey design is used if a short-term (i.e. within-year) assessment is required. Use of a BACI design relaxes the need for before and after surveys to be done at the same time of year.

Skills

Those responsible for the survey design must:

- Understand, and budget for, cameras with appropriate specifications for the planned survey
- Have a good understanding of target species' spatial and seasonal movements so that cameras can be deployed at appropriate locations to ensure an adequate encounter rate while also avoiding biasing the index by targeting specific habitat types
- Recognise the importance of mitigating confounding factors (by designing a survey protocol that standardises as many of these factors as possible)

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 location and deployment of the cameras

Those responsible for analysis must:

- Be familiar with the standard procedures for image review and data storage
- Be able to recognise all relevant species when reviewing images
- Be familiar with the availability and use of AI software to assist in processing of animal images

Resources

Surveys utilising camera traps require a training component to ensure field crews are competent in placing and activating cameras, including finding and marking camera locations using GPS waypoints.

The method requires the following resources for field staff:

- An appropriate number of cameras meeting required specifications (see 'Full details of technique and best practice') each with a unique camera IDs (electronically entered during the camera setup and marked on a durable sticky label placed inside the camera).
- 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; for example, 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 tree or wooden stakes. Treated screws are resistant to locking over time due to hardening sap. Nails or staples should not be used to mount cameras as 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.
- [Optional] 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 lock-boxes to protect against kea damage and/or human interference.
- Plastic cable ties to prevent camera door latches being opened by possums and kea.
- Side cutters for removing cable ties.
- 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 transport of cameras in the field.
- Clear, resealable small plastic bags (62 × 75 mm, or similar) for storing and labelling SD cards retrieved from cameras, plus a container to transport the bagged 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 data-recording app installed.
- Cloth/wipes/paper towel for cleaning camera door seals.
- Flagging tape.
- Minimum personal protective equipment (PPE) for operators:
  - Hi-viz vest
  - Appropriate footwear
  - Emergency communication device (e.g. Garmin In-Reach)
  - Personal locator beacon
  - Waterproof parka and thermal clothing appropriate for location and time of year

  - Epi-Pen 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:

- 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
- In the near-future, AI image-classification software running on a high-specification computer, including a graphics card with a minimum of 8 GB VRAM

Minimum attributes

DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-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'). Any deviations from the plan or protocol, and the reasons for these, must be recorded in detail.

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 retrieved on or after a nominal 'end date', with subsequent analysis limited to images recorded between these dates.

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 top of each datasheet or spreadsheet)

- Site ID and Camera ID (cameras will need to be changed or replaced for various reasons, so SiteID should be an independent attribute from CameraID)
- Observer (field crew's names and initials)
- 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)
- New camera number for replaced cameras (plus a label is placed inside the new camera stating 'Replaces CamAAA'; in app/notebook, state 'Replaced CameraXXX with CamAAA')
- Habitat variables of interest
- Weather: dry or wet (note that opening cameras during wet weather can damage cameras and/or shorten or reduce battery life, so it should be avoided if possible)

Data storage

- In the field, store each retrieved SD card in a small, sealed plastic bag along with a small waterproof (Wetnote) label recording (i) camera ID, (ii) the date the SD card was removed, and (iii) 'Working' or 'Not working' depending on the status of the camera.
- If any camera needs replacement, place a temporary sticky note labelled 'replaces CamAAA' inside the replacement camera so that the sequence of cameras at that site can be tracked. Subsequent SD labels will record the camera's ID as 'CamAAA_BBB'.
- At the end of the day, reconcile the number of SD cards retrieved against the number of cameras on the field datasheet recorded as removed or receiving new SD cards. 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 with (i) the survey location, (ii) the trip dates, (iii) the name of the field trip leader, and (iv) 'Not downloaded'.
- Upon returning from the field, either scan and forward each completed field datasheet to the survey administrator as a pdf or enter the data into an appropriate spreadsheet. Then file the paper field sheet.
- Hard copies of any notes on deviations from the project plan or standard protocols should be 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 container labelled 'Empty cards'.
- Label the root hard drive folder (if internal drives) or the drive itself (if external drives) 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 'Full details of technique and best practice' for how 'working/not working' and 'visits' are defined. After the final data record, add an 'End of period' service record.
- For cameras recorded '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 the minimum number of days the camera was operational to be calculated later.) After that data record, add a 'Camera not working' service record.
- A decision to analyse data from 'not working' cameras is made based on the length of time the camera was operating, if and when it was replaced, and the survey's objective. For inventory, all images will be analysed, but for monitoring operations the data should not be used if the camera (and any replacement) was operational for less than an agreed-on percentage of the survey period (e.g. 80%).
- If the start and end times vary widely between cameras, or years, only data collected between the nominal start and end dates outlined in the project plan are used. Note that other standards for possums and some other animals is encounters per 2,000 camera hours (Gillies 2023, unpublished report).
- The number of animal visits and the days operational are then used to calculate a CTCI for each species, defined as the number of visits per unit time (day, week or month depending on visitor rate and length of deployment) recorded by the camera.

- Depending on the length of the monitoring period and analysis requirements, CTCIs can be consolidated over multiple service intervals by calculating the mean of the interval indices, or they can be recalculated for the monitoring period as a whole.

Case study A

Case study A: Using motion-sensing cameras to monitor deer and tahr populations at Timaru Creek Recreation Reserve in Otago, New Zealand.

Synopsis

In 2018, possum control was carried out in Timaru Creek Recreation Reserve (Timaru Creek), Otago. The control area was divided into two blocks: one receiving baits coated with Epro deer repellent (EDR) and one receiving baits without deer repellent. Motion-sensing cameras were used to index the relative abundance of deer and tahr for 3 months before and after the operation in the two blocks and in an untreated block in the Dingle Burn.

Objective

- To assess the benefit of using EDR-coated cereal bait to protect deer during a possum control operation

Methods

Sampling design

A BACI study design was employed, with contiguous EDR (3,071 ha) and no-EDR (3,754 ha) blocks in Timaru Creek (Fig. 1) and a non-treatment block in the Dingle Burn, 10 km to the north. Woody vegetation in the EDR and non-treatment blocks was predominately beech forest, whereas the no-EDR block was dominated by mānuka, sweet briar and other shrubs.

Camera deployment

Three months (92 days) before the control operation, 22, 33 and 30 motion-sensing cameras were deployed in the EDR, no-EDR, and non-treatment blocks, respectively. Cameras were placed at locations easily accessible by helicopter, with no minimum distance between cameras specified. Most cameras were placed in forest/scrub clearings and along forest or scrub margins, which in the treatment areas tended to be close to the control operation boundary. Mean camera density in the treatment blocks was 1 per 124 ha, with the majority (> 80%) at higher elevations. Forested slopes in the central and lower valleys received less coverage.

The cameras (a mix of Reconyx PC900, Reconyx XR6, Bushnell Aggressor, and Bushnell Trophy cameras) were mounted 1.5 m above the ground on waratahs or tree trunks, aimed slightly downward at a generally southward bearing that protected the lens from direct sun while maintaining ≥ 10 m visibility. Locations with deer sign (such as deer trails) were favoured, while steep terrain and dense understorey were avoided. Cameras were set to high sensitivity, to take 5-image bursts at 1-second intervals when triggered, and with no delay between triggering events. The cameras, which were not serviced during the study, were retrieved 92 days after the baiting operation.

Analysis

Cameras operated for the same number of days before and after baiting, so the statistical analysis was done on simple tallies of the number of animal visits to cameras before and after baiting (rather than on a time-based CTCI, such as deer visits per camera per month).

A ‘visit’ was defined as bursts of images separated by at least 5 minutes from other images of the same species; if more than one identifiable animal was seen during a visit, the number of individuals identified was recorded. The change in the number of visitors before vs. after baiting was compared between blocks using Pearson’s chi-squared tests, or with Fisher’s exact tests for comparisons with low tallies.

‘Natural’ change in the non-treatment block was used to adjust the percentage-change in ungulate visitation rates in the treated blocks to enable estimation of change in deer activity on the treated blocks due to possum control. These adjustments were not analysed statistically.

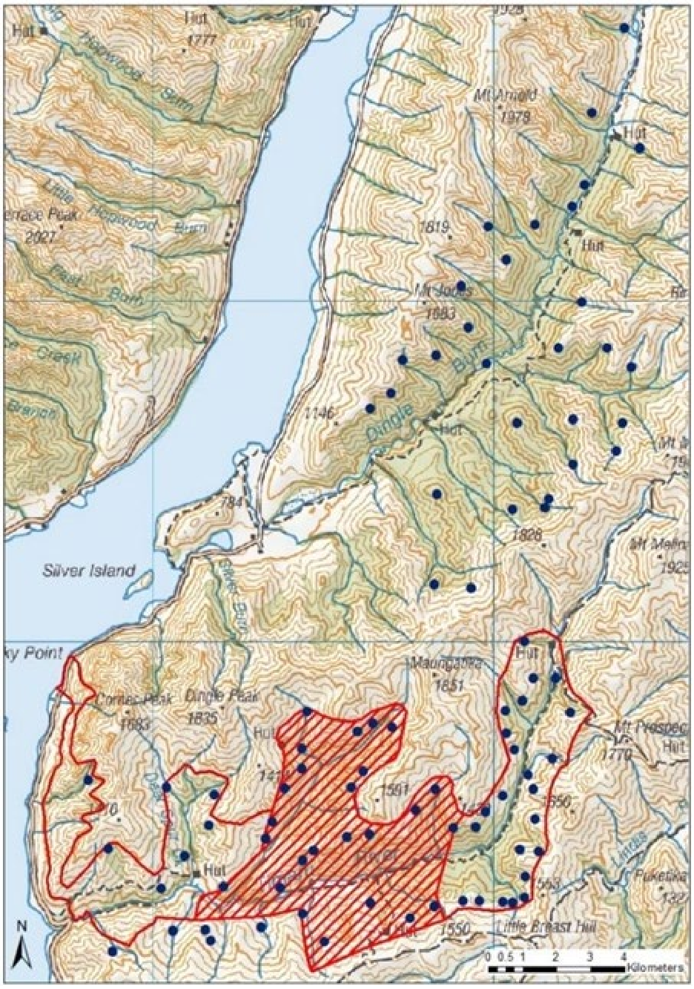

Figure 1. Locations of trail cameras (dots) deployed in Timaru Creek and the Dingle Burn, Otago, March–September 2018. The red line indicates the possum control operational boundary, with the cross-hatched central portion treated with Epro deer repellent (EDR) coated cereal bait and the surrounding areas treated with no-EDR bait. Five cameras in the southwest were outside the control area due to boundary changes in the period between camera deployment and baiting. There was no buffer between the EDR and no-EDR blocks, so animals near those boundaries potentially had access to both bait types.

Results

During the 6-month deployment, 22 of the 85 cameras failed (including one that was stolen; G. Morriss, Manaaki Whenua Landcare Research, pers. comm. 2023). Of these, 15 failed within the first 8 weeks, with possums opening five and knocking three out of alignment. Five cameras stopped recording, including three that took images continuously until their batteries failed after about 2 weeks.

Cameras that failed, or were outside the operational boundaries, or were < 1 km from the EDR/no-EDR boundaries (Fig. 1) were excluded from the analysis; c. 145,000 images from 65 cameras remained.. The majority of these images had been triggered by wind-buffeted vegetation or moving sun patches; only 20,456 (14.1%) were of deer and 2,153 (1.5%) were of tahr. When the images of animals were categorised into 'visits', the most frequent visitors were possums (2,228 visits), followed by deer (1,436) and hares (731). Only 249 tahr visits were recorded.

In the non-treatment block, the number of deer visitors recorded over 3 months was 38% lower after possum control than before. The decline in the two treatment blocks combined (93%) was significantly greater than this. Decline in the no-EDR block (96%) was significantly greater than in the EDR blocks (77%), indicating a protective effect of EDR.

After adjusting for the ‘natural’ change in activity seen on the non-treatment block, the camera data indicated a 50–62% reduction in deer activity in the EDR block (depending on whether 1, 2 or 3 months of post-control data were used) and a 90–95% reduction in the no-EDR block.

Seventeen distinctively antlered stags were seen at multiple camera sites with an average maximum distance between sightings of 3.3 km. One stag was seen on cameras 7.2 km apart over a 2.5-month period.

Limitations and implications

Sample sizes and data quality

The outcomes of this study emphasise that camera failure, theft and misplacement need to be factored in when deciding on how many cameras to deploy. For a 6-month study, around 20% data loss is a reasonable expectation. The 26% failure rate during this study could have been reduced by, for example, using plastic cable ties to secure door latches and using more robust camera mounts. Servicing the cameras midway through this study would have added to the cost but would have reduced the loss rate to 8%.

Failure rates can be substantially higher than seen here if low-end camera makes and models are used. Purchasing quality cameras (e.g. Reconyx, Bushnell) and ball mounts, having protocols to keep cameras dry and the door seals clean and in good order, and securing camera doors against possum entry will all help to maximise camera data quantity and quality.

Motion-sensing cameras can generate enormous numbers of images that require substantial resources to process (until reliable AI is available). The majority of images are typically false triggers (wind) and non-target species (especially when livestock are present). False triggers can be reduced by selecting a lower camera sensitivity setting, but at the potential loss of target species records. The optimal sensitivity setting for ungulates has not been investigated. False triggers can also be minimised by avoiding or trimming leaves and long grass along the line of sight.

Camera placement

Placement of cameras at relatively open, helicopter-accessible sites with sign of deer was judged by the authors of this study to have been a ‘successful strategy’. Many more target animal images were recorded than would have been obtained through random placement of cameras, which would have resulted in many cameras being placed on steep terrain and in thick vegetation with low visibility. The accessible-site approach rests, however, on the untested assumption that target animal response to management actions at accessible sites is representative of the population as a whole. Large, forested areas in the valley bottoms and mid-slopes—some several kilometres wide—were unmonitored in this study, adding uncertainty to the results. Greater effort should have been made to sample valley-bottom sites.

Independence of blocks

The CTCI method assumes that management blocks are demographically closed and independent, which implies adequate buffer zones between the blocks. Deer, goats and other ungulates can have large home ranges; indeed, one deer was seen to have moved at least 7.2 km in this study. None of the three blocks in this study were truly independent, so the results were probably affected by animal movements between blocks, especially between the two treatment blocks. Nor were the blocks likely to have been closed; monitoring was conducted up to the edges of the possum control area, so animals from untreated areas could have appeared in front of cameras during the 3 months of post-treatment monitoring. Such movements may not have been common at Timaru Creek, as the control boundaries mostly followed the upper limits of the woody vegetation where most deer were over-wintering. Nevertheless, the possibility of immigration subsequent to the control operation cannot be discounted.

The importance, and limitations, of a non-treatment area

This study illustrates that changes in ungulate CTCIs depend not only on management interventions but also, potentially, on changes in ungulate activity unrelated to management. If the aim is to understand the short-term impact of the management intervention, it is crucial to monitor nearby non-treatment areas as well as managed areas. (Exclusion of unmanaged areas from monitoring programmes may be warranted if long-term, multi-year monitoring can be undertaken before and after a change in management regime.)

The use of an experimental control for ungulate monitoring relies on underpinning assumptions that:

- The non-treatment block is independent of management actions in the treatment blocks
- 'Natural' (i.e. unrelated to management) temporal changes in animal activity are similar in all blocks

The Timaru Creek study potentially violated both assumptions. First, vegetation in the no-EDR block was predominantly short scrub, whereas the other two blocks were dominated by taller beech forest. This difference probably contributed to different monthly activity patterns for deer, tahr and possums between blocks before the control operation. It may have also affected the relative vulnerability of deer to the possum baits.

Second, the non-treatment block may not have been truly independent of the treatment blocks. One camera was only 2 km from the possum control boundary, and 11 (46%) were within 7 km, equivalent to the range length of at least one stag during the study.

Third, it was assumed that hunting pressure (recreational and commercial) followed similar seasonal patterns in all blocks, but this seems unlikely. The control area would have been closed to dogs for at least 6 months following baiting, so hunting pressure there probably dropped dramatically after the possum operation. This displacement of hunters from Timaru Creek probably increased hunting pressure in the Dingle Burn, which was the closest large area of forest. Given these limitations, changes in deer activity estimated by this study need to be interpreted with caution.

Sampling effort

At the start of the study, deer were present at moderate densities (2.9–7.2 visits per camera per month; G. Morriss, Manaaki Whenua Landcare Research, pers. comm. 2023) and a sufficient number of working cameras were deployed (22–33 per block) to produce statistically robust ($P < 0.01$) evidence of changes in deer visitation rates. In contrast, tahr were present at much lower densities (0.2–1.6 visits per camera per month), and the number of cameras deployed was insufficient to produce statistically significant estimates of activity change.

These findings suggest that 25 cameras per management regime, deployed for 3 months, are sufficient to detect large changes in the abundance of a moderate-density deer population but insufficient for low-density populations or for detecting small changes. See the power analysis information in 'Full details of technique and best practice' for more discussion of this topic.

Reference for case study A

Morriss. G.; Nugent, G. 2018: Impact of 1080 poisoning with and without Epro deer repellent on a red deer and tahr population in Otago. Manaaki Whenua – Landcare Research contract report LC3383 for TBfree New Zealand. 21 p. https://doi.org/10.7931/a260-eg24

Case study B

Case study B: Monitoring deer after possum control using motion-sensing cameras at Willowflat Forest Hawkes Bay, New Zealand

Synopsis

Possum control using Prodeer, a deer repellent cereal bait, was carried out over 5,395 ha at Willowflat Forest, Hawke's Bay, in October 2021. Relative deer abundance was monitored using motion-sensing cameras deployed for 4 months before, and 2 months after, the possum operation in the control area and in a nearby untreated area.

Objective

- To assess the benefit of using Prodeer deer-repellent bait to protect deer during a possum control operation

Sampling design and methods

A before-after control impact (BACI) treatment/non-treatment design was used to estimate change in deer activity resulting from the possum control operation. Deer-repellent Prodeer bait was sown over 5,395 ha of predominantly *Pinus radiata* plantation on 15 October 2021. The treatment area was largely surrounded by further pine plantations. A 2,600-ha area 1.5–6.0 km northwest of the treatment block was selected as a non-treatment area; this block comprised former pine plantation now covered in regenerating scrub and pines plus planted mānuka that was part of an ecological restoration project. The non-treatment area was surrounded by mixed *Nothofagus* forest. A total of 40 motion-sensing cameras (Bushnell Aggressor, Reconyx XR6, and one Bushnell Trophy Cam) were subjectively deployed in each block at sites with high animal use (in clearings or along roads and forest edges where game trails were obvious; Fig. 2). Cameras within blocks were spaced at least 300 m apart; 11 cameras in the non-treatment block were within 1.5–3.0 km of the possum control boundary, and 15 cameras in the southern part of the treatment block were within 1 km of the possum control boundary.

Cameras were deployed in June 2021, 4 months before the possum operation. Cameras were mounted to trees 1.5 m above the ground and aimed towards areas with at least 5 m visibility. Cameras were angled 'slightly downwards' to reduce triggering by animals at distances beyond the range of the camera's infrared (IR) illuminator. They were set to high sensitivity, 5-image bursts at 1-second intervals when triggered, and with no minimum interval before the next detection trigger. Camera doors were secured with cable ties. Cameras were serviced (SD cards and batteries replaced) once, at the time of the possum operation, and retrieved in mid-December, 2 months after the operation.

Discrete animal visits were defined as images of identifiable target species separated by at least 5 minutes from other images of the same species. Time (before vs after possum control) and site patterns in visitor rates were modelled using a Bayesian generalised mixed model of the counts of visitors per camera, with an offset term to account for the different number of camera days, different length of monitoring periods before and after the possum operation, and cameras not operating for the full duration of each period.

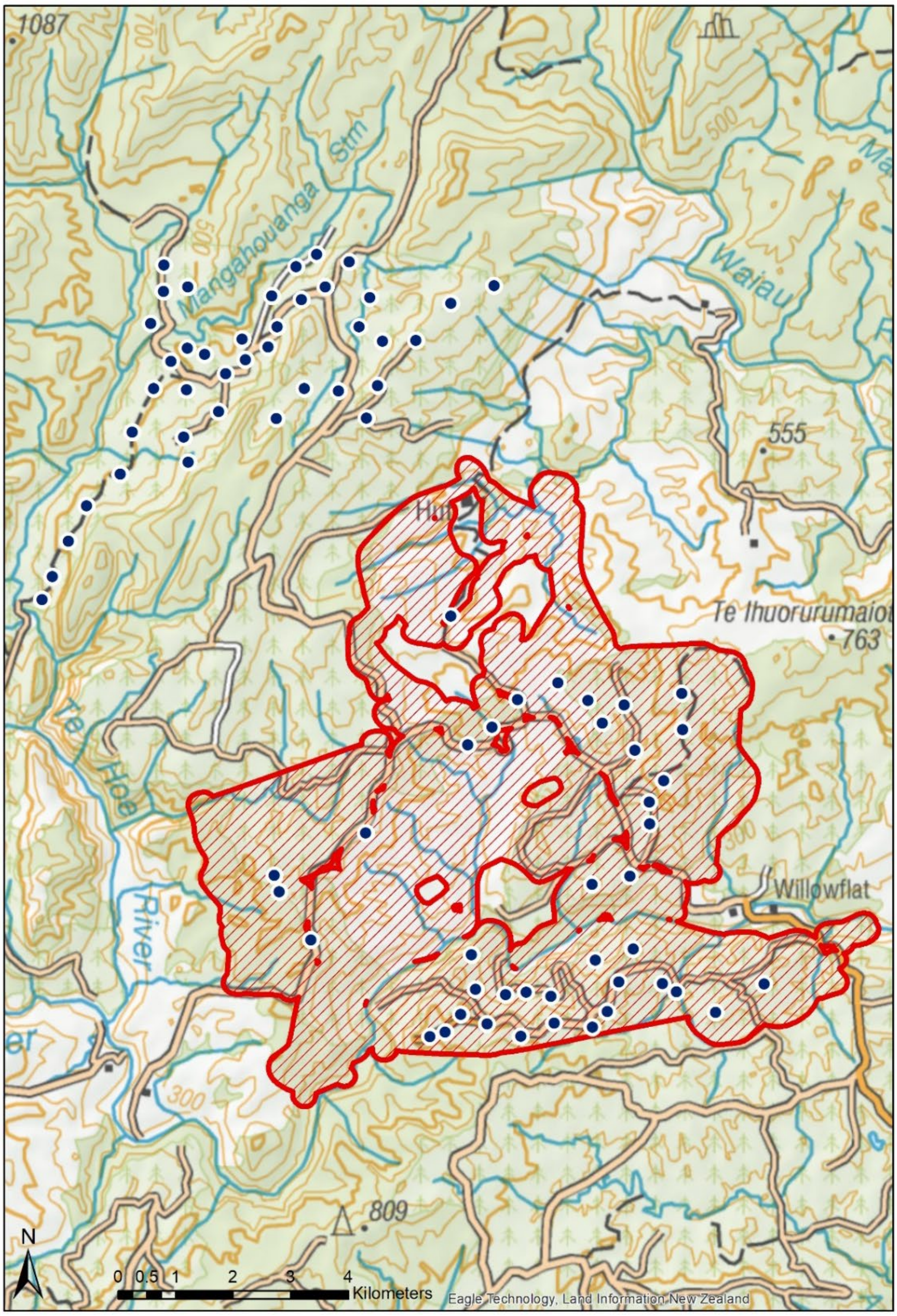

Figure 2. Locations of cameras (dots) in a possum control area at Willowflat Forest (cross-hatched) and an adjacent non-treatment area at Maungataniwha Forest (unhatched).

Results

Seven (6.3%) of the pre-operation and 12 (15.0%) of the post-operation cameras stopped working before the end of the monitored periods. Metadata indicated that 4 (5.0%) and 7 (8.8%) of pre- and post-operation cameras, respectively, failed during the first 8 weeks of each period (G. Morriss, Manaaki Whenua Landcare Research, pers. comm.2023). The reason for these failures included three windfalls, two setup errors, two instances of wind-induced false triggers draining the batteries, one case of vandalism, a camera malfunction, and a camera lost when the forest was logged during the monitoring period. No cameras were opened or bumped out of alignment by possums.

Camera failure rate increased with increasing deployment time. They failed at a rate of 0.046 per day during the first 16 weeks leading up to the camera service, and at a rate of 0.21 cameras per day during the 10 weeks following that service: a 3.7-fold increase.

Over 383,000 images were recorded during the study, including 14,683 deer visits. Before possum control, the treatment block cameras were averaging 12 deer visits per camera per month whereas the non-treatment block cameras were averaging 38 deer visits per camera per month. In both blocks, deer captures on cameras increased from the first to second week, declined over the next 2 weeks, and thereafter generally trended upwards (Fig. 3).

After accounting statistically for time x site effects, the estimated change in visitation rate in the treatment area after possum control was +2%, with a 95% credible interval of −5.5% to 10%. The researchers concluded, therefore, that there had been no detectable deer by-kill in the treatment area.

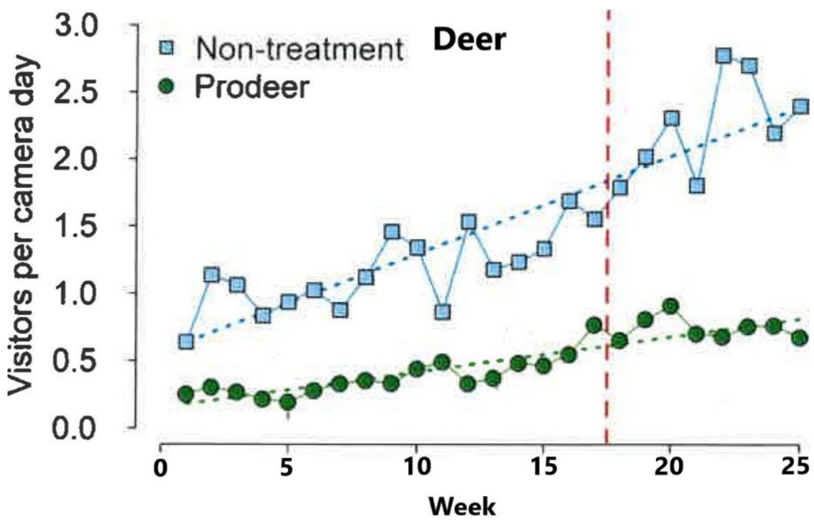

Figure 3. Weekly CTCIs for the non-treatment (blue squares) and treatment (green circles) blocks from Willowflat Forest, 2021. The vertical dashed line indicates when possum control baits were sown and cameras were serviced.

Limitations and points to consider

Camera failure rate during the first 8 weeks following deployment or servicing (5–9%) was much lower than during case study A, mainly due to the use of cable ties to secure camera doors and stable camera mounts to prevent possum interference. Stricter adherence to the setup protocols and more diligent clearing of interfering vegetation could have reduced these failures by a further 50%.

This study suggests that camera failure rates increase with longer deployments, despite servicing. This may reflect an increasing risk of water ingress with longer deployments, and perhaps a need for greater care to prevent water ingress during servicing, including cleaning door seals.

Over 350,000 images were recorded during the study, illustrating that image processing is a substantial task that needs to be adequately budgeted for. It also supports the argument that cameras should only be deployed for as long as necessary to achieve the desired levels of precision (illustrated by the power analysis in Appendix A).

Different blocks within BACI design studies are assumed to be independent and closed (i.e. not affected by deer movements in and out of the blocks during the study). Both assumptions were probably violated at Willowflat Forest, as some non-treatment cameras were within 1.5 km of the treatment block and more than a third of the treatment-block cameras were within 1 km of untreated areas. It is likely, therefore, that some deer captured on non-treatment cameras were exposed to possum baits, and some deer not exposed to possum baits were photographed by treatment-block cameras.

The vegetation composition differed between the two blocks with regenerating scrub surrounded by beech forest at the non-treatment site and pine plantation in and around the possum control block. This could well have influenced the result, particularly during the spring post-treatment period when deer become more mobile. Deer may have been attracted by spring flushing of herbaceous vegetation in areas of regenerating scrub and clearings in the non-treatment block from adjacent deep beech forest. That might account for the apparent steep post-operational increase in deer detection rates there compared with inside the treatment block, which highlights the need for careful selection of comparable areas when comparisons between areas will be made.

In this study, and at Timaru Creek Recreation Reserve in Otago (case study A), there was no evidence of avoidance of cameras by deer immediately after the cameras were established or serviced. This suggests that ‘standdown periods’ (i.e. exclusion of data that might have been affected by reactions of deer to human odour) are not necessary.

Reference for case study B

Morriss, G.; Gormley, A. 2022: Operational field testing of the efficacy of deer-repellent Prodeer 1080 possum bait in Hawke’s Bay. Manaaki Whenua – Landcare Research contract report LC4100 for OSPRI (OP-1004). 15 p.

Full details of technique and best practice

Setting a clear objective

The objective of the monitoring programme must be explicit, specifying the type of monitoring to be undertaken (i.e. presence/absence inventory, trend survey, or assessment of a management intervention) and where and when the monitoring will be done.

Survey design

Study block location and size

The boundary of each study block area must be delineated on a map, 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 study areas are preferable. Densities of hunted deer populations in New Zealand forests are typically in the range of 2–7 per 100 ha, with seasonal home ranges of up to several hundred hectares (Nugent et al. 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.

Where the study design requires a non-treatment block for comparison with a management intervention (i.e. a BACI design), great care needs to be taken when selecting blocks. Large biases can be introduced if blocks are not well-matched in physical features (e.g. vegetation type, altitude, aspect, topography, animal density, management history, ease of public access).

Blocks need to be sufficiently separated to ensure independence. All cameras in the non-treatment block should ideally be at least > 10 km apart from all cameras in the treatment block, and at an absolute minimum > 2 km apart. Avoid placing cameras within 1 km of a block boundary if that boundary coincides with a change in management regime.

As illustrated by case study A, use of a non-treatment block as part of the design to monitor the impacts of a possum control operation on deer and goats is particularly problematic because the operation will affect recreational and commercial hunting patterns. The treated area will receive little hunting effort because it will be closed to dogs for at least 6 months, and hunters will probably perceive the area as not worth hunting due to potential deer by-kill. Furthermore, the untreated area, if nearby, may receive increased hunting pressure following the operation as displaced hunters seek alternative hunting grounds.

Approaches for determining camera locations

To avoid bias in design and in any resulting population estimates, random or systematic approaches are required for camera locations. Camera locations can be chosen subjectively with the caveat that results from these cameras are not representative of the broader population. In summary, making inferences across a pre-defined population or area requires random or systematic approaches to determine camera locations. This is also reliant on having a well-defined description of the population of interest (e.g. red deer in indigenous forest in *XX* Conservation Area) and a spatial representation of this in the form of a polygon.

Camera locations can be determined subjectively if the objective is to gain information about what species and how often they are detected at specific locations. Therefore, subjective determination of camera locations is best used for the purposes of surveillance rather than for estimating a population's abundance and distribution.

The relative merits of the two approaches will vary depending on the survey objective, the study area size, and the terrain. The key point is that once a location method has been chosen, the same method needs to be used in all blocks and in all future surveys.

Random locations for cameras

There are several approaches that can be used to generate random locations for camera placement. We recommend using a family of methods that fall under the umbrella of spatially balanced sampling (Stephens & Olsen 2004). Two of the main spatially balanced sampling methods are generalised reverse tessellation stratified (GRTS) (Olsen at al. 2012) and Balanced Acceptance Sampling (BAS) (Robertson et al. 2013). Both GRTS and BAS produce an ordered list of sites that can be used to determine camera placement.

It can be useful to generate an 'oversample' consisting of additional sites over and above the sample size required for a study. Such an oversample is useful if a potential camera location is not feasible for some reason (e.g. a site is inaccessible or the habitat is unsuitable), in which case it can be discarded and a replacement site selected from the oversample. If the study site is part of a broader network of sites, there are advantages in considering if camera locations can be derived from a master sample of sites (van Dam Bates et al. 2018)

Systematic locations for cameras

When the priority is to obtain broad coverage while prioritising reduced travel time and lower cost for ground-based field crews, we recommend systematic placement of cameras. Systematic placement is particularly suitable for small study areas, where random camera placement can result in clusters of cameras in close proximity.

- Starting from a randomly located starting point, establish parallel transects at a fixed interval across the study area (spaced at least 300 m apart and preferably ≥ 1 km apart apart).
- Place cameras at fixed intervals along each transect, at least 300 m apart and preferably ≥ 500 m apart.
- Spacing between and along transects will be determined by the number of cameras to be deployed (*N*) and the size of the study area. Having closer spacing along transects than between transects reduces travel time and costs for the field crew.
- Record the GPS coordinates of each transect point as the target location for each camera.

Subjective locations for cameras

If the priority is to maximise the detection of low-density target species at the expense of even coverage of a study area, then subjective camera placement can be considered. The method is not suitable for assessing hunting impacts on a deer or goat population because hunting effort and camera placement will both be biased towards open, accessible habitats. Subjective placement means the data cannot be used for more advanced statistical analyses. It also increases the potential for observer bias, so the same field staff should place the cameras in each block being surveyed.

- Select areas likely to be preferentially used by deer and goats, including forest clearings, forest/grassland boundaries, seral forest, regenerating slip faces, and valley floor terraces and flats.
- Within those areas, select high-use sites (game trails, sites with tracking and/or scat, rut wallows, antler rub, recent browse) that have > 10 m visibility along the camera's line of sight.
- Where ease of access is important, consider placing cameras near walking and vehicle tracks, helicopter landing sites and sites accessible by boat, as these can be preferred sites for ungulate grazing. Such sites may, however, be at higher risk of camera theft and vandalism.
- Record the GPS coordinates of the target location for each camera.

Camera placement at the chosen locations

Regardless of the location method used, we recommend an 'at best sign' approach to placing the camera at the GPS coordinate. An important survey design specification is the maximum distance the camera can be placed from the GPS point. As a general guide, we recommend that this be no greater than 50 m.

- At the target location, place the camera on the nearest game trail or patch of favourable habitat that maximises the chances of the camera recording the target species.
- Avoid areas with thick undergrowth or with steep topography that result in < 10 m line of sight for the camera.
- Place cameras at least 20 m away from frequently used walking tracks to minimise human-scent avoidance.
- Avoid placing cameras where they are easily visible to the public (i.e. walking tracks, huts, camp sites and other heavily used areas) to minimise theft and vandalism.

For repeated measurements over time, use the same mounting point and camera orientation each time. Using the same field crew to place cameras in all survey blocks, and for repeat surveys (if feasible), is desirable, as this will help minimise biases in camera site selection and setup.

Survey timing

- To minimise seasonal changes in activity and habitat, avoid April/May and September/October for camera monitoring of New Zealand ungulates.
- Deer are less active during winter than at other times of the year, so monitoring from June to August will result in lower visitation rates than from November to March.
- If the timing of monitoring is constrained by the timing of a management operation, it may not be possible to avoid the above exclusion periods. For example, monitoring a winter management operation might require installing cameras in mid-May. In this situation, efforts minimising confounding factors between treatment and non-treatment blocks will be particularly important.
- Presence/absence monitoring can involve extended deployment of cameras for many months or years, with the timing primarily dependent on funding and staffing considerations rather than ungulate biology.

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.

A power analysis of data from the two case studies in this Toolbox method (Appendix A) demonstrates that, for a specified level of precision, the number of cameras required rises as deer abundance declines. Our guidance on number of cameras and their deployment period, based on this power analysis, is as follows:

- The recommended sampling intensity for monitoring purposes is 30 cameras per treatment block. (That number, run for 3 months, should provide images from at least 25 functional cameras.)
- If the survey specifies a BACI design that requires a non-treatment block, 60 cameras should be deployed. Similarly, if a study includes multiple treatments, or replicate blocks, each additional block requires a further 30 cameras.
- If it is important to be able to detect trends in abundance within a low to very-low population, the number of cameras per block should be doubled. If the objective is simply to confirm that abundance remains 'low', then 30 cameras remains appropriate.
- In areas where deer or goat density is high, the number of cameras per block can be reduced to 20.
- Cameras should be deployed for a minimum of 8 weeks, increasing to 10 weeks if ungulate abundance is low. For BACI designs, this implies a survey duration of at least 16 weeks: 8 weeks before and 8 weeks after the management intervention. Longer deployments do not increase precision appreciably and run the risk of greater camera failure rate and theft.

For detecting incursions or confirming eradications, the number of cameras will depend on the size of the area to be monitored, as the aim is to place a camera in the home range of all potential immigrants. At very low population densities, ungulates typically have very large home ranges (from hundreds to thousands of hectares), with isolated individuals likely to roam widely. Our recommendation in such situations is to place cameras at a density of no less than 1 per 100 ha (i.e. spaced at 1-km intervals) throughout the survey area.

Minimum camera specifications

- White flash (wavelength < 700 nm) and standard IR flash (about 850 nm) alter the behaviour of red deer and some other wildlife, although it is unclear whether these flashes significantly affect ungulate visitation rates. Consequently, we recommend the use of cameras with ‘black’ or ‘no glo’ flash (wavelength = 940 nm, which has a similar disturbance rate to cameras operating without a flash; Henrich et al. 2020).
- Trigger speed: < 1 sec.
- Recovery time: < 1.5 sec.
- Passive infrared (PIR) detector coverage: same as field of view.
- 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 need to be written to the card.)
- Battery life: 20,000 images or 1 year.
- Ball-joint brackets need to be sturdy and pre-tested against possums.

Camera settings

- Set the camera ID (this must match the sticky label inside the camera) and siteID.
- Set time, date and time format (use 24 hr).
- Set image data strip to ‘On’ (to record date, time, camera ID and siteID).
- 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.
- For surveillance/incursion detection, set picture delay to rapid fire, none, or the minimum available. For monitoring, a delay may be appropriate, depending on the objectives of the specific survey.
- Set ‘Quiet period’ to no interval before next trigger (or minimum interval available).
- Set temperature to Celsius.
- Enable code lock if available (this renders the camera useless if stolen).
- Select the correct battery type (alkaline, lithium, rechargeable).

Camera mounting and setup

- Attach each camera to a suitable (10–70 cm diameter) tree trunk, if available. Alternatively, use a 50 mm square wooden stake or steel waratah, driven in firmly with a mallet or waratah rammer, respectively.
- Mount the camera 100 cm above ground level using either camera straps (on a tree) or a ball-joint mounting bracket (on a tree, stake or waratah; e.g. Fig. 4).
- 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.
- Attach mounting brackets to trees and stakes using two square-drive treated pine screws.
- Attach mounting brackets to pre-drilled waratahs using suitable hex nuts and bolts.
- 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 preinstalled, insert a blank card. **Ensure the camera is turned off before inserting or removing the SD card.**
- Use '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, to avoid direct sun impinging on the PIR sensor, which can cause false triggers.
- Angle the camera so that the centre of the captured field of view is of the ground 10 m from the camera (on flat ground this will be a 20° angle from horizontal).
- Use the 'Walk-test' or 'Test' function to ensure the camera triggers when a large animal walks through the target zone. (Walk bent over across the line of sight at various distances, out to at least 10 m, checking that the LED flashes.)
- Check that the door seal is clean, dry, and fully closed.
- 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.
- Before leaving, ensure the camera takes one or more images of you. This will later provide confirmation that the camera is turned on and has the correct time and date setting.

Figure 4. A waratah-mounted trail camera aimed at a game trail along a spur above the bush edge, deployed at Timaru Creek Recreation Reserve, Otago, March–September 2018.

Camera servicing

- Service cameras at least once every 3 months, even if battery and SD card capacity will far exceed this, to correct any unexpected issues that arise.
- At each service check, determine if the camera is still operational by walking in front of the camera and watching for the flashing IR LED (for some camera models, this may require the camera to be switched to 'Walk-test' mode). Ensure that images of the operator are recorded, as during later image processing this will provide additional confirmation of whether the camera was still operating before being serviced.
- Remove the cable lock, cut the cable tie, and open the camera.
- **Ensure the camera is turned off before inserting or removing the SD card or batteries.**
- Replace batteries as needed. Place removed batteries in a container labelled 'Not charged'.
- Swap out camera SD cards at each check. Place SD card in a sealed plastic bag labelled with camera ID, date, operator, and 'Working' or 'Not working' as appropriate.
- Insert a new SD card and use the 'Erase data' function to erase any old data.
- Turn the camera back on. If it is still not working, replace it with a spare camera. Place a 'Replaces Cam AAA' note inside the replacement camera.
- Clearly label the non-working camera as 'Not working'.
- Check the date and time are correct at each service (this is particularly important if batteries were flat).
- Check camera alignment (conduct a 'Walk test' if in doubt).
- Check the door seal is clean and dry and that insects have not obstructed the lens.
- Ensure the camera is turned back on and armed.
- Close the camera door and secure it with a cable tie.
- Reattach the cable lock if one is being used.

- Record the camera ID, date, operator, and any service notes (new batteries, SD card, camera realigned, working/not working) in a field notebook or app.

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, cameras should be open as briefly as possible to minimise ingress of moisture into the camera.
- 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 for 24 hours) before being stored.
- Remove batteries when storing cameras for an extended period.
- **Rechargeable batteries should be fully charged before being stored**. Battery chargers with a discharge function are recommended—if these are available, fully discharge the batteries before recharging them.
- 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.
- Do not store rechargeable batteries in a discharged state. If batteries have been in storage for many months then an additional discharge and recharge cycle is recommended before placing them in the camera.

Data analysis

Data analysis will depend on the site-specific objectives and survey design, so only general guidance is provided here. A biometrician should be consulted before any survey to discuss design and analysis, and in many cases will be needed to undertake the analyses.

Image and statistical analysis

- Review images to identify ‘visits’ by each species of interest (*X*).
- The raw data for analysis consist of a record for each visit that records:
  - Date, time and location (i.e. camera ID and site ID)
  - Species present (there can be more than one)
  - Number of visitors of each species during that visit (there can be more than one)

- Each visit is defined as an image (or series of images) of species *X* that is preceded and followed by 5 minutes without additional images of the same species.
- If field notes or the SD card label indicate a camera was not working when checked, record the date stamp of the last image on the card as an estimate of when the camera stopped functioning and thus the minimum number of days the camera was operational.
- Depending on the survey objective, data from cameras operating for < 80% of the monitoring period may need to be excluded from analysis.
- When cameras are first established, deer avoidance of human scent needs to be considered. Check for unusually low visitation rates during the first 3 weeks after camera deployment; if avoidance seems likely, discard data from the first week or two of monitoring. In a BACI-design survey, however, early weeks' data can be retained provided the cameras were established in all blocks at the same time by the same mix of observers.

Camera trap catch index (CTCI) for monitoring abundance trends

- Raw CTCIs measure the total number of visitors of each species to a camera over a specified time period (e.g. weekly)

  $CTCI_{xij}$ = total number of visitors of species *x* during week *i* at camera site *j*

- CTCIs include multiple visits by the same individual, so they are really a measure of local animal activity that, when averaged over space and time, is assumed to correlate with overall population abundance.
- For visual presentation of results, calculate and plot the mean CTCI and its 95% confidence interval (CI) for each survey block, for each time period of interest:
  - The standard error (SE) of the mean is:

    $$SE = \sqrt{\frac{var}{n}}$$

    where *var* = variance of the mean, and *n* = the number of cameras in the block.
  - The 95% CI around the mean is:

    $$95\%\ CI = \pm t \times SE$$

    where *t* is Student's *t* distribution, which at the 95% confidence level is approximately 2 (2.08–1.96) for sample sizes over 20.
- As illustrated by case study A, if pre- and post-management camera monitoring have the same number of camera nights, then BACI-design surveys can be analysed using simple 2 × 2 contingency tables of the raw counts of species' visits to the treatment vs. non-treatment blocks.
- If the number of camera nights varies between surveys or treatments, more advanced methods—such as the Bayesian generalised linear mixed model used in case study B—should be used to analyse variation in CTCIs over space and time. For example, in a BACI

survey, management effects can be investigated by assessing the significance of the block x time interaction term in a suitable statistical model. Such models may also allow confounding variables to be accounted for.

- For monitoring surveys, changes in mean CTCIs over multiple surveys can be tested using repeated measures analysis of variance (ANOVA).

Presence/absence surveys

- One or more detections of the target species will confirm that the target species is present in the survey area, with no further data analysis required.
- Zero detections of the species across all cameras throughout a survey period is more challenging to interpret. While there is the possibility that the species is indeed absent from the area, the likelihood of that absence will need to be modelled (Ramsey et al. 2023). This requires:
  i. An estimate of the sensitivity of the cameras, usually expressed as ‘the one-day probability of detecting an individual of the target species if the camera is placed at the centre of the individual’s home range’ (termed g0)
  ii. A measure of the rate of decline in capture probability at increasing distance from the home range centre (termed sigma σ). Estimating g0 requires camera-trapping-marked individuals whose home range is known, although estimates of g0 from another area with a similar habitat and target species density can be used.

References and further reading

Gillies, C. 2023: Interim DOC trail camera guide v1.1.1: Using camera traps to monitor feral cats, mustelids and rats. Unpublished report, DOC Biodiversity Group, Hamilton. 8 p.

Henrich, M.; Niederlechner, S; Kroschel, M.; Thoma, S.; Dormann, C.F.; Hartig, F.; Heurich, M. 2020: The influence of camera trap flash type on the behavioural reactions and trapping rates of red deer and roe deer. *Remote Sensing in Ecology and Conservation 6*: 399–410.

Hickling, G.J.; Warburton, B.; Sweetapple, P. 2024: Wild animal monitoring methods for the Department of Conservation’s Inventory and Monitoring Toolbox. Manaaki Whenua – Landcare Research contract report LC4465 for Department of Conservation. 42 p.

Morriss, G.; Gormley, A. 2022: Operational field testing of the efficacy of deer-repellent Prodeer 1080 possum bait in Hawke’s Bay. Manaaki Whenua – Landcare Research contract report LC4100 for OSPRI (OP-1004). 15 p.

Morriss, G.; Nugent, G. 2018: Impact of 1080 poisoning with and without Epro deer repellent on a red deer and tahr population in Otago. Manaaki Whenua – Landcare Research contract report LC3383 to TBfree New Zealand. 21 p. https://doi.org/10.7931/a260-eg24

Nugent, G.; Forsyth, D.M.; Latham, A.D.M.; Speedy, C.; Asher, G.W.; Tustin, K.G. 2021: Family Cervidae. Pp. 447–527 in King, M.K.; Forsyth, D.M. (Eds): The handbook of New Zealand Mammals. Dunedin, Otago University Press. 538 pp.

Olsen, A.R.; Kincaid; T.M.; Payton; Q. 2012: Spatially balanced survey designs for natural resources. Pp. 126–150 in Gitzen, R.A.; Millspaugh, J.J; Cooper, A.B.; Licht, D.S. (Eds): Design and analysis of long-term ecological monitoring studies. Cambridge University Press, Cambridge, UK.

Ramsey, D.S.L.; Anderson, D.P.; Gormley, A.M. 2023: Invasive species eradication: How do we declare success? *Cambridge Prisms: Extinction 1*(e4): 1–8. https://doi.org/10.1017/ext.2023.1

Robertson, B.L.; Brown, J.A.; McDonald, T.; Jaksons, P. 2013: BAS: Balanced acceptance sampling of natural resources. *Biometrics 69*(3): 776–784, https://doi.org/10.1111/biom.12059

Sollmann, R.; Mohamed, A.; Samejima, H.; Wilting, A. 2013: Risky business or simple solution – Relative abundance indices from camera trapping. *Biological Conservation 159*: 405–412.

Stevens, D.L.; Olsen, A.R. 2004: Spatially balanced sampling of natural resources. *Journal of the American Statistical Association 99*(465): 262–278. https://doi.org/10.1198/016214504000000250

Trolliet, F.; Huynen, M.; Vermeulen, C.; Hambuckers, A. 2014: Use of camera traps for wildlife studies. A review. *Biotechnolgie, Agronomie, Société et Environment 18*: 446–454.

van Dam Bates, P.; Gansell. O.; Robertson, B. 2018. Using balanced acceptance sampling as a master sample for environmental surveys. *Methods in Ecology and Evolution 9*(7): 1718–1726.

Appendix A

Power analysis

A power analysis of raw data from the two case studies in this Toolbox method (G. Morriss, Manaaki Whenua Landcare Research, pers. comm. 2023) was undertaken to provide guidance on the number of cameras and deployment periods. These studies provided five blocks and seven CTCIs (including pre- and post-treatment indices in two blocks) across a range of low to high deer abundances:

- Willowflat Forest non-treatment block was considered 'high abundance' (46 deer visits/camera/month).
- Willowflat Forest treatment block, Dingleburn, and the pre-treatment data from two Timaru Creek Recreation Reserve blocks were considered 'moderate abundance' (4–11 visits per camera per month).
- Two post-treatment blocks in Timaru Creek were considered 'low abundance' (< 1 visit per camera per month).

Coefficients of variation (CVs = standard deviation/mean) were calculated from the first 2, 4, 6 weeks etc. until the end of the study for each block using data pooled from all cameras that operated for the whole study period within each block. CVs were then plotted against number of weeks deployed (Fig. A1), which revealed that deployment beyond 8 weeks did not improve precision (i.e. no further reduction in CV values) on the moderate- and high-abundance deer blocks. For the two blocks with low deer abundance, precision continued to improve until 10 weeks of deployment, with no further improvement after 12 weeks.

Next, least significant differences (LSDs) were calculated for data from 8 weeks (moderate and high abundance blocks) or 10 weeks (low abundance block) of camera deployment. Two means are considered statistically different (95% level) if their difference is larger than the LSD. LSDs were calculated for each abundance class across a range of camera numbers from 5 to 100. These are presented in Fig. A2, which demonstrates that the camera numbers required to achieve a target level of precision rises sharply with decreasing deer abundance.

Fig. A2 can be used to predict the level of precision that can be expected from a particular sampling intensity. For example, 20 cameras will allow for detection of a 40% change in CTCI between surveys of abundant populations, whereas 70 and > 100 cameras are required to attain this level of precision for moderate and low abundance populations, respectively. These data suggest that 30 cameras can detect a 35%, 60% or 100% change in CTCI for high, moderate and low abundance populations, respectively. This seems a reasonable compromise between precision and sampling effort.

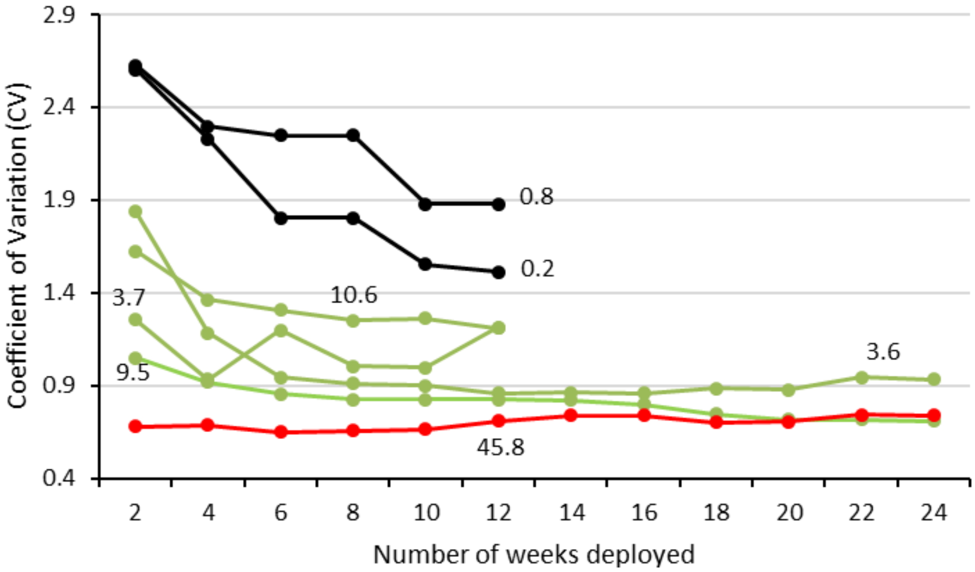

Figure A1. Increasing the number of weeks cameras are deployed reduces the coefficient of variation (CV) of camera trap catch indices (CTCIs) for two blocks with low deer abundance (black lines), four blocks with moderate deer abundance (green lines), and one block with high deer abundance (red line). The number beside each trend line is the mean CTCI (number of deer visits per month) for that block.

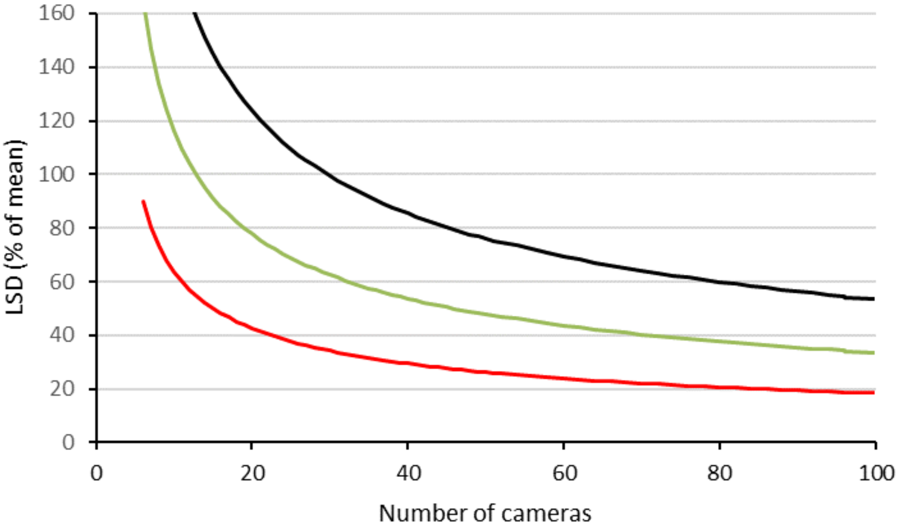

Figure A2. Increasing the number of cameras deployed increases the precision of camera trap catch indices (CTCIs) of deer abundance for low abundance (black), moderate abundance (green), and high abundance (red) deer populations. Cameras were deployed for either 8 weeks (moderate and high abundance blocks) or 10 weeks (low abundance block). Precision is presented as the least significant difference (LSD) at the 95% level, expressed as a percentage of the mean CTCI.

Appendix B

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

doccm-146272	Standard inventory and monitoring project plan