**Remote Camera Survey Guidelines**

Guidelines for Western Canada

2024

Version 2.0

Prepared by

Cassondra Stevenson and Anne Hubbs

on behalf of the

Alberta Remote Camera Steering Committee (RCSC) and Wildlife Cameras for Adaptive Management (WildCAM)

Remote Camera Survey Guidelines: Guidelines for Western Canada

Published by the Alberta Remote Camera Steering Committee (RCSC) and Wildlife Cameras for Adaptive Management (WildCAM)

Prepared by Cassondra Stevenson and Anne Hubbs on behalf of the RCSC and WildCAM

***Citation for this document:***

Alberta Remote Camera Steering Committee (RCSC), Stevenson, C., Hubbs, A., & Wildlife Cameras for Adaptive Management (WildCAM), (2024). Remote Camera Survey Guidelines: Guidelines for Western Canada. Edmonton, Alberta.

© Alberta Remote Camera Steering Committee

For more information about these guidelines or regarding the Alberta Remote Camera Steering Committee, please email [Anne.Hubbs@gov.ab.ca](mailto:Anne.Hubbs@gov.ab.ca).

To learn more about Wildlife Cameras for Adaptive Management (WildCAM), please visit the [WildCAM website](https://wildcams.ca/) (https://www.wildcams.ca).

For further information about The Fisheries and Wildlife Management Information System (FWMIS), please visit the [FWMIS website](https://www.alberta.ca/fisheries-and-wildlife-management-information-system-overview.aspx) (https://www.alberta.ca/fisheries-and-wildlife-management-information-system-overview.aspx).

For further information about WildTrax, please visit the [WildTrax website](http://www.wildtrax.ca/) (<http://www.wildtrax.ca/>).

# Acknowledgments

We would like to honour and acknowledge that work contributed by the RCSC took place on the traditional and ancestral land of the nêhiyaw (nay-hee-yow)/Cree, Denesuline (dene-su-lee-neh)/Dene (deh-neyh), Niitsitapi (nit-si-tahp-ee)/Blackfoot, Anishinaabe (ah-nish-in-ah-bay)/Saulteaux (so-toe), Nakota Sioux (na-koh-tah sue), and Métis’ (may-tee) Peoples since time immemorial, and we recognize this history. We would also like to honour and acknowledge that work contributed by the WildCAM Advisory Committee took place on the traditional, ancestral, and unceded territories of the Coast Salish Peoples – the Sḵwx̱wú7mesh (Squamish; squa-mish), Stó:lō and Səl̓ílwətaʔ/Selilwitulh (Tsleil-Waututh; slay-wa-tuth) and xʷməθkʷəy̓əm (Musqueam; mus-kwee-um) Nations – the sngaytskstx (Sinixt; sin-eyekst) and lək̓ʷəŋən (le-kwung-en) Peoples, and the Songhees (song-geez), Esquimalt (es-kwai-malt), and WSÁNEĆ (wh-say-nuch) Peoples whose historical relationships with the land continue to this day. We thank the diverse Indigenous Peoples whose ancestors’ footsteps have marked these territories for centuries. We also acknowledge that this document presents a western science perspective of remote camera science; we hope to incorporate Traditional Knowledge in the future, where respectful and supported by Indigenous Knowledge holders.

We would like to thank the many contributing agencies and individuals who prepared this document with guidance from the Alberta Remote Camera Steering Committee (RCSC) and the WildCAM Advisory Committee. These include the Alberta Biodiversity Monitoring Institute (ABMI; Marcus Becker, Greg Brooke, Corrina Copp and Monica Kohler), Alberta Environment and Protected Areas (Anne Hubbs), the Alberta Remote Camera/Steering Committee Coordinator (Cassie Stevenson), and Wildlife Cameras for Adaptive Management (WildCAM; Jamie Clarke, Alexia Constantinou, Alys Granados, Kate McKeown, Laura Stewart).

We would also like to thank our funders – The Office of the Chief Scientist (Alberta Environment and Protected Areas) and the Alberta Conservation Association.

This document was greatly improved by reviewers from across Alberta and British Columbia. A special thanks to Jason Airst, Rodrigo Ayala, Tyne Baker, Joanna Burgar, Andrew Braid, Lisa Bridges, Kristie Derkson, Philip DeWitt, Alannah Gallo, Saul Greenberg, Dave Evans, Annie Loosen, Christa MacNevin, Sejer Meyhoff, Anna Moeller, Gary Ordog, and Lucas Pittman.

# Table of Contents

[Acknowledgments iii](#_Toc162347819)

[Table of Contents iv](#_Toc162347820)

[List of Tables vi](#_Toc162347821)

[List of Figures vii](#_Toc162347822)

[1.0 Background 2](#_Toc162347823)

[2.0 Intended Audience and How to use this document 3](#_Toc162347824)

[2.1 Supporting documents 4](#_Toc162347825)

[3.0 Design hierarchy 4](#_Toc162347826)

[4.0 Objectives 6](#_Toc162347827)

[5.0 Detection probability 6](#_Toc162347828)

[6.0 Study design 9](#_Toc162347829)

[6.1 Study area 10](#_Toc162347830)

[6.2 Site selection and camera arrangement 10](#_Toc162347831)

[6.2.1 Random (or “simple random”) design 11](#_Toc162347832)

[6.2.2 Systematic design 12](#_Toc162347833)

[6.2.3 Stratified design 12](#_Toc162347834)

[6.2.4 Clustered / Paired designs 13](#_Toc162347835)

[6.2.5 Targeted design 13](#_Toc162347836)

[6.2.6 Convenience design 13](#_Toc162347837)

[6.2.7 Pseudoreplication 14](#_Toc162347838)

[6.3 Camera spacing 14](#_Toc162347839)

[6.3.1 Modelling approach 15](#_Toc162347840)

[6.3.2 Avoidance behaviour 16](#_Toc162347841)

[6.3.3 Site closure assumption 16](#_Toc162347842)

[6.4 Survey effort and timing 16](#_Toc162347843)

[6.4.1 Survey effort – Number of cameras 16](#_Toc162347844)

[6.4.2 Survey effort – Camera days per camera location 17](#_Toc162347845)

[6.4.3 Survey effort – Total number of camera days 17](#_Toc162347846)

[6.4.4 Species rarity 18](#_Toc162347847)

[6.4.5 Number of cameras vs. Camera days per camera location 18](#_Toc162347848)

[6.4.6 Survey timing 18](#_Toc162347849)

[7.0 Camera deployment 19](#_Toc162347850)

[7.1 Camera hardware options 19](#_Toc162347851)

[7.1.1 Battery type 21](#_Toc162347852)

[7.1.2 SD cards 21](#_Toc162347853)

[7.2 Camera settings 22](#_Toc162347854)

[7.2.1 Photos vs. video 22](#_Toc162347855)

[7.2.2 Trigger Mode(s) – Time-lapse vs. motion detector 23](#_Toc162347856)

[7.2.3 Trigger Sensitivity, Photos Per Trigger, Motion Image Interval, and Quiet Period 23](#_Toc162347857)

[7.3 Attractants *vs.* no attractants 24](#_Toc162347858)

[7.4 Camera placement 25](#_Toc162347859)

[7.4.1 FOV Target Feature 26](#_Toc162347860)

[7.4.2 Camera height 27](#_Toc162347861)

[7.4.3 Camera angle 27](#_Toc162347862)

[7.4.4 Camera direction 28](#_Toc162347863)

[7.4.5 Field of View (FOV) and Walktest 28](#_Toc162347864)

[7.4.6 Test image 29](#_Toc162347865)

[7.4.7 Deployment area photos (optional) 30](#_Toc162347866)

[7.4.8 Camera location characteristics 30](#_Toc162347867)

[7.4.9 Field equipment 30](#_Toc162347868)

[7.5 Metadata 31](#_Toc162347869)

[7.5.1 Metadata – Deployment, Service and Retrieval 31](#_Toc162347870)

[7.5.2 Spatial information 32](#_Toc162347871)

[7.5.3 SD card retrieval 32](#_Toc162347872)

[8.0 Data management and processing 32](#_Toc162347873)

[8.1 Software and tools 32](#_Toc162347874)

[8.2 Data storage (archival) 33](#_Toc162347875)

[8.3 Image processing 33](#_Toc162347876)

[8.3.1 Image names 33](#_Toc162347877)

[8.3.2 Image classification and tagging 34](#_Toc162347878)

[8.3.3 Use of artificial intelligence (MegaDetector) 34](#_Toc162347879)

[8.3.4 Human images 35](#_Toc162347880)

[8.4 Data analysis 35](#_Toc162347881)

[8.5 Useful websites 37](#_Toc162347882)

[9.0 References 38](#_Toc162347883)

[10.0 Glossary 53](#_Toc162347884)

[11.0 Appendix A 69](#_Toc162347885)

[12.0 Appendix B 98](#_Toc162347886)

# List of Tables

[**Table 1.** A subset of software platforms and tools for data storage, image processing, and data analysis / analytics. Refer to https://wildcams.ca/library/camera-trap-software-and-data-management/ for a comprehensive comparison of commonly used software platforms. 37](#_Toc162353627)

**Appendix A -** [**Table A1.** Summary of the assumptions and pros/cons of the different modelling approaches (adapted from Wearn & Glover-Kapfer [2017] and Clarke et al. [2022])..................69](#_Toc162352630)

**Appendix A -** [**Table A2.** Summary of appropriate study design, camera spacing, and survey effort (adapted from Wearn & Glover-Kapfer [2017] with additional references included) for various modelling approaches. Note – these are guidelines only, using best available information. There is uncertainty associated with each of the different approaches. To address this, the table contains ‘minimum’, ‘ideal’ and ‘often’ used values, as well as qualifiers. 81](#_Toc162352631)

**Appendix A -** [**Table A3.** Example of camera settings and recommended camera settings options (Reconyx Camera Models). 87](#_Toc162352632)

**Appendix A -** [**Table A4.** Recommended equipment for field deployments (checklist). 89](#_Toc162352633)

**Appendix A -** [**Table A5.** Steps to deploy a remote camera. 90](#_Toc162352634)

**Appendix A -** Camera Deployment Field Datasheet……………………...…….……………….....93

**Appendix A -** Test Image Sheet………………………………………………………………………95

**Appendix A -** Camera Service/Retrieval Field Datasheet………………………………………….96

# List of Figures

[**Figure 1.** Three conditional probabilities (Pr) of detection that may impact the detection probability of an animal (or species) by a camera (adapted from Moeller et al. [2023], Hofmeester et al. [2019], and Findlay et al. [2020]). 7](#_Toc162352709)

[**Figure 2.** Spatial scales (1-6) and processes that determine the detection probability (Hofmeester et al., 2019; abbreviated figure caption). 9](#_Toc162352710)

[**Figure 3.** Examples of sampling designs: (a) simple random, (b) systematic, (c) stratified (each grid cell is a stratum), and (d) clustered (adapted from Schweiger, 2020). 11](#_Toc162352711)

[**Figure 4.** Examples of the a) external components and b) internal controls and components of a remote camera (Reconyx PC900) (Reconyx Inc., [2017]). 19](#_Toc162352712)

[**Figure 5.** The ability to detect an animal will vary according to the camera specifications (and settings). Important specifications include the camera’s detection zone (here termed “trigger area”), Field of View (FOV; “viewable area’), and “registration area“ (the area in which an animal entering has at least some probability of being captured on the image) (Moeller et al., 2023). 21](#_Toc162352713)

[**Figure 6.** Illustration of a remote camera showing (A) the FOV Target Feature (a trail), (B) the camera’s detection zone (everything inside the red outline), and (C) the distance of the camera to the FOV Target Feature. Note that the detection zone will vary according to Camera Make and Camera Model. Camera users will need to identify a suitable attachment point (e.g., tree, fence post/ stake) near the target area. The most suitable attachment point will depend on the Camera Height, angle, and direction since these choices will impact the FOV (see section 7.4). Figure from WildCAM Network (2019). 27](#_Toc162352714)

[**Figure 7.** The **Walktest Distance** and **Walktest Height** are the horizontal and vertical distances from the camera, respectively, at which the user performs the walk test. A walktest should be performed 5 m away from the camera, at both 0 m (ground) and 0.5–1 m height. 29](#_Toc162352715)

[**Appendix B - Figure B1.** “Adapted from Gilbert et al. (2021) and Sun (unpublished). Decision tree for selecting camera trap density models. The models in the yellow rectangle are for marked and partially-marked populations; the remaining models are for unmarked populations. Note, the models in this decision tree are not necessarily ordered from strongest to weakest, but rather are organized by key features” (Clarke et al., 2022). 98](#_Toc162352860)

# Background

Effectively managing and conserving wild species and their habitats requires an understanding of species’ distributions, population levels and habitat requirements, along with knowledge of the factors that may threaten their long-term survival.

Remote cameras (also referred to as “wildlife cameras” or “camera traps”) are a valuable tool for detecting a wide range of wildlife species (Burton et al., 2015; Lahoz-Monfort & Magrath, 2021; O’Connell et al., 2011a). While they are most commonly used to monitor medium to large-sized mammals, they have also been used to detect small mammals (e.g., Lazenby et al., 2015; Mills et al., 2016; Tschumi et al., 2018) and birds (e.g., Kruger et al., 2018; Lynch et al., 2015; Randler & Kalb, 2018; Suwanrat et al., 2015).

Remote cameras consist of a digital camera with an external flash and/or passive infrared (PIR) detector (sensor) (see Lahoz-Monfort & Magrath, 2021; Rovero et al., 2013 for detailed reviews). Cameras can be [triggered](#trigger_event) through different means (e.g., mechanical triggers, active infrared sensors); PIR detectors followed by time-lapse triggers are most commonly used (Welbourne et al., 2016). The camera is [triggered](#trigger_event) when motion is sensed within the camera’s [detection zone](#detection_zone) and the infrared sensor registers a difference in infrared radiation above a certain threshold emitted from an object’s surface (e.g., animal fur; Welbourne et al., 2016). Cameras may capture images or video based on the user settings. The resulting images or videos are stamped with the date and time. Date and time stamps are valuable because they provide a permanent spatial and temporal record of wildlife occurrences.

Remote cameras have been used to measure presence / absence (e.g., Kucera & Barrett, 2011), [relative abundance](#mods_relative_abundance) (e.g., Carbone et al., 2001), [density](#density) of [marked](#typeid_marked) (e.g., Karanth et al., 2006) and [unmarked](#typeid_unmarked) (e.g., Becker et al., 2022) animals, population composition (age/sex ratios; e.g., Duquette et al., 2014), species richness / diversity (e.g., Ahumada et al., 2011), habitat use / distribution (e.g., Bowkett et al., 2008; O’Connell et al., 2006; Whittington et al., 2019), diel / seasonal activity patterns (e.g., Frey et al., 2017), individual breeding status (e.g., Fisher et al., 2014; Muhly et al., 2011), and behaviour (e.g., Holinda et al., 2020; Murray et al., 2016).

There are several advantages to using remote cameras over other inventory methods, including their ability to continuously collect data (images or video) for multiple species simultaneously in a cost-effective and non-invasive fashion (Kucera & Barrett, 2011; O’Brien, 2011; Steenweg et al., 2017). The advantages of remote cameras have led to a large increase in their use over time and the growing need to standardize[survey](#survey) methods (and [metadata](#metadata) reporting) (Fisher & Burton, 2012; Steenweg et al., 2017).

These guidelines were developed by the Alberta Remote Camera Steering Committee (RCSC) in collaboration with the Alberta Biodiversity Monitoring Institute (ABMI) and Wildlife Cameras for Adaptive Management (WildCAM). The Alberta RCSC and B.C. Advisory Committee (WildCAM; <https://wildcams.ca/about-us/>) are remote camera experts from academia, government and not-for-profit organizations who aim to advance the science of remote camera monitoring and research while facilitating collaboration and sharing knowledge among users in western Canada.

These guidelines are intended to be a “living document” that will be updated as new information becomes available. At a minimum, they will be reviewed on an annual basis.

# Intended Audience and How to use this document

The purpose of the Remote Camera Survey Guidelines is to provide recommendations on study design and implementation (including equipment and deployment recommendations) for novice to advanced users of remote cameras in Western Canada in a format aligned with standardized methods for [metadata](#metadata) reporting. The intended audience for this document includes consultants, researchers, and wildlife biologists working for government, non-government agencies and industry.

Summary tables, step-by-step procedures, and field data sheets have been provided in [Appendix](#_Appendix_A) [A](#_heading=h.3oy7u29) to help readers quickly locate and distill key information. There is also a useful decision tree for selecting [density](#density) models for remote camera data in [Appendix B - Figure B1](https://ualbertaca-my.sharepoint.com/personal/cjsteven_ualberta_ca/Documents/Adapted#surv_guidelines_fig_b1) (Clarke et al. [2022] adapted from Gilbert et al. [2021] and Sun [unpublished]). This document addresses the more common [modelling approaches](#mods_modelling_approach) (e.g., species diversity and richness, [occupancy](#occupancy), relative abundance, and [density](#density)). Research is ongoing to test the different approaches and to develop new methods. Refer to [*WildCAM’s resource library*](https://wildcams.ca/library/camera-trapping-papers-directory/) (<https://wildcams.ca/library/camera-trapping-papers-directory/>) and the sources provided for more information on the different approaches. For information on other methods, please refer to the literature (e.g., [intensity of use](#intensity_of_use) [Keim et al., 2019, 2021]; resource selection functions [Manly et al., 1993] etc.).

The goal of this document is to support consistency in the collection of remote camera data across western Canada by offering guidance on the appropriate study design, camera [deployment](#deployment) methods and data management.

There are several benefits to having standardized methods for remote cameras, including:

* Enabling province-wide consistency and reliability in data collection;
* Enabling data consolidation amongst [project](#project)s and enhancing the ability to answer large-scale management / research questions;
* Facilitating comparison between [surveys](#survey) or studies;
* Promoting higher-quality data, which facilitates data sharing and tracking;
* Enhancing common design standards for reproducible research;
* Allowing for efficient [project](#project) and data review;
* Ensuring [project](#project) planning meets required government and research institute standards.

The information provided in these guidelines is intended to be as prescriptive as possible to support consistency in data collection while allowing for flexibility where needed. The [deployment](#deployment) of remote cameras following this standard can help establish a robust foundation for camera programs. These guidelines build on the experiences of remote camera specialists in Alberta, British Columbia and other jurisdictions and should help guide camera users, even where no regulatory requirements exist.

Two companion documents exist, the [Remote Camera Metadata: Standards for Alberta](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (Alberta Remote Camera Steering Committee [RCSC], 2024; “AB Metadata Standards” hereafter) and [*Wildlife Camera Metadata Protocol: Standards for Components of British Columbia’s Biodiversity No. 44* (RISC, 2019;](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) “B.C. Metadata Standards” hereafter), which should be viewed alongside this document to establish a clear and consistent understanding of the recommendations and requirements. The [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024), as well as this Remote Camera Survey Guidelines, are available online (https://ab-rcsc.github.io/RCSC-WildCAM\_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/index.html), and on the [WildTrax](https://www.wildtrax.ca/home/resources/methods-and-protocols.html) (https://www.wildtrax.ca/home/resources/methods-and-protocols.html) and [Wildlife Cameras for Adaptive Management (WildCAM)](https://wildcams.ca/library/other-organizations-protocols/) (https://wildcams.ca/library/other-organizations-protocols/) webpages. The [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019) are available on the [WildCAM](https://wildcams.ca/library/other-organizations-protocols/) (https://wildcams.ca/library/other-organizations-protocols/) and [B.C. Government’s](https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/inventory-standards/terrestrial-ecosystems-biodiversity) webpages (https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/laws-policies-standards-guidance/inventory-standards/terrestrial-ecosystems-biodiversity).

## Supporting documents

Additional to the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) and [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019), there are several other supporting documents that are consistent with these guidelines and standards, including the following:

* Remote Camera Survey Guidelines supporting documents:
  + Camera Deployment Field Datasheet (RCSC et al., 2024)
  + Camera Service/Retrieval Field Datasheet (RCSC et al., 2024),
  + Test Image Sheet (RCSC et al., 2024),
  + Survey123 Template (RCSC et al., 2024), and
  + [EpiCollect Template](https://five.epicollect.net/project/rcsc-and-wildcam-remote-camera-survey-guidelines) (RCSC et al., 2024) (https://five.epicollect.net/project/rcsc-and-wildcam-remote-camera-survey-guidelines)
* [Alberta](https://docs.google.com/spreadsheets/d/1D0dIQY1pu5rwxHs_HC-0bRXScWWE7A2O/edit?usp=drive_link&ouid=104398155365933821384&rtpof=true&sd=true) Remote Camera Metadata Standards: Metadata Template (RCSC, 2024)

Copies of the [[Camera Deployment Field Datasheet](#_Camera_Deployment_Field)](#_camera_deployment_Field), [Test Image Sheet](#test_image_sheet) and [Camera Service/Retrieval Field Datasheet](#_camera_Service/Retrieval_Field) are also available within this document in [Appendix A.](#_Appendix_A)

# Design hierarchy

When designing a remote camera [project](#project) (e.g., scientific study, [inventory](#mods_inventory), or monitoring program), it is helpful to think of the hierarchy of information collected throughout the study. Doing so will:

* help the user align with the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) and [[B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019), thus promoting standardized data collection and information sharing](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf);
* provide those designing remote camera studies with the foundational concepts required to align their design with best practices and to implement appropriate data analyses.

The [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) propose that data should be collected at six broad levels ([project](#project), [study area](#study_area), [survey](#survey), [sample station](#sample_station) / [[camera location](#Heirch_Camera_location)](#camera_location), [deployment](#deployment), and image/[sequence](#sequence)). This hierarchy was adapted from Forrester et al. (2016) and the [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019) by adding one more level ([sample station](#sample_station) / [[camera location](#Heirch_Camera_location)](#camera_location)):

* **Project** – a scientific study, [inventory](#mods_inventory) or monitoring program that has a certain [objective](#survey_objectives), defined methods, and a defined boundary in space and time (recorded as “[Project Name](#project_name)“).
* **Study area** – a unique research, [inventory](#mods_inventory) or monitoring area(s) (spatial boundary) within a [project](#project) (there may be multiple [study areas](#study_area) within a single [project](#project)) (recorded as “[Study Area Name](#study_area_name)“).
* **Survey** – a unique deployment period (temporal extent) within a [project](#project) (recorded as “[Survey Name](#survey_name)“).
* **Sample station / Camera location –** 
  + **Sample station** – a grouping of two or more non-independent [camera location](#camera_location)s, such as when cameras are clustered or paired (recorded as “[Sample Station Name](#sample_station_name)“)
  + **Camera location** –the location where a single camera was placed (recorded as "[[[[Camera Location Name](#ID_Camera_location)](#ID_Camera_location)](#Heirch_Camera_location)](#camera_location_name)").
* **Deployment** – a unique placement of a camera in space and time (recorded as “[Deployment Name](#deployment_name)“). There may be multiple deployments for one [camera location](#camera_location). [Deployments](#“deployment”) are often considered as the time between visits (i.e., deployment to service, service to service, and service to retrieval). Any change to [camera location](#camera_location), sampling period, camera equipment (e.g., [Trigger Sensitivity](#settings_trigger_sensitivity) setting, becomes non-functioning), and/or conditions (e.g., not baited then baited later; camera SD card replaced) should be documented as a unique [deployment](#deployment).
* **Image/sequence**
  + **Image** – an individual image captured by a camera, which may be part of a multi-image [sequence](#sequence) (recorded as “[Image Name](#image_name)“).
  + **Sequence** – a user-defined group of images or video clips considered as a single “[detection event](#detection_event)“ (recorded as "[Sequence Name](#sequence_name)); often users choose a certain time threshold (or “[inter-detection interval](#_Glossary)“) to define [independent ‘events,’](#detection_event) e.g., 30 minutes (O’Brien et al., 2003; Gerber et al., 2010; Kitamura et al., 2010; Samejima et al., 2012) or 1 hour (e.g., Tobler et al., 2008; Rovero & Marshall, 2009). The threshold should be recorded in the [Survey Design Description](#survey_design_description)).

Note that these levels do not equate to individual CSV files. Refer to the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) for more information.

# Objectives

An essential first step when designing any [survey](#survey) is to clearly define its [objectives](#survey_objectives). [Survey Objectives](#survey_objectives) should be specific, measurable, achievable, relevant and time-bound (i.e., SMART). [Survey Objectives](#survey_objectives) should describe the following:

* [Target Species](#target_species) - the species that the [survey](#survey) is designed to detect,
* [State variable(s)](#state_variable) - a formal measure that summarizes the state of a community or population at a particular time (Wearn & Glover-Kapfer, 2017) (e.g., species richness or population abundance), and
* Proposed [modelling approach(es)](#mods_modelling_approach) - the method used to analyze the camera data, which should depend on the [state variable](#state_variable) (e.g., [occupancy models](#mods_occupancy) [MacKenzie et al., 2002], [spatially explicit capture-recapture (SECR) models](#mods_scr_secr) [e.g., Royle et al., 2009] for [density](#density) estimation, etc.) and the [Target Species](#target_species). To learn more about the different [modelling approaches](#mods_modelling_approach), refer to [*Appendix A - Table A1*](#surv_guidelines_table_a1), [*Appendix A - Table A2*](#surv_guidelines_table_a2), and [*WildCAM’s resource library*](https://wildcams.ca/library/camera-trapping-papers-directory/) (<https://wildcams.ca/library/camera-trapping-papers-directory/>).

An example of a clearly defined [Survey Objective](#survey_objectives) could be “to monitor trends in wolverine [occupancy](#occupancy) at 5-year intervals from March – December 2020 to 2030 in wildlife management unit 539”.

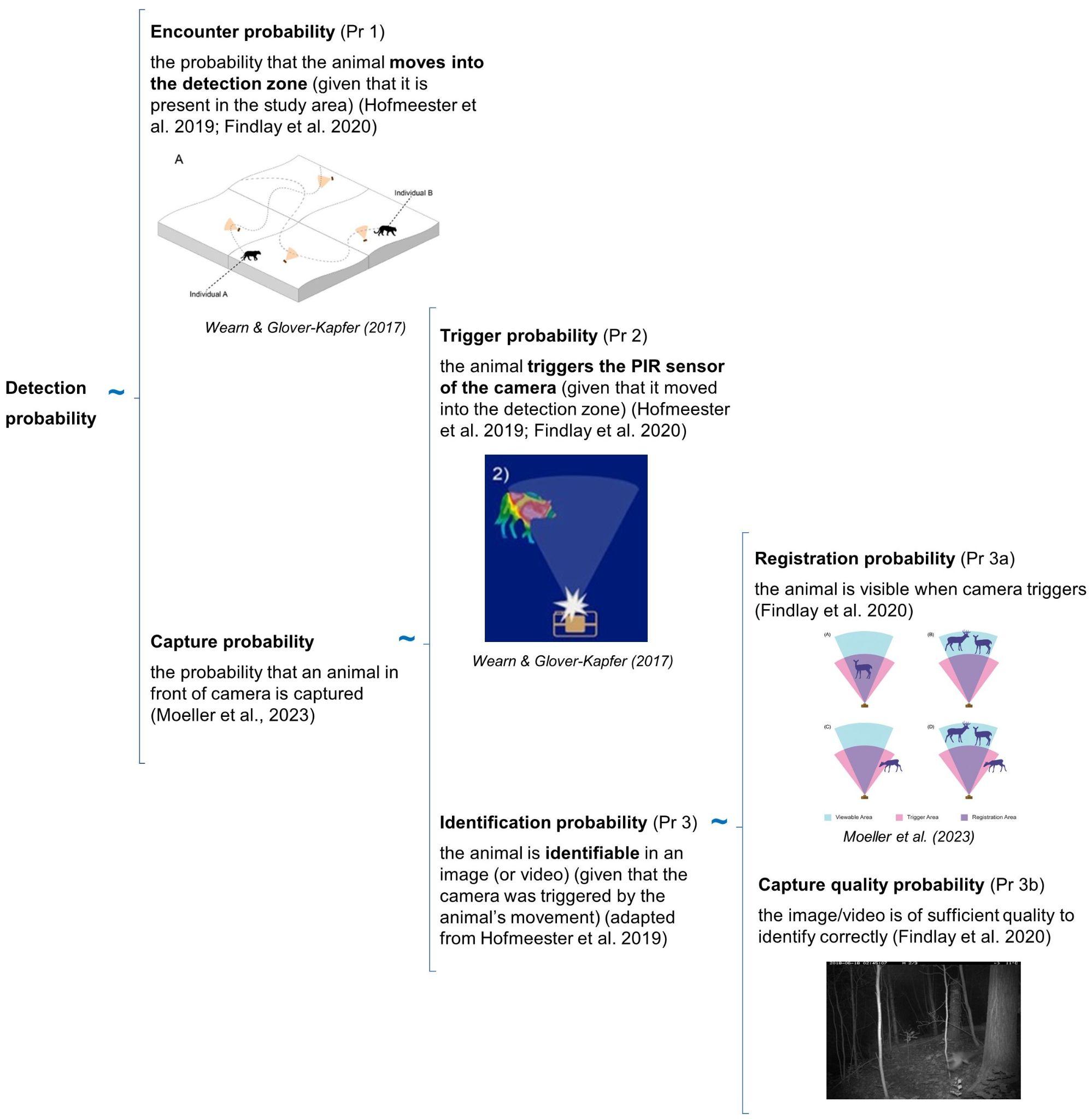
The [survey objective](#survey_objectives) will determine the appropriate [study design](#survey) and [deployment](#deployment) considerations (e.g., [camera spacing](#camera_spacing), [survey](#survey) effort, attractants or not). For example, based on the above objective for our wolverine [occupancy](#occupancy) [project](#project), we “randomly selected [camera location](#camera_location)s within a 15 km x 15 km grid cell with one camera per location and a total of 60 stations across our [study area](#study_area). We will place [lure](#baitlure_lure) dispensers at each [camera location](#camera_location) to increase the likelihood of detecting a wolverine.” to increase the likelihood of detecting a wolverine.”

# Detection probability

Before study design choices are made, there is one critical concept to understand in remote camera research, which may impact study design choices at all levels of the data hierarchy. Reliable use of remote cameras to detect wildlife species hinges on the [assumption](#mods_modelling_assumption) that what is captured on the cameras accurately reflects what is present on the landscape. However, species are often detected "imperfectly," meaning that they are not always detected when they are present (i.e., [imperfect detection](#imperfect_detection); e.g., due to cover of vegetation, cryptic nature or small size) (MacKenzie et al., 2004). [Imperfect detection](#imperfect_detection) can occur because the camera failed to capture an individual present at the site or because the animal was simply not present during the [survey](#survey) period (Martin et al., 2005).

[Imperfect detection](#imperfect_detection) results in “false absences” and may lead to incorrect conclusions from the data. Understanding and correcting for sources of “false absences” is often thought of in terms of probabilities. [Detection probability](#detection_probability) is the probability (likelihood) that an individual from the population of interest is included in the count at time or location *i* (MacKenzie & Kendall, 2002). [Detection probability](#detection_probability) can be influenced through multiple processes and at multiple scales. Understanding the sources of “false absences” and factors that affect [detection probabilities](#detection_probability) is an essential step when designing a study, deploying cameras and analyzing camera data.

[The detection probability](#“detection_probability”) of an animal by a camera depends on three **conditional probabilities (Pr)** **of detection** that may operate alone or potentially in combination ([Figure 1](#surv_guidelines_fig_1)).



**Figure 1.** Three conditional probabilities (Pr) of detection that may impact the detection probability of an animal (or species) by a camera (adapted from Moeller et al. [2023], Hofmeester et al. [2019], and Findlay et al. [2020]).

[Detection probability](#“detection_probability”) can be affected by species-specific characteristics, [Camera Model](#camera_model) specifications and set-up, and environmental variables (Hofmeester et al., 2019). For example, **species-specific characteristics** (individuals or populations), such as body size (e.g., O’Brien et al., 2011), behaviour (e.g., Caravaggi et al., 2020; Rowcliffe et al., 2011), and rarity can influence [detection probability](#detection_probability), with larger, bolder and more common species generally having higher [detection rates](#detection_rate). [**Camera Model**](#camera_model) **specifications and set-up**, such as the [Trigger Sensitivity](#settings_trigger_sensitivity), [Camera Height](#camera_height), or [angle](#camera_angle) may affect[detection probability](#detection_probability) in that smaller species might not be detected or identifiable if the [Trigger Sensitivity](#settings_trigger_sensitivity) is low, or the [Camera Height](#camera_height) or [angle](#camera_angle) is too high. The[Camera Direction](#camera_direction) could impact the probability of an animal triggering a camera if it is directed towards an object that impedes the [Field of View (FOV)](#field_of_view) or image quality (e.g. due to sun glare). **Environmental factors** (e.g., vegetation cover, snow depth) may affect [detection probability](#detection_probability) and occurrence (e.g., Becker et al., 2022; Hofmeester et al., 2019; Iknayan et al., 2014; Steenweg et al., 2019). For example, a low number of detections in a densely vegetated site might be because of poor camera visibility or avoidance of this habitat by the species of interest.

Hofmeester et al. (2019) suggested there are **six scales (orders) that may impact** [detection probability](#detection_probability)and that should be considered within an explicit time period (adapted from Hofmeester et al. [2019]; [Figure 2](#surv_guidelines_fig_2)):

1)  **Distribution range** (1st order; i.e., the physical or geographical range of a species)

2) **Landscape** (2nd order; i.e., the location of an individual’s home range within the geographic range)

3) **Habitat patch** (3rd order; i.e., usage of habitat components within an individual’s home range)

4) **Microsite** (4th order; usage of microhabitats such as food items/feeding patches/nest sites/movement trails, etc. within a habitat)

5)  **Camera specification / set-up** (5th order; i.e., factors that affect the probability that an animal [triggers](#trigger_event) the camera if present)

6)  **Image** (6th order; i.e., factors that affect correct identification of animals or individuals)

A screenshot of a computer

Description automatically generated

**Figure 2.** Spatial scales (1-6) and processes that determine the [detection probability](#detection_probability) (Hofmeester et al., 2019; abbreviated figure caption).

It is important to consider how all these factors and scales will impact study design. Unmeasured variation in [detection probability](#detection_probability) can result in the inability to differentiate the effects of [detection probability](#detection_probability) *vs.* habitat preference (Jennelle et al., 2002) and, in turn, cause erroneous estimates of occurrence and abundance (Burton et al., 2015; Dénes et al., 2015; Kays et al., 2021).

Factors that influence [detection probability](#detection_probability) at the microsite and camera specification / set-up scales are likely to result in the largest biases and thus warrant the most consideration (see Hofmeester et al. [2019] for details). Therefore, it is particularly important to consider *how* to place cameras to avoid such biases. Deploying cameras in a consistent fashion (e.g., carefully ensuring that cameras are always set at the same [Camera Height](#camera_height), orientation ([direction](#camera_direction)), and [angle](#camera_angle)) is essential.

# Study design

[Project](#project) or[survey](#survey)-level aspects of design that camera users should consider (at a minimum) are:

* [Study area](#study_area) extent and method of delineation (e.g., watershed or minimum convex polygon)
* Criteria for site selection (e.g., [random](#sampledesign_random), [systematic](#sampledesign_systematic), or [targeted](#sampledesign_targeted) habitat types or features)
* Camera arrangement (e.g., [random](#sampledesign_random) vs. cameras ‘[clustered](#sampledesign_clustered)’ into hierarchical groups with common characteristics)’ into hierarchical groups with common characteristics)
* [Camera spacing](#camera_spacing) (e.g., 1 km spacing between cameras) km spacing between cameras)
* Number (or [density](#density)) of cameras
* [Survey](#survey) effort and timing (i.e., the number of days the camera was active and functioning during the [survey](#survey) period; the “[camera days per camera location](#camera_days_per_camera_location),“ the [total number of camera days](#total_number_of_camera_days), time of year, and [survey](#survey) duration)

These decisions will depend on the study [objectives](#survey_objectives) as well as the resources available.

Decisions concerning study design are a critical component of any wildlife [project](#project). These decisions can be complex, and in these cases, it is highly advisable to consult an expert for direction.

## Study area

A [study area](#study_area) is a unique area(s) within a [project](#project). There may be multiple [study areas](#study_area) within a larger [study area](#study_area). Aspects to consider when identifying the [study area](#study_area) include the spatial extent (and method of delineation), shape (Foster & Harmsen, 2012), and composition and configuration of features within it (including habitat types, land uses and disturbances).

Several factors influence the size (spatial extent) of the study area, including the [objectives](#survey_objectives), ecosystem, the biology of the [Target Species](#target_species) (e.g., dispersal ability, habitat preferences, etc.) and/or [modelling approach.](#mods_modelling_approach)

For example, [density](#density) models using the [capture-recapture (CR)](#mods_cr_cmr) [modelling approach](#mods_modelling_approach) requires that the[study area](#study_area) encompasses the entire area in which individuals can move during the [survey](#survey) and that each individual can be detected by a camera (Karanth & Nichols, 1998). In this case, the animal’s home range size could be used (e.g., four times the home range size [Maffei & Noss, 2008]) (Wearn & Glover-Kapfer, 2017) in combination with a finite number of cameras available (e.g., 20 cameras are available; ideally, they should be [paired](#sampledesign_paired) and there should be > 4 cameras in each home range [Wearn & Glover-Kapfer, 2017]) to define the [project](#project)’s spatial extent.

Methods to delineate the appropriate spatial extent include, for example, minimum convex polygons (i.e., a polygon surrounding the locations of previous detections) or [kernel density estimators](#kernel_density_estimator) (e.g., via the probability of "utilization" [Jennrich & Turner, 1969]). Geographic Information Systems (GIS, e.g., ESRI software) or programming languages (e.g., R) contain useful tools for these delineation methods.

## Site selection and camera arrangement

Remote [camera locations](#camera_location) (or [sample stations](#sample_station)) and their spatial arrangement are integral components of any study design; these choices will affect the user’s ability to draw inference(s) about the species or question of interest. There are many species-specific characteristics (e.g., body size, behaviour, rarity, etc.) and environmental factors (e.g., vegetation cover, snow depth) that influence the [detection probability](#detection_probability) and probability of occurrence of a species, as well as the size of the area that should be surveyed (e.g., Becker et al., 2022; Hofmeester et al., 2019; Iknayan et al., 2014; Steenweg et al., 2019). When there are multiple [Target Species](#target_species), a mix of study designs may be valuable (Iannarilli et al., 2021; van Wilgenburg et al., 2020).

The [objectives](#survey_objectives) of the [survey](#survey) will determine the most appropriate study design ([Appendix A - Table A2](#surv_guidelines_table_a2)). There are five commonly used study designs in camera studies: [simple random](#sampledesign_random), [systematic random](#sampledesign_systematic_random) (grid), [stratified random](#sampledesign_stratified_random), [clustered](#sampledesign_clustered) (including [paired design](#sampledesign_paired)) and [targeted](#sampledesign_targeted) (or opportunistic) (Wearn & Glover-Kapfer 2017). A [convenience sampling](#sampledesign_convenience) study design is also used when it is impractical to use another design. Sampling design can occur hierarchically, where one approach is used at a larger scale (i.e., to select grids to place cameras within), and another approach is used at a smaller scale (i.e., to select the location within each grid to place the camera). Refer to the following literature for additional recommendations on study design: Burton et al., 2015; Cusack et al., 2015; Fisher & Burton, 2012; Kolowski and Forrester, 2017; Meek et al., 2014b; O’Connell et al., 2011b; Rovero et al., 2013; Steenweg et al., 2015; Wearn & Glover-Kapfer, 2017 and [WildCAM’s “sampling design & effort section section”](https://wildcams.ca/library/camera-trapping-papers-directory/) of their resource library (https://wildcams.ca/library/camera-trapping-papers-directory/).

Note that we refer to different configurations of cameras more generally as study design and sampling design; however, the term “[**Survey Design**](#survey_design)“ is how the study design is referred to when it applies to an individual [survey](#survey). There may be multiple [Survey Designs](#survey_design) for [surveys](#survey) within a [project](#project); the [Survey Design](#survey_design) should be reported separately for each [survey](#survey) within a [project](#project). When the [Survey Design](#survey_design) is hierarchical, “Hierarchical (multiple)\*” should be reported and additional details should be included in the [Survey Design Description](#survey_design_description). Refer to the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) for more information.

A close-up of a grid

Description automatically generated with low confidence

**Figure 3.** Examples of sampling designs: (a) simple [random](#sampledesign_random), (b) [systematic](#sampledesign_systematic_random), (c) [stratified](#sampledesign_stratified) (each grid cell is a stratum), and (d) [clustered](#sampledesign_clustered) (adapted from Schweiger, 2020).

### Random (or “simple random”) design

**Random (or “simple random”) design** ([Figure 3a](#surv_guidelines_fig_3)) – cameras occur at randomized locations (or sample stations) across the [study area](#study_area), sometimes with a predetermined minimum distance between [camera location](#camera_location)s (or [sample stations](#sample_station)). A [random design](#sampledesign_random) may help reduce biases that arise from selecting [camera locations](#camera_location) deliberately. It may also allow the user to make inferences about areas that were not surveyed when employing use-based approaches (e.g. [occupancy models](#mods_occupancy) [MacKenzie et al., 2002]; [intensity of use](#intensity_of_use) methods [Keim et al., 2019]). Some [modelling approaches](#mods_modelling_approach) (e.g., [random encounter and staying time [REST]](#mods_rest); Nakashima et al., 2018) and [random encounter models [REM](#mods_rem); Rowcliffe et al., 2008, 2013]) require a simple [random design](#sampledesign_random) ([Appendix A - Table A2](#surv_guidelines_table_a2)).

A disadvantage of using a simple random design is the tendency to see fewer animals (i.e., is less efficient) when animals are [[clustered](#sampledesign_clustered)](#sampledesign_clustered) or exhibit habitat preferences, and the possibility of missing rare habitat types. The proportion of different strata (e.g., habitat types) sampled should be the same as (or close to) the true proportion in the [study area](#study_area). For example, if the [study area](#study_area) consists of 25% young deciduous forest, then 25% of randomly selected sites should be within young deciduous forest, on average.

### Systematic design

**Systematic design** ([Figure 3b](#surv_guidelines_fig_3)) – [camera locations](#camera_location) occur within a regular pattern (e.g., a grid pattern) across the [study area](#study_area).

**Systematic random** – [camera locations](#camera_location) are selected using a two-stage approach. Firstly, grids are selected systematically (to occur within a regular pattern) across the [study area](#study_area). The location of the camera within each grid is then selected randomly.This method is similar to the [simple random](#sampledesign_random) design. The same advantages apply in terms of unbiased landscape representation, and the same [modelling approaches](#mods_modelling_approach) can be used. The disadvantage of using a [systematic random](#sampledesign_systematic_random) (or [simple random](#sampledesign_random) design) is that rare habitat types may be missed.

**Systematic non-random** design – sets of [[[[clustered](#sampledesign_clustered)](#sampledesign_clustered)](#sampledesign_clustered)](#sampledesign_clustered) cameras can be deployed within a [systematic non-random](#sampledesign_systematic) approach (i.e., “systematic clustered” or “systematic paired”) to assess the effects of disturbance along a gradient, over time, at multiple scales and/or with control (i.e., reference) [sample stations](#sample_station). **Hierarchical Before-After Dose-Response (BADR)** is one such method that requires cameras to be placed within a systematic non-random approach, where [camera locations](#camera_location) occur along transects or in [[[[clustered](#sampledesign_clustered)](#sampledesign_clustered)](#sampledesign_clustered)](#sampledesign_clustered) arrays ([sample stations](#sample_station)), selected using a nested spatial hierarchy of sampling to control for variability in land-use type and large-scale patterns (Bayne et al., 2022). The [study area](#study_area) is divided into land-use regions based on land-use type, then into landscape units, which are assessed for environmental variability to determine where [sample stations](#sample_station) should be placed (Bayne et al., 2022). The “Before-After” component of BADR incorporates the phase of stressors (i.e., proposed or current development) (Bayne et al., 2022). The “Dose-Response” component of BADR controls for the variable distribution of activity (and the potential impacts) by incorporating control (or reference) [sample stations](#sample_station) and/or by placing cameras in [sample stations](#sample_station) along a gradient of disturbance (Bayne et al., 2022).

### Stratified design

**Stratified randomdesign** ([Figure 3c](#surv_guidelines_fig_3)) – the area of interest is divided into smaller strata (e.g., habitat type, disturbance levels), and then a proportional random sample of sites is selected within each stratum (e.g., 15%, 35% and 50% of sites within high, medium and low disturbance strata). This design can help ensure that the sample adequately reflects the major or uncommon strata of interest and may be an efficient approach when users are limited by accessibility constraints (Wearn & Glover-Kapfer, 2017). This design can also be used to increase precision if animal densities are known to be highly variable (Junker et al., 2021) or when a species is expected to occur in certain habitat types more often (Gillespie et al., 2015). For example, studies that wish to assess species richness, or [occupancy](#occupancy) rates for a particular species, amongst strata would use a [stratified random](#sampledesign_stratified_random) design.

### Clustered / Paired designs

**Clustered**design ([Figure 3d](#surv_guidelines_fig_3)) – multiple cameras are deployed at a [sample station](#sample_station). The distance between cameras ([[camera spacing](#Camera_spacing)](#camera_spacing)) will be influenced by the chosen sampling design, the [Survey Objectives](#survey_objectives), the [Target Species](#target_species) and data analysis. A [clustered design](#sampledesign_clustered) can be used within a [systematic](#sampledesign_systematic) or [stratified](#sampledesign_stratified) approach (i.e., systematic clustered design or as a clustered random design) (Wearn & Glover-Kapfer, 2017). A [clustered design](#sampledesign_clustered) is common when users are interested in individual identification, such as [density](#density) estimation from [marked](#typeid_marked) or [partially marked populations](#typeid_partially_marked) (e.g., [spatially explicit capture-recapture [SECR](#mods_scr_secr); Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008] or [spatial mark-resight [SMR](#mods_smr); Doran-Myers, 2018]). A [clustered](#sampledesign_clustered)design can also be used in an [occupancy framework](#mods_occupancy) (O'Connell & Bailey, 2011; Pacifici, 2015) when interested in measures of species richness (O'Brien et al., 2011).

A [clustered](#sampledesign_clustered) design can be a cost-efficient approach to increase the number of replicates at each site (especially when accessibility is limiting; Gálvez et al., 2016) and to reduce measurement error and improve precision (Clarke et al., 2019). However, [spatial autocorrelation](#spatial_autocorrelation) may occur with this design (Moqanaki et al., 2021), depending on the [camera spacing](#camera_spacing) (see [section 6.2.7](#psuedoreplication)).

**Paired design** – a form of “[clustered design](#sampledesign_clustered)“ where two cameras that are placed closely together to increase detection probability ("paired cameras"), to evaluate certain conditions ("paired sites,” e.g., on- or off trails), etc. Paired placements can help to account for other variability that might occur (i.e., variation in habitat quality). For some [objectives](#survey_objectives), pairs of cameras might be considered subsamples within another sampling design (e.g., [simple random](#sampledesign_random), [stratified random](#sampledesign_systematic_random), [systematic](#sampledesign_systematic)).

### Targeted design

**Targeted design** – cameras are placed in areas that are known or suspected to have higher activity levels (e.g., game trails, mineral licks, etc.). This design is useful when monitoring rare or cryptic species that are unlikely to be detected with other designs. This design is commonly used when estimating densities of [marked populations](#typeid_marked) (e.g., [spatially explicit capture-recapture [SECR](#mods_scr_secr); Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008]) or behaviour studies. It is, however, important to understand that [targeted](#sampledesign_targeted) sampling may impede one’s ability to make inferences beyond the [survey](#survey) area. For some [objectives](#survey_objectives), [targeted](#sampledesign_targeted) sampling may be used within another sampling design (e.g., a [stratified random](#sampledesign_stratified_random) sample of game trails and seismic lines; Keim et al. 2021).

### Convenience design

**Convenience design** – [camera locations](#camera_location) or [sample stations](#sample_station) are chosen based on logistic considerations (e.g., remoteness, access constraints, costs). When cost is a key consideration, other more rigorous sampling designs (e.g., stratified; van Wilgenburg et al., 2020) that can incorporate cost should be considered first. One should be cautious when generalizing or drawing conclusions from data collected using [convenience sampling](#sampledesign_convenience), given that estimates can be biased if the sample poorly represents the population of interest. The [convenience sampling](#sampledesign_convenience) design can be used where the goal is to[survey](#survey) a specific location(s) without the intent to generalize to un-surveyed areas (Gillespie et al., 2015; e.g., Kusi et al., 2020) or to [survey](#survey) an area following a report of the occurrence of a rare species. Both [randomized](#sampledesign_random) (e.g., Found & Patterson, 2020) or [targeted](#sampledesign_targeted) approaches can be used within a [convenience sampling](#sampledesign_convenience) approach, although the user should still be cautious about extrapolating inferences to areas (or habitat types in an [occupancy framework](#mods_occupancy) [MacKenzie et al., 2002]) that were not sampled and, therefore, not represented in the data (Gillespie et al., 2015).

### Pseudoreplication

[**Spatial autocorrelation**](#spatial_autocorrelation) (i.e., the tendency for sites that are close together to be more similar) may occur when multiple cameras are placed nearby (such as in *clustered, paired or array sampling*). [Spatial autocorrelation](#spatial_autocorrelation)is a form of[pseudoreplication](#pseudoreplication) (Hurlbert, 1984; when observations are not statistically independent but are treated as if they are) and can be problematic because it can artificially inflate or diminish ecological effects.The degree to which this is a problem will depend on the [Target Species](#target_species) (i.e., how far they can travel may dictate the distance at which another camera is too near) and the [modelling approach](#mods_modelling_approach).In these cases, users should consider an analytical framework that accommodates autocorrelation to avoid issues of spatial [pseudoreplication](#pseudoreplication) (Hurlbert, 1984) and false conclusions (Ramage et al., 2013) (e.g., using random effects [Wearn & Glover-Kapfer, 2017] or spatial autoregressive models [Kelejian & Prucha, 1998]).

Note that [pseudoreplication](#pseudoreplication) (Hurlbert, 1984) can also occur over time (e.g., if [camera locations](#camera_location) are sampled repeatedly to obtain detection rates as repeated counts, or if the [inter-detection interval](#inter_detection_interval) is too short for a subsequent detection to be truly independent of the first detection).

## Camera spacing

The distance between cameras (the "[camera spacing](#camera_spacing),” also referred to as "inter-trap distance") is an important consideration when designing a camera [survey](#survey). This will be influenced by the chosen sampling design, the [Survey Objectives](#survey_objectives), the [Target Species](#target_species), the [modelling approach](#mods_modelling_approach) and data analysis.

For example, if the [objective](#survey_objectives) is to estimate grizzly bear [occupancy](#occupancy) and cameras are placed close together, detections may not be statistically independent if the same individual is detected at neighbouring camera sites within a short time period. In contrast, if the objective was to estimate [occupancy](#occupancy) for a different species such as marten, the [[[camera spacing](#Camera_spacing)](#Camera_spacing)](#camera_spacing) may be statistically independent in this case.

It is important that you understand how the [Survey Objectives](#survey_objectives) influence sampling design and decisions about [[[camera spacing](#Camera_spacing)](#Camera_spacing)](#camera_spacing) (Wearn & Glover-Kapfer, 2017). When estimating [density](#density) from [marked](#typeid_marked) populations using a [[clustered design](#sampledesign_clustered)](#sampledesign_clustered) and [SECR](#mods_scr_secr) [modelling approach](#mods_modelling_approach) (Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008), for example, the spacing between clusters and cameras within a cluster are important considerations (Clarke et al., 2019). In this case, placing cameras in close proximity to one another can increase the [detection probability](#detection_probability) and in turn, increase statistical power, shorten[survey](#survey) lengths, and reduce costs (WildCAM Network, 2019). However, detections from nearby cameras may not be independent and could lead to issues with [pseudoreplication](#pseudoreplication) (Hurlbert, 1984) and false conclusions (Ramage et al., 2013).

The spacing requirements of the different [modelling approaches](#mods_modelling_approach) (dictated by the[objectives](#survey_objectives)) vary and should be considered carefully. The recommendations for [[[camera spacing](#Camera_spacing)](#Camera_spacing)](#camera_spacing) for various [modelling approaches](#mods_modelling_approach) are summarized below and in [Appendix A - Table A2](#surv_guidelines_table_a2).

### Modelling approach

The spacing requirements of the different [modelling approaches](#mods_modelling_approach) (dictated by the[objectives](#survey_objectives)) vary and should be considered carefully. The recommendations for [[[camera spacing](#Camera_spacing)](#Camera_spacing)](#camera_spacing) for various [modelling approaches](#mods_modelling_approach) are summarized below.

* There are no guidelines for spacing requirements for [species inventory](#mods_inventory) [projects](#project).
* For **species richness**, **species diversity**, and [**relative abundance**](#mods_relative_abundance), spacing of at least 1–2 kilometres apart should be adequate to ensure that cameras are spatially independent (Colyn et al., 2018; Rovero et al., 2013; Wearn & Glover-Kapfer, 2017). It is important when combining [relative abundance](#mods_relative_abundance) data from multiple [surveys](#survey) to use the same [camera spacing](#camera_spacing), as [relative abundance](#mods_relative_abundance) estimates can increase as [camera spacing](#camera_spacing) decreases (and vice-versa; Anile & Devillard, 2016)].
* For[**occupancy models**](#mods_occupancy)(MacKenzie et al., 2002), the [camera spacing](#camera_spacing) should be comparable to the size of the home range of the [Target Species](#target_species) (i.e., one home range diameter apart) to ensure that only one animal is recorded per sampling unit (Linden et al., 2017; Neilson et al., 2018; Rovero et al., 2013; Steenweg et al., 2018; Wearn & Glover-Kapfer, 2017).
* For [**capture-recapture (CR) models**](#mods_cr_cmr)([density](#density); Karanth, 1995; Karanth & Nichols, 1998), [camera spacing](#camera_spacing) should be analogous to the home-range scale or smaller. With the advent of [spatially explicit capture-recapture [SECR](#mods_scr_secr); Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008] models, [CR models](#mods_cr_cmr)(Karanth, 1995; Karanth & Nichols, 1998) are seldom used and no longer recommended.
* For [**spatially explicit capture-recapture**](#mods_scr_secr) **(SECR**; Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008) models, the optimum [camera spacing](#camera_spacing) is 0.3times the home range diameter of the [Target Species](#target_species), with up to 0.8times the home range diameter being acceptable (O’Brien & Kinnaird, 2011; Rovero et al., 2013; Soria-Díaz et al., 2010; Wearn & Glover-Kapfer, 2017). [SECR](#mods_scr_secr) models (Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008) are, however, robust to increased [camera spacing](#camera_spacing) (Sollmann et al., 2012; Zimmermann, 2013). Sampling over a larger spatial extent may be more important in some cases than preserving recommended [camera spacing](#camera_spacing) (Sollmann et al., 2012; Zimmermann et al., 2013).
* For [random encounter models (REM](#mods_rem); [density](#density); Rowcliffe et al., 2008), the [camera spacing](#camera_spacing) should be large enough to avoid sampling the same individual repeatedly (i.e., observations are independent; Rovero et al., 2013; Wearn & Glover-Kapfer, 2017). Cameras should be spaced farther apart than the home range diameter of the [Target Species](#target_species) (Wearn & Glover-Kapfer, 2017).

Refer to [Appendix A - Table A2](#surv_guidelines_table_a2) for additional recommendations on [[[camera spacing](#Camera_spacing)](#Camera_spacing)](#camera_spacing) for the different [modelling approaches](#mods_modelling_approach).

### Avoidance behaviour

Interactions between species can also influence the choice of [[[[camera spacing](#Camera_spacing)](#Camera_spacing)](#Camera_spacing)](#camera_spacing). For example, a study of interactions between Tasmanian devils and domestic cats found that cats avoided Tasmanian devils over short distances. Such avoidance behaviours can be problematic when a [survey](#survey) targets the species showing these behaviours, or when the behaviours are not accounted for in the study design or data analyses (Fancourt, 2016).

### Site closure assumption

Many [modelling approaches](#mods_modelling_approach) (e.g. [occupancy models](#mods_occupancy) [MacKenzie et al., 2004]; [Appendix A - Table A1](#surv_guidelines_table_a1)) assume “site closure” (i.e., that there is no change in state (e.g. species presence/ absence, immigration/ emigration, births/deaths) during the [survey](#survey) period (MacKenzie et al., 2004). For some approaches, violation of the site closure [assumption](#mods_modelling_assumption) can result in an underestimate of [detection probabilities](#detection_probability) and, in turn, over-estimate [density](#density) (e.g., with spatial recapture models) or result in simply averaging detections over the sampling period (e.g., [REM](#mods_rem) [Rowcliffe et al., 2008, 2013], [REST](#mods_rest) [Nakashima et al., 2018] models). To meet the “site closure” [assumption](#mods_modelling_assumption), thestudy design might include spacing cameras far enough apart that the same individual is not detected at multiple sites (e.g., larger than the species' home range size). The[survey](#survey) duration might also be short enough that the probability of [occupancy](#occupancy) does not change (i.e., not confounded by other processes, e.g., by changes in the population since [occupancy](#occupancy) is a function of abundance) (O'Connell & Bailey, 2011). Refer to [Appendix A - Table A2](#surv_guidelines_table_a2) for recommendations on how to deploy cameras to meet “site closure” [assumption](#mods_modelling_assumption)s.

## Survey effort and timing

### Survey effort – Number of cameras

[Appendix A - Table A2](#surv_guidelines_table_a2) shows the recommended minimum number of cameras according to the [Survey Objectives](#survey_objectives) and [modelling approach](#mods_modelling_approach). The optimal number of cameras required will be influenced by factors such as landscape heterogeneity, [survey](#survey) duration and spatial scale, species rarity and desired level of precision (Colyn et al., 2018; Rovero et al., 2013). For example, Kays et al. (2020) found that 25–35 cameras were needed for precise estimates of species richness, depending on the spatial scale of the[survey](#survey) and landscape diversity. The number of cameras required for precise estimates of [occupancy](#occupancy) was highly sensitive to the occurrence rate of species, with <20 cameras required for common species and >150 cameras required for rare species (Kays et al., 2020). In general, deploying more cameras and/or for longer durations always results in more precise estimates; however, users can consider rotating cameras across multiple sites for shorter durations (if feasible). There are several useful references and applications available to help determine the optimal number of cameras for a [survey](#survey) (e.g., Efford & Boulanger, 2019).

When the [objectives](#survey_objectives) and [modelling approach](#mods_modelling_approach) warrant, placing multiple cameras at a site (either on the same attachmentpoint or nearby) can significantly increase the [detection probability](#detection_probability) of less common species (more than increasing the number of [camera days per camera location](#camera_days_per_camera_location); O’Connor et al., 2017; Pease & Holzmueller, 2016; Stokeld et al., 2016) or be useful for individual identification.

### Survey effort – Camera days per camera location

A second related consideration in terms of[survey](#survey) effort is how long to[survey](#survey) (i.e., the number of “[camera days per camera location](#camera_days_per_camera_location)") at each [camera location](#camera_location). Specifically, the number of [camera days per camera location](#camera_days_per_camera_location) is the number of days each camera was active and functioning during the period it was deployed (e.g., 24-hour periods or the difference in days between the [Deployment Start Date Time](#deployment_start_date_time) and the [Deployment End Date Time](#deployment_end_date_time) if there were no interruptions). It is important to consider how the [Survey Objectives](#survey_objectives) and [assumption](#mods_modelling_assumption)s of the chosen [modelling approach](#mods_modelling_approach) may influence this decision.

Wearn and Glover-Kapfer (2017) suggested that for estimates of [density](#density), species richness, [relative abundance](#mods_relative_abundance) and [occupancy](#occupancy), each camera should remain active for a minimum of 30 camera days. Steenweg et al. (2019) found that increasing the number of [camera days per camera location](#camera_days_per_camera_location) improved the likelihood of detecting a change in [occupancy](#occupancy), but only when the [cumulative detection probability](#cumulative_det_probability) (i.e., “the probability of detecting a species at least once during the entire [survey](#survey)“ [Steenweg et al., 2019]) was below a certain threshold (<0.80). In other words, if cameras were deployed long enough to reach a [cumulative detection probability](#cumulative_det_probability) >0.8 for the [Target Species](#target_species) and [survey](#survey) period, there was no benefit to surveying longer at one [camera location](#camera_location) (Long et al., 2008; Steenweg et al., 2019) (see also [section 6.4.4](#species_rarity)).

For measures of species richness or diversity, it is presumed that a camera is active long enough to detect rare species that may occur at a specific location (Wearn & Glover-Kapfer, 2017). If this is not the case, the results will indicate that the species was not present when it was (i.e., a “false negative”). False negatives may also be problematic for other measures, such as [**relative abundance indices**](#mods_relative_abundance) (count data, with or without [zero-inflation](#mods_zero_inflation) and/or [overdispersion](#mods_overdispersion)), even if the model type used can account for [imperfect detection](#imperfect_detection) explicitly (e.g., combined occurrence/[relative abundance](#mods_relative_abundance); [N-mixture models](#mods_n_mixture)).

Variability in sampling effort amongst cameras can be accounted for in many approaches (e.g., for count data, an "offset" can be used to convert the count to a rate per unittime while still abiding by the [assumption](#mods_modelling_assumption)s of count-distributed data [Gallo et al., 2022; Moll et al., 2020]).

### Survey effort – Total number of camera days

The [**total number of camera days**](#total_number_of_camera_days) is the number of days that all cameras were active during the[survey](#survey). [Appendix A - Table A2](#surv_guidelines_table_a2) provides recommendations on the minimum number of [total number of camera days](#total_number_of_camera_days).

An adequate sample size (in terms of the [total number of camera days](#total_number_of_camera_days)) in multiple seasons is often required to capture seasonal variation in [occupancy](#occupancy) or [detection rates](#detection_rate). As a general guideline, Kays et al. (2020) recommended that cameras run for 3-5 weeks across 40-60 sites per array and that small-scale variation in [detection probability](#detection_probability) across sites (e.g., microhabitats) should be accounted for in subsequent statistical analyses.

Becker et al. (2022) evaluated how the [effective detection distance](#effective_detection_distance) of cameras changed across species, habitat type and season. [Effective detection distance](#effective_detection_distance) refers to the distance from a camera that would give the same number of detections if all animals up to that distance are perfectly detected, and no animals that are farther away are detected; Buckland [1987], Becker et al. [2022]). In general, deploying more cameras and/or for longer durations always resulted in more precise estimates (Becker et al., 2022).

### Species rarity

Species' rarity can influence the ideal number of cameras and[survey](#survey) length (Chatterjee et al., 2021) (see also [section 6.4.2](#_Survey_effort_–)). Low [detection probability](#detection_probability) of rare or cryptic species can result in imprecise estimates if there are too few cameras or if cameras are not deployed for long enough (e.g., Steenweg et al. 2019). Chatterjee et al. (2021) suggested that for [occupancy models](#mods_occupancy) (MacKenzie et al., 2002) of common species, to survey a minimum of 50 sites for 15–20 days. For rare, elusive species, they recommended surveying 100 sites at a minimum for 20–30 days (Chatterjee et al., 2021).

### Number of cameras vs. Camera days per camera location

If a user must choose between more cameras *vs.* fewer cameras with longer [surveys](#survey), Chatterjee et al. (2021) suggested that for rare species, the optimal precision can be obtained by increasing the number of sites, whereas for common species, increasing the number of samples is more effective. For measuring species richness, Si et al. (2014) found that rotating cameras to new sites was more efficient than leaving cameras at fewer sites for longer periods. O’Connor et al. (2017) also recommended utilizing more cameras *vs*. increasing study length to increase [detection probabilities](#detection_probability). [Spatially explicit capture-recapture (SECR; Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008)](#mods_scr_secr) models were the only models shown to be quite robust to small camera quantities, with just spacing cameras farther out being a more efficient way to increase precision (Sollmann et al., 2012).

In general, regardless of species and [objective](#survey_objectives), increasing the number of [survey](#survey) locations or the [survey](#survey) length improved precision (Chatterjee et al., 2021). Tools such as the [secrdesignapp](https://www.stats.otago.ac.nz/secrdesignapp/) can help camera users determine the optimal study design for improved precision (Efford & Boulanger, 2019).

### Survey timing

The season of the [survey](#survey) should be considered when designing a remote camera study. [Detection probability](#detection_probability) of species may vary seasonally due to changes in species movement rates, behaviour, use patterns, and vegetation growth. Certain species may not be detectable during certaintimes of year (e.g., hibernation or migration; Kays et al., 2020). Other species have seasonal activity patterns (e.g., birthing period, wet/dry seasons) that influence [detection probability](#detection_probability) and, thus, the data collected.

# Camera deployment

Once the[project](#project)-level aspects of a [survey](#survey) have been decided, the next step is to consider the camera hardware options (e.g., [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make)), camera settings, field equipment, whether to use attractants ([bait](#baitlure_bait) or [lure](#baitlure_lure)), camera placement considerations, and important metadata to collect.

## Camera hardware options

Remote cameras consist of a digital camera with a lens, external flash, and a passive infrared and/or motion detector (among other features; [Figure 4](#surv_guidelines_fig_4)).

A close-up of a camera

Description automatically generated

**Figure 4.** Examples of the a) external components and b) internal controls and components of a remote camera (Reconyx PC900) (Reconyx Inc., [2017]).

The camera “make” is the manufacturer of a particular camera (e.g., Reconyx), and the “model” is the model number of a particular camera (e.g., PC900). There are many different options and features to choose from when deciding upon the best [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make) for a particular study, which differ in their impacts on [detection probability](#detection_probability). For this reason, deploying multiple [Camera Model](#camera_model)s within a study is not advisable (Palencia et al., 2022; Wellington et al., 2014).

It is common for new camera users to confuse the specifications of a particular [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make) with the camera’s settings. Specifications refer to the camera’s features (characteristics), while settings are options that the user can change. When choosing a [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make), important specifications include [trigger speed](#trigger_speed), [recovery time](#recovery_time), [detection zone](#detection_zone) (i.e., the area [conical in shape] in which a remote camera can detect the heat signature and motion of an object [Rovero & Zimmermann, 2016; see [Figure 5](#surv_guidelines_fig_5)), battery life and flash type. The best choice of [Camera Model](#camera_model) will depend on the [Survey Objectives](#survey_objectives), [modelling approach](#mods_modelling_approach), [Target Species](#target_species), and physical environment.

Here are a few examples of specifications to achieve certain [Survey Objectives](#survey_objectives):

* To estimate [density](#density) with the [random encounter models (REM;](#mods_rem) [density](#density)) approach – use a camera with a fast [trigger speed](#trigger_speed), a wide [detection zone](#detection_zone), no-glow infrared (IR) flash, and the ability to take bursts of photos (Rovero et al., 2013).
* To estimate [density](#density) or abundance with mark-recapture methods – use a camera with a white flash, a short [recovery time](#recovery_time), and a fast [trigger speed](#trigger_speed) (Rovero et al., 2013). Note that white flashes may scare some animals and potentially reduce the number of recaptures (Séquin et al., 2003; Wegge et al., 2004).
* [Occupancy studies](#mods_occupancy) need a fast [trigger speed](#trigger_speed) ([Trigger Sensitivity](#settings_trigger_sensitivity) - high) (although the importance of which is species-dependent; Rovero et al., 2013).
* Faunal detections generally require a fast [trigger speed](#trigger_speed) ([Trigger Sensitivity](#settings_trigger_sensitivity) - high) and a wide [detection zone](#detection_zone).

***Note:*** most [modelling approaches](#mods_modelling_approach) require a fast [trigger speed](#trigger_speed) (however, the use of [bait](#baitlure_bait) or [lure](#baitlure_lure) may compensate for slower [trigger speeds](#trigger_speed) in some cases).

Given the numerous [Camera Model](#camera_model)s available and the frequent release of new models, it would be difficult to recommend a make and model to fit all users' needs. However, there are many studies and reviews that compare the specifications and the utility of different [Camera Model](#camera_model)s (e.g., see <https://www.trailcampro.com/collections/trail-camera-reviews>; <https://www.mammalweb.org/images/schools/Camera-trap-buying-guide.pdf>; Fisher & Burton, 2012; Rovero et al., 2014; Rovero & Zimmermann, 2016; Seccombe, 2017; Wearn & Glover-Kapfer, 2017).

Chart, funnel chart

Description automatically generated

**Figure 5.** The ability to detect an animal will vary according to the camera specifications (and settings). Important specifications include the camera’s [detection zone](#detection_zone) (here termed “trigger area”), [Field of View (FOV](#field_of_view); “viewable area’), and “[registration area](#fov_registration_area)“ (the area in which an animal entering has at least some probability of being captured on the image) (Moeller et al., 2023).

### Battery type

Most remote cameras require AA batteries. It is recommended to use **lithium batteries,** as opposed to alkaline or nickel metal hydride, because they are less affected by cold temperatures. Battery life will be affected not only by the type of batteries but also by the camera settings, temperature, and number of images or videos taken (which are dependent on the camera settings, placement, and level of activity in front of the camera) (Wearn & Glover-Kapfer, 2017). However, some camera user manuals contain information on battery performance and the total number of images a camera can be expected to collect before the batteries die (based on the operating temperature and battery type, e.g., [Reconyx HyperFire Instruction Manual](https://images.reconyx.com/file/HyperFireManual.pdf) [Reconyx Inc., 2017]).

### SD cards

It is important to consider the **size**, **type**, and **class** of **SD (Secure Digital) card** since the available options vary in storage capacity, compatibility, and write-speed (Wearn & Glover-Kapfer, 2017).

The **size of the SD card** (i.e., storage capacity) should be considered in relation to the expected duration of [deployment](#deployment), the deployment area, and the level of activity expected to occur in front of the camera. For example, a camera placed in a grassy area might be expected to produce more [false triggers](#false_trigger) due to grass waving in front of the camera. Or perhaps a camera placed near a den might be expected to have higher animal activity. Both situations might warrant using a larger SD card. A 4 GB SD card is capable of storing ~8,000-20,000 images (400-900 KB in size), which might be sufficient if you plan to revisit the camera frequently (~every four weeks) (Wearn & Glover-Kapfer, 2017). We suggest using a card with at least 16 GB, and Wearn & Glover-Kapfer (2017) suggest larger (32 GB) if the video is enabled or if the camera will be active for long periods.

There are three **types of SD card:** standard (SD; maximum memory of 2 GB), high-capacity (SDHC; maximum memory of 32 GB) and extended-capacity (SDXC; maximum memory of > 32 GB) (Wearn & Glover-Kapfer, 2017). Note that SDHC cards are not compatible with most [Camera Model](#camera_model)s. Be sure to check the camera user manual to confirm the compatible SD card type(s) (Wearn & Glover-Kapfer, 2017).

The **“class” of an SD card** (e.g., class 2, 4, 6, or 10) indicates the “write-speed” (i.e., the speed at which the SD card can read and write data; Wearn & Glover-Kapfer, 2017). Slower write speeds may perform poorly if the camera is set to collect images continuously, as fast as possible (i.e., rapid-fire or “near-video”) or if the video setting is activated. It is recommended to use an SD card of class 4 or higher, ideally class 10 (Wearn & Glover-Kapfer, 2017).

Caution should be used when deploying older SD cards (Wearn & Glover-Kapfer, 2017) and, perhaps, microSD card types; a few remote camera users in Alberta have described a 50% SD card failure rate with microSD cards (St. Clair, personal communications). See Wearn & Glover-Kapfer (2017) for additional information on choosing and maintaining (i.e., regularly formatting) SD cards.

## Camera settings

As mentioned above, in [camera hardware options](#_camera_hardware_options), it is important to distinguish between camera specifications (features) versus settings (user-defined options). Important settings often include [Trigger Sensitivity](#settings_trigger_sensitivity) (which may affect [detection probability](#detection_probability)), [Motion Image Interval](#settings_motion_image_interval) and [Quiet Period](#settings_quiet_period). The setting option selected may vary according to the [Survey Objectives](#survey_objectives), [modelling approach](#mods_modelling_approach), [Target Species](#target_species), and use (or not) of attractants. Consideration of the camera settings is an important step when designing a [survey](#survey)and in the interpretation of the resulting images.

An example of the settings available in a Reconyx camera is included in [Appendix A - Table A3](#surv_guidelines_table_a3).

### Photos vs. video

Some [Camera Model](#camera_model)s allow the user to record video as well as photos. Videos typically use more memory on SD cards, drain camera batteries sooner and are more difficult to process (i.e., extract data) than images. Limiting the length of video taken when the camera is [triggered](#trigger_event) (possible for most [Camera Model](#camera_model)s) could help slow how quickly an SD card becomes full. Some [Camera Model](#camera_model)s have hybrid settings, which lets you capture photos and videos for each animal detection.

It is generally recommended that cameras are set to capture images rather than videos unless the [objective](#survey_objectives) is related to monitoring animal behaviours, understanding group size and/or determining recruitment (e.g. calves per female), in which case continuous observation may be important. Video is also useful when individual identification is needed, such as for creating “marked” individuals for use in machine learning or computer vision (e.g., Schneider et al., 2019; Vidal et al., 2021).

By default, cameras are set to record images when an animal is detected by the motion and/or infrared detector(s).

### Trigger Mode(s) – Time-lapse vs. motion detector

By default, remote cameras are [triggered](#trigger_event) to take photos when the motion detector detects an animal. Many [Camera Model](#camera_model)s allow you to set your camera in both [time-lapse](#timelapse_image) and default motion detector settings.

[Time-lapse images](#timelapse_image)are images taken at regular intervals (e.g., hourly or daily, on the hour), regardless of whether an animal is present or not. It is critical to take a minimum of one[time-lapse image](#timelapse_image) per day at a consistent time (e.g., 12:00 p.m. [noon]) to create a record of camera functionality or local environmental conditions (e.g., snow cover, plant growth, wildfire; Sun et al., 2021)

[Time-lapse images](#timelapse_image) may always be useful for [modelling approaches](#mods_modelling_approach) that require estimation of the “[viewshed](#fov_viewshed)“ (i.e., “[viewshed density estimators](#fov_viewshed_density_estimators),” such as [REM](#mods_rem) or [time-to-event (TTE)](#mods_tte) models; see Moeller et al., [2018] for advantages and disadvantages).

### Trigger Sensitivity, Photos Per Trigger, Motion Image Interval, and Quiet Period

The[**Trigger Sensitivity**](#settings_trigger_sensitivity) is camera setting responsible for how sensitive a camera is to activation (to "[triggering](#trigger_event)") via the infrared and/or heat detectors (if applicable, e.g., Reconyx HyperFire cameras have a choice between "Low," "Low/Med," "Med," "Med/High," "High," "Very high" and "Unknown"). That is, how the camera is activated once the animal enters the [detection zone](#detection_zone). A high [Trigger Sensitivity](#settings_trigger_sensitivity) is ideal when estimating [density](#density) or abundance using mark-recapture or [occupancy modelling](#mods_occupancy) (Rovero et al., 2013). The more easily (and faster) the camera is [triggered](#trigger_event), the more likely it is to photograph approaching animals as they enter the area (Apps & McNutt, 2018). High [Trigger Sensitivity](#settings_trigger_sensitivity) (and fast [Motion Image Intervals](#settings_motion_image_interval)) are less necessary if attractants are present (Rovero et al., 2013). Refer to [section 6.2](#_Site_selection_and) for examples of ideal [Trigger Sensitivity](#settings_trigger_sensitivity) settings to achieve certain [Survey Objectives](#survey_objectives).

The camera user can also predefine the number of photos taken each time the camera is [triggered](#trigger_event) (i.e., “[Photos Per Trigger](#settings_photos_per_trigger), e.g., 1, 2, 3, 5 or 10 photos). The user can specify the time interval between images (i.e., the “[Motion Image Interval](#settings_motion_image_interval)“) or the time interval between image [sequences](#sequence) (i.e., the “[**Quiet Period**](#settings_quiet_period)“ or “time lag,” depending on the [Camera Make and Camera Model](#camera_make)). The [Quiet Period](#settings_quiet_period) differs from the [Motion Image Interval](#settings_motion_image_interval) in that the delay occurs between multi-image [sequences](#sequence) rather than between the images contained within multi-image [sequences](#sequence) (as in [Motion Image Interval](#settings_motion_image_interval)). Setting the camera to take continuous photos (i.e., the [Quiet Period](#settings_quiet_period) set to “no delay”) will fill the SD card with more photos per detection; however, it may provide important information for identifying individual animals, determining enter-leave times and regarding animal behaviours / interactions.

Generally, it is recommended to set the [Trigger Sensitivity](#settings_trigger_sensitivity) to “high,” [Photos Per Trigger](#settings_photos_per_trigger) to “1” and the [Quiet Period](#settings_quiet_period) to “no delay” between consecutive [triggers](#trigger_event) ([Appendix A - Table A3](#surv_guidelines_table_a3)).

## Attractants *vs.* no attractants

Attractants (i.e., [bait](#baitlure_bait) or [lure](#baitlure_lure)) can increase the [detection probability](#detection_probability) by drawing animals into the camera’s [detection zone](#detection_zone), thereby effectively increasing the sampled area.

[Bait](#baitlure_bait) is a food item (or other substance) that is placed to attract animals via the sense of taste and olfactory cues (Schlexer, 2008). [Lure](#baitlure_lure) is any substance that draws animals closer; [lures](#baitlure_lure) include [scent (olfactory) lure](#baitlure_scent_lure), [visual lure](#baitlure_visual_lure) and [audible lure](#baitlure_audible_lure) (Schlexer, 2008).

There are many options of [bait](#baitlure_bait) and [lure](#baitlure_lure) available, and those used in camera studies have included commercial [scent lures](#baitlure_scent_lure), food [bait](#baitlure_bait)s, carcasses and compact disks (see Wearn & Glover-Kapfer, 2017 for details and examples). [Scent lure](#baitlure_scent_lure) is typically applied to objects in the [detection zone](#detection_zone) (e.g., trees or rocks), whereas a food [lure](#baitlure_lure) is generally hung up or placed behind wire mesh to limit tampering by animals. Food rewards ([baits](#baitlure_bait) or carcasses) are also used but are more likely to influence behaviour and inter- and intra-specific interactions (e.g., avoidance of an area or conflict between individuals or species) and may result in food conditioning, which in turn may lead to human-wildlife conflict.

Some options are costly and require frequent reapplication during the[survey](#survey) [deployment](#deployment). Users should consider the additional cost of supplies and labour required to revisit the field to reapply at the frequency necessary to maintain effectiveness. [Scent lure](#baitlure_scent_lure) dispensers, such as those developed by the Woodland Park Zoo, may help reduce the number of visits needed for reapplication and associated costs.

Few studies have compared the efficacy of different types of attractants, but both Espartosa et al. (2011) and Thorn et al. (2009) suggested that food [baits](#baitlure_bait) are more effective than [scent lures](#baitlure_scent_lure) for many species (although these evaluations did not include wildlife species from Canada).

Since species may respond to [lure](#baitlure_lure) types and scents differently, the type of [lure](#baitlure_lure) chosen (if any) should be based on the biology of the [Target Species](#target_species) but also on the[Survey Objectives](#survey_objectives) and the[survey](#survey) environment. For example, liquid products may be less suitable in areas where precipitation is high. Some [lure](#baitlure_lure) types smell like the urine of a particular species, which could result in higher detections of certain species by activating an investigative response while resulting in avoidance by other species. Interestingly, a [study](https://www.biorxiv.org/content/10.1101/2020.01.30.926618v1.abstract) (Holinda et al., 2020) by members of WildCAM found no evidence that [scent lure](#baitlure_scent_lure) placed at camera stations repelled non-target (i.e., prey) animals (see also Mills et al., 2019); rather, both predators and prey showed varied responses to the [scent lure](#baitlure_scent_lure).

For many [modelling approaches](#mods_modelling_approach), placing [bait](#baitlure_bait) or [lure](#baitlure_lure) may violate [model assumptions](#mods_modelling_assumption) and increase the likelihood of biased results (e.g., [lure](#baitlure_lure) might amplify measures of occurrence, biasing estimates of space use [Stewart et al., 2019]). Attractants may also introduce variation in the response by species, individuals or [Sex Class](#sex_class)es (or over space ortime) that would not naturally occur. It may be possible to address biased samples in the analysis stage, but this can require substantial amounts of data.

In contrast, placing [bait](#baitlure_bait) or [lure](#baitlure_lure) can also help to better satisfy the [assumptions](#mods_modelling_assumption) of some [modelling approaches](#mods_modelling_approach). For example, attractants might be deployed to help satisfy the [assumption](#mods_modelling_assumption) of constant [detection probability](#detection_probability) of [occupancy](#mods_occupancy) (when using a [systematic random design](#sampledesign_systematic_random)), [relative abundance](#mods_relative_abundance) and [capture-recapture (CR](#mods_cr_cmr); Karanth, 1995; Karanth & Nichols, 1998) models by increasing individuals’ [detection probability](#detection_probability) (Wearn & Glover-Kapfer, 2017).

[Bait](#baitlure_bait) or [lure](#baitlure_lure) may be a “necessity” for species (or areas) where detection is unlikely without a large number of remote cameras or lengthy[surveys](#survey). Most studies that use attractants target carnivore species, which are often elusive, difficult to monitor and occur at low densities.

In general, we recommend against the use of [bait](#baitlure_bait) or [lure](#baitlure_lure) for [project](#project)s focused on unbiased detection of as many species as possible. Overall, the use of attractants is not recommended unless the study is an [occupancy](#mods_occupancy) or [capture-recapture](#mods_cr_cmr) study of a [Target Species](#target_species) with low [detection probability](#detection_probability) (Wearn & Glover-Kapfer, 2017).

We advise against the use of [bait](#baitlure_bait) in or near urban areas due to the possible increase in human-wildlife conflict. To minimize this potential, [bait](#baitlure_bait) or [lure](#baitlure_lure) should not be placed within 200 m of residences, industrial or recreational facilities, campgrounds, 100 m of active human-use trails (e.g., hiking trails), or 50 m of roads.

Where attractants are used, users must follow provincial policy and legislation (e.g., [BC Wildlife Act – Section 33.1](https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/00_96488_01#section33), [Alberta Wildlife Act](https://open.alberta.ca/publications/w10#:~:text=The%20Act%20provides%20for%20the,controlled%20animals%20and%20endangered%20species.) and [Wildlife Regulation](https://open.alberta.ca/publications/1997_143)), as well as local bylaws. Before deploying any remote cameras in the field, users must also obtain the necessary permits from provincial and/or research institutions (e.g., animal care permits). In Alberta, a wildlife research and collection permit is required when using [bait](#baitlure_bait) or [lure](#baitlure_lure). Special conditions or restrictions may also apply. Refer to <https://www.alberta.ca/wildlife-research-and-collection.aspx> for further details. In British Columbia, a research permit is required when using [bait](#baitlure_bait), but not [scent lure](#baitlure_scent_lure). Special conditions or restrictions may also apply in each province.

Consideration of placement locations should include proximity and potential impacts to First Nations Reserves and Metis Settlements. You can find information on First Nations Reserves and Metis Settlements using the [[Landscape Analysis Indigenous Relations Tool (LAIRT)](https://www.alberta.ca/proponent-led-indigenous-consultations.aspx)](https://www.alberta.ca/proponent-led-indigenous-consultations.aspx) (Government of Alberta, 2023a) located within the [[Landscape Analysis Tool (LAT)](https://www.alberta.ca/lat-overview.aspx)](https://www.alberta.ca/lat-overview.aspx) (Government of Alberta, 2023b) (see “Non-Administered Areas”). The results produced by LAIRT do not provide an official list of First Nations and Metis settlements to consult if consultation is required since “LAIRT will report on where government ordinarily considers requiring consultation with a particular First Nation or Metis Settlement, which is subject to be revised at any time” (Government of Alberta, 2023a).

## Camera placement

When deploying a remote camera, important considerations include whether to place cameras on or aim cameras toward specific features, as well as the attachment point, [height](#camera_height),  [[angle](#Camera_angle)](#camera_angle) and [direction](#camera_direction).

The information in this section is also included in a step-by-step description of the [deployment](#deployment) process ([Appendix A - Table A5](#surv_guidelines_table_a5)).

### FOV Target Feature

Remote cameras may be deployed to capture detections on specific man-made or natural features (i.e., “[**FOV Target Feature**](#fov_target)“) to maximize the detection of wildlife species or to measure the use of that feature. [FOV Target Features](#fov_target) may include, for example, game trails, human trails, watering holes, mineral licks, rub trees, nest sites, etc.

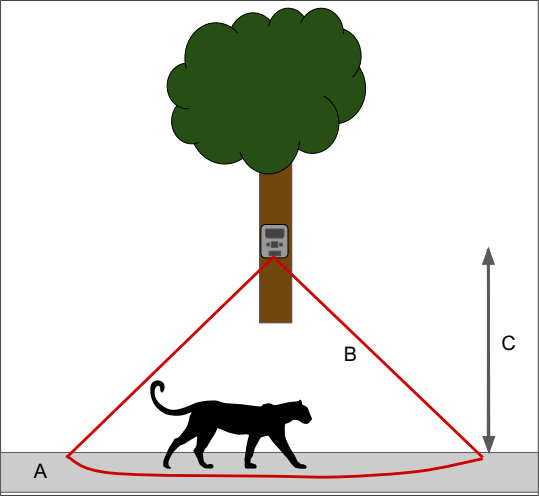
[FOV Target Features](#fov_target) differ from [Camera Location Characteristics](#camera_location_characteristics) (see below) in that [FOV Target Features](#fov_target) are features the camera is aimed towards (e.g., a seismic line). In contrast, a [Camera Location Characteristics](#camera_location_characteristics) may include features outside of the camera’s [FOV](#field_of_view) (e.g., meadow habitat).

The decision of where exactly to place the camera will be influenced by the feature to target, the [Survey Objectives](#survey_objectives) and the number of [Target Species](#target_species), and, importantly, the sampling design, intended analysis and associated statistical [assumption](#mods_modelling_assumption)s.

Deploying cameras on or near [FOV Target Features](#fov_target) can provide meaningful information for some [objectives](#survey_objectives), but often introduces detection biases (Wearn & Glover-Kapfer, 2017). These biases make it difficult to extrapolate findings to areas without these features or to collect data on multiple [Target Species](#target_species) that vary in their use of these features (Wearn & Glover-Kapfer, 2017). To reduce potential biases, cameras should ideally be deployed using a [paired design](#sampledesign_paired), with cameras on- and off-[FOV Target Features](#fov_target) (e.g., on- and off-trails).

In general, cameras should be placed approximately **3–5 m from the** [FOV Target Feature](#fov_target) ([Figure 6](#surv_guidelines_fig_6); the “[FOV Target Feature Distance (m)](#fov_target_distance)“ [[Figure 7](#surv_guidelines_fig_7)]). If cameras are placed too close to the [FOV Target Feature](#fov_target), some species may not be detected since the camera may be too high to capture smaller species or the movement speed of certain species. In contrast, if cameras are placed too far from the [FOV Target Feature](#fov_target) (e.g., > 5 m), animals detected at night may not be visible in the images because they are less likely to be illuminated by the infrared flash.

This recommendation can be relaxed if users plan to estimate the [detection distance](#detection_distance) (i.e., “the maximum distance that a sensor can detect a target” [Wearn and Glover-Kapfer, 2017]) and account for variability in [detection probability](#detection_probability).



**Figure 6.** Illustration of a remote camera showing (A) the [FOV Target Feature](#fov_target) (a trail), (B) the camera’s [detection zone](#detection_zone) (everything inside the red outline), and (C) the distance of the camera to the [FOV Target Feature](#fov_target). Note that the [detection zone](#detection_zone) will vary according to [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make). Camera users will need to identify a suitable attachment point (e.g., tree, fence post/ stake) near the target area. The most suitable attachment point will depend on the [Camera Height](#camera_height), [[angle](#Camera_angle)](#camera_angle), and [direction](#camera_direction) since these choices will impact the [FOV](#field_of_view) (see [section 7.4](#_camera_placement)). Figure from WildCAM Network (2019).

### Camera height

The [**Camera Height**](#camera_height)is the height from the ground (below snow) to the bottom of the lens (metres; to the nearest 0.05 m). Cameras should be positioned and secured to an attachment point at **~0.5–1 m height** (from the ground to the bottom of the lens; Meek et al., 2014). The most appropriate [Camera Height](#camera_height) will be influenced by the terrain (e.g., slope), the angle of the tree, as well as the [Target Species](#target_species). Cameras placed closer to the ground reduce the probability that large animals (e.g., moose) will be fully in the frame in the photos. Similarly, if the camera is placed too high, only larger animals will activate the motion detector, and smaller species may be missed (e.g., hares, squirrels, marten) (Meek et al., 2016). The user should ensure that the [Camera Height](#camera_height) adequately detects motion at a specified [Walktest Distance (m)](#walktest_distance) and [Walktest Height (m)](#walktest_height). If snow is a consideration, users may need to place cameras higher or plan to revisit seasonally to adjust as needed, being sure to record adjustments that could affect [detection probability](#detection_probability).

### Camera angle

The **Error! Hyperlink reference not valid.** is the degree to which the camera is pointed towards the [FOV Target Feature](#fov_target) relative to the horizontal ground surface (with respect to slope, if applicable). The [camera angle](#camera_angle) differs from the camera [viewshed](#fov_viewshed) angle, which is the area visible to the camera as determined by its camera lens angle and trigger distance (Moeller et al., 2023).

Cameras should be **angled slightly downward**, such that they should be able to detect both small and large species at a target distance of approximately **3–5 m** from the camera and/or the user ensures that the [[angle](#Camera_angle)](#camera_angle) adequately detects motion at a specified [Walktest Distance (m)](#walktest_distance) and [Walktest Height (m)](#walktest_height). Cameras should not be angled upwards, as upward facing angleswill result in fewer detections, especially of smaller species (Glen et al., 2013). If snow is a consideration, users may need to angle cameras higher or plan to revisit seasonally to adjust as needed, being sure to record adjustments that could affect [detection probability](#detection_probability).

### Camera direction

The [[Camera Direction](#Camera_direction)](#camera_direction) is the cardinal direction that a camera faces. Cameras are usually positioned to maximize detections of the [Target Species](#target_species) (except when [random](#sampledesign_random) placement is required).

The direction a camera faces is an important consideration because it affects the amount of light that reaches the area, which has implications for both [detection probability](#detection_probability) and image quality (reduced quality via sun glare). Ideally, cameras should face north (N, i.e. “0” degrees), or south (S; i.e. “180” degrees) if north is not possible. Sun glare is the most problematic for cameras that face east or west by causing [false triggers](#false_trigger) unless there is thick tree cover blocking the sun (standing water may also produce similar problems with sun glare).

The camera direction should be chosen to ensure the field of view (FOV) is of the original FOV target feature. Generally, cameras should be placed **perpendicular to the expected direction of animal travel** (e.g., along a game or human trail). Since there is a delay between when an animal enters the camera’s [detection zone](#detection_zone) and when it captures an image, placing the camera perpendicular to the trail increases the likelihood that an animal will be in the frame when the camera [triggers](#trigger_event) (Apps & McNutt, 2018). The delay is typically < 1 s, depending on the [trigger speed](#trigger_speed) for a particular camera and the settings applied. The size of the [detection zone](#detection_zone) will depend on the [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make).

### Field of View (FOV) and Walktest

It is important to try to ensure an unobstructed [Field of View (FOV)](#field_of_view) from the camera to avoid impairing the [detection rates](#detection_rate) of wildlife (or humans). Moll et al. (2019) reported decreased [detection rates](#detection_rate) with increasing obstruction for most mammals in their study and two- to three-fold decreases in detections per week per camera. They concluded that it was critical to account for [viewshed](#fov_viewshed) obstruction when interpreting [detection rates](#detection_rate) as indices of abundance and habitat use.

To determine a camera’s [FOV](#field_of_view), a [walktest](#walktest) should be performed every time a camera is deployed or re-positioned. See the camera’s user manual for instructions on how to perform the [walktest](#walktest) for your particular [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make) (see also [Appendix A - Table A5](#surv_guidelines_table_a5)).

An **unobstructed** [**FOV**](#field_of_view) **of at least 5 m wide and 10 m long** is ideal for capturing wildlife images in most cases. To achieve this desired [FOV](#field_of_view), ensure that the camera is detecting motion 5 m in front of the camera, at both 0 m and 0.5–1 m heights ([Figure 7](#surv_guidelines_fig_7)).

This may require repositioning the camera to avoid large objects (e.g., rocks, logs) and/or trimming or removing vegetation that interferes with the visibility of the target area (or is likely to in the future). These objects may block areas within the camera’s [FOV](#field_of_view) and reflect the flash, making it more difficult to detect animals at night. Trimming or removing vegetation will also minimize the likelihood of [false triggers](#false_trigger)(i.e., blank images (no wildlife or human present) that can occur because of blowing vegetation). [False triggers](#false_trigger) will drain batteries and fill SD cards and increase the time to process images.

Important considerations with respect to [FOV](#field_of_view) include:

* Situations (e.g., open habitats) where animals in background my be viewable but would not trigger the detector (sensor),
* how animals in the distance should be treated (i.e., at what distance is an animal captured in an image no longer considered a detection)

Placing a stake in front of the camera at a specified distance (i.e., the “stake distance”) is one method used to standardize the [FOV](#field_of_view). Applying a standardized reference distance can help with interpretation and analysis (ABMI, 2021).

A picture containing diagram

Description automatically generated

**Figure 7.** The [**Walktest Distance**](#walktest_distance) and [**Walktest Height**](#walktest_height) are the horizontal and vertical distances from the camera, respectively, at which the user performs the walk test. A [walktest](#walktest) should be performed 5 m away from the camera, at both 0 m (ground) and 0.5–1 m height.

### Test image

A [**test image**](#test_image)is an image taken from a camera after it has been set up to provide a permanent record of the [visit metadata](#visit_metadata) (e.g., Sample Station Name, Camera Location Name, Deployment Name, Crew, and Deployment Start Date Time [DD-MMM-YYYY HH:MM:SS]). Taking a [test image](#test_image) can be useful to compare the information from the [test image](#test_image) to that which was collected on the [Camera Service/Retrieval Field Datasheet](#_camera_Service/Retrieval_Field) after retrieval, which can help in reducing recording errors.

A [test image](#test_image) should each include a [Test Image Sheet](#test_image_sheet) or whiteboard with information on the [Sample Station Name](#sample_station_name), [Camera Location Name](#camera_location), Crew, and [Deployment Start Date Time (DD-MMM-YYYY HH:MM:SS)](#deployment_start_date_time).

See [Appendix A - Table A5](#surv_guidelines_table_a5) for details on how to capture a [test image](#test_image), and to the provided [Test Image Sheet](#test_image_sheet).

### Deployment area photos (optional)

It is useful to collect photos of the area around the [camera location](#camera_location) (i.e., [**deployment area photos**](#deployment_area_photos)) as a permanent, visual record of the [FOV Target Features](#fov_target), [Camera Location Characteristics](#camera_location_characteristics), environmental conditions (e.g., vegetation, ecosite, or weather),or other variables of interest.

Take [deployment area photos](#deployment_area_photos) with a handheld digital camera or phone at each [camera location](#camera_location) at deployment, service and retrieval. The recommendation includes collecting four photos taken from the centre of the target detection zone ([Figure 5](#surv_guidelines_fig_5)), facing each of the four cardinal directions. The documentation of the collection of these photos is recorded as "deployment area photos taken" (Y/N).

Record the image numbers (e.g., DSC100; “[Deployment Area Photo Numbers](#deployment_area_photo_numbers)“) for each set of camera [deployment area photos](#deployment_area_photos) on a [[Camera Deployment Field Datasheet](#_Camera_Deployment_Field)](#_camera_deployment_Field).

### Camera location characteristics

**[Camera Location Characteristics](#“camera_location_characteristics”)** are any significant features around the camera at the time of the visit. This may include for example, manmade or natural linear features (e.g., trails), habitat types (e.g., wetlands), wildlife structure (e.g., beaver dam). [Camera Location Characteristics](#camera_location_characteristics) differ from [FOV Target Features](#fov_target) in that [Camera Location Characteristics](#camera_location_characteristics) could include those not in the camera's Field of View.

Researchers typically record information about the environment at [camera locations](#camera_location) to better understand how this might affect animal occurrence or behaviour. It is recommended to record all [Camera Location Characteristics](#camera_location_characteristics) and upload these to a digital data-collection platform with private or open settings like [Epicollect](https://five.epicollect.net/) (https://five.epicollect.net/), using the template provided. Alternatively, you may choose to upload these photos using species identification models to an open-source platform like [inaturalist](https://inaturalist.ca) (https://inaturalist.ca), [WildTrax](https://ualbertaca-my.sharepoint.com/personal/cjsteven_ualberta_ca/Documents/RCSC_RC-Survey-Guidelines_AB-Metadata-Standards/WildTrax) (http://www.wildtrax.ca/) and/or [FWMIS](https://www.alberta.ca/fisheries-and-wildlife-management-information-system-overview.aspx).

### Field equipment

Refer to [Appendix A - Table A4](#surv_guidelines_table_a4) for a recommended list of field equipment for remote camera studies.

## Metadata

[Metadata](#metadata) (i.e., data that provides information about other data) is critical to any scientific study or monitoring program. It helps to ensure that data are consistent and accurate and facilitates data sharing across [project](#project)s. Alberta and British Columbia have established [metadata](#metadata) standards ([AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) [RCSC, 2024] and the [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) [RISC, 2019]) that all camera [project](#project)s in the provinces should follow. In these guidelines, we focus on the metadata fields that pertain to the deployment of cameras, which should be collected when the user “visits” the location.

***Note:*** These guidelines do not describe all fields relevant to/required by the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) and [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019). Similarly, there may be additional/alternative fields required by the Alberta Government’s [FWMIS loadform](https://www.alberta.ca/wildlife-loadforms.aspx) for camera studies (https://www.alberta.ca/wildlife-loadforms.aspx) compared to those within these guidelines or the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024). Every effort has been made to align the various sources where possible.

### Metadata – Deployment, Service and Retrieval

A **visit** is when a [crew](#crew) has gone to a location to deploy (“[deployment visit](#deployment_visit)“), service, or retrieve (“[service/retrieval visit](#service_retrieval_visit)“) a remote camera.

A “**deployment visit**” is when a [Deployment Crew](#deployment_crew) has gone to a location to deploy a remote camera. Relevant [metadata](#metadata) should be recorded when a camera is initially set up (deployed) using the [[Camera Deployment Field Datasheet](#_Camera_Deployment_Field)](#_camera_deployment_Field). Each event should have its own [Camera Deployment Field Datasheet](#_camera_deployment_Field).

If a camera is deployed for more than one [survey](#survey), the field [crew](#crew)s will need to revisit the [camera location](#camera_location) to “**service**” the camera and/or equipment (“[Service/Retrieval Crew](#service_retrieval_crew)“; e.g., to refresh batteries or swap out SD cards. If the [Service/Retrieval Crew](#service_retrieval_crew) visits the [camera location](#camera_location) to collect the camera and other equipment (i.e., the [camera location](#camera_location) will no longer be used and cameras, SD cards, and batteries are not replaced), this is referred to as a “**retrieval**” (i.e., the [camera location](#camera_location) will no longer be used, and the camera, SD card, and batteries are not replaced).

Whether the [crew](#crew) services or retrieves the camera, relevant [Service/Retrieval metadata](#service_retrieval_metadata) should be collected if there have been any changes to [[camera location](#Heirch_Camera_location)](#camera_location), sampling period, and/or setting type (e.g., not [baited](#baitlure_bait) and then [baited](#baitlure_bait) later) using the [Camera Service/Retrieval Field Datasheet](#_camera_Service/Retrieval_Field).

***Note:*** the list of [Service/Retrieval metadata](#service_retrieval_metadata) include additional [metadata](#metadata) fields that are not included in the list of [deployment metadata](#deployment_metadata).

Nested under the deployment level of the hierarchy, there are a few “groups” of information that help to comprehend the field metadata; these include:

* Visit Metadata (collected at deployment and service/retrieval)
* Equipment Information (collected at both deployment and service/retrieval; fields vary by visit type)
* Camera Settings (collected at deployment)
* Camera Placement (collected at deployment)
* Site Characteristics (collected at deployment)
* Equipment Checks (collected at both deployment and service/retrieval)
* Image Set Information (collected as a combination of information from deployment and service/retrieval visits metadata)

Refer to [Appendix A - Table A5](#surv_guidelines_table_a5) for a detailed step-by-step and full lists of metadata fields and to the [[Camera Deployment Field Datasheet](#_Camera_Deployment_Field)](#_camera_deployment_Field), and the [Camera Service/Retrieval Field Datasheet](#_camera_Service/Retrieval_Field).

### Spatial information

Coordinates collected in the field are often used to obtain land cover information via GIS and can be imperative to finding [camera location](#camera_location)s later. A large margin of error in collecting coordinates may result in the misclassification of land cover (Robinson et al., 2020) or increase the difficulty of another field [crew](#crew) finding a camera. It is important to record the accuracy(margin of error) of the GPS unit used to record spatial information (coordinates) (i.e., the [GPS unit accuracy](#gps_unit_accuracy),e.g., Garmin GPS devices are accurate to within +/- 15 metres 95% of the time). [GPS unit accuracy](#gps_unit_accuracy) may vary by the make and model of the GPS unit (Hall et al., 2008), but it also may be affected by nearby vegetation, infrastructure, atmospheric interference, etc. (Ganskopp & Johnson, 2007).

### SD card retrieval

When retrieving camera SD cards, remove the SD card from the camera and place it into a SD card case, a 2.25" x 3.5"-coin envelope, or a similar pouch labelled with the [Deployment Name](#deployment_name) and SD card number. If certain camera units are part of a larger[survey](#survey) area, group these pouches into a larger envelope and mark it with the[Project Name](#project_name)/[Survey Name](#survey_name).

# Data management and processing

## Software and tools

There are several software platforms and tools available to help camera users enter metadata as well as store, [process](#image_processing), and analyze their image data (refer to [Table 1](#_heading=h.pv6qcq) for a subset of those currently available). Commonly used platforms include [WildTrax,](https://www.wildtrax.ca/home.html) [Timelapse2](http://saul.cpsc.ucalgary.ca/timelapse/) (Greenberg, 2018), and [eMammal](https://emammal.si.edu/) (McShea et al., 2015). [Reconyx MapView](http://www.reconyx.com/software/mapview) (Reconyx, Holmen, WI, USA) may be especially useful for batch renaming (see [section 8.4](#_Useful_websites)).

For a summary of software programs for managing and processing camera data, refer to Wearn and Glover-Kapfer (2017), Young et al. (2018) and Scotson et al. (2017). For a comprehensive comparison of data platforms and their capabilities, we strongly recommend referring to WildCAM’s “[A comparison of different camera data platforms](https://wildcams.ca/library/camera-trap-software-and-data-management/).”

These guidelines do not endorse any specific remote camera image processing software but do highly recommend the use of such software.

## Data storage (archival)

It is strongly encouraged/may be required that camera datasets (images, [[[deployment area photos](#Deploymnet_area_photos)](#Deploymnet_area_photos)](#deployment_area_photos) and [metadata](#metadata)) are submitted to an open data repository.

There are regulatory requirements to submit data to the [FWMIS database](https://www.alberta.ca/fisheries-and-wildlife-management-information-system-overview.aspx) (not images, although this is strongly encouraged) according to specific government policies (e.g., Sensitive Species Inventory Protocols, Research and Collection permits, etc.). Refer to the Government of Alberta web pages, and the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) and [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019) for further information.

There are other cloud or server-based repositories available to house all camera datasets, including [WildTrax](http://www.wildtrax.ca), [eMammal](https://emammal.si.edu/) (McShea et al., 2015), [Wildlife Insights](https://www.wildlifeinsights.org/) (Ahumada et al., 2019) and others (see Young et al., [2018] for a comparison of 12 available programs for the management of camera data).

[WildTrax](http://www.wildtrax.ca) is the recommended data storage (and data analysis) platform in Alberta. It has multiple privacy options and can accommodate all categories of images that users may prefer to manage separately, including [false triggers](#false_trigger) and images of humans (which require special handling for privacy reasons; see [section 8.2.5](#_Human_images)). All data, including the images, [[deployment area photos](#Deploymnet_area_photos)](#deployment_area_photos) and complete [metadata](#metadata), can be uploaded and stored in the [WildTrax repository](http://www.wildtrax.ca). WildTrax can be used to then collaborate to manage data or share data to answer broader scientific questions.

Users are strongly encouraged to submit all the original images from each [deployment](#deployment) for storage to a data repository. Although only the first image of a [sequence](#sequence) is often used to characterize the [sequence](#sequence), other images within the [sequence](#sequence) provide additional information (e.g., images of all individuals in a group). If it is not possible to submit all of the images from a [deployment](#deployment), ideally, users should submit the image(s) from a [sequence](#sequence) that best represents the [sequence](#sequence) (e.g., those that can be used to verify the species and number of individuals).

## Image processing

[Image processing](#image_processing) is the series of operations taken to extract information from images. In the case of remote camera data, it can include loading the images into a processing platform (see [section 8.4](#_Useful_websites)), extracting information from the image [metadata](#metadata) (e.g., the date and time the image was taken), running an artificial intelligence (AI) algorithm to identify empty images, or [classifying](#image_classification) animals or other entities within the image (see [section 8.2.4](#_Use_of_artificial)).

### Image names

If you wish to rename your images, it is highly recommended that users develop a photo naming convention prior to entering data. Using naming conventions will minimize the risk of having images from different [deployments](#deployment),[study areas](#study_area), or[surveys](#survey) with the same name.

Note that it is not always necessary to rename images. For example, renaming would not be required if data are stored in a folder structure that identifies the [camera location](#camera_location) and the [survey](#survey) from which it was collected). Refer to the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) and [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019) for more information on the suggested naming conventions. Data entry software can be used for batch processing of image names, which can significantly reduce data processingtime compared to renaming images manually (e.g., [Timelapse](http://saul.cpsc.ucalgary.ca/timelapse/)2 [Greenberg, 2018], [Reconyx MapView](http://www.reconyx.com/software/mapview;) [Reconyx, Holmen, WI, USA]) or other tools (e.g., [WildCo Lab’s Image Renamer](https://github.com/WildCoLab/WildCo_Image_Renamer) [WildCo Lab, 2021b]).

### Image classification and tagging

[Image classification](#image_classification) refers to the process of [assigning class labels](#image_classification) to an image according to the wildlife species, other entities (e.g., human, vehicle), or conditions within the image (e.g., snow presence or depth [Sirén et al., 2018]). [Image classification](#image_classification) can be performed manually or automatically by an artificial intelligence (AI) algorithm ([see section 8.2.4](#_Use_of_artificial)). [Classifying images](#image_classification) with AI is commonly used to filter images into relevant categories prior to [image tagging](#image_tagging) (Fennell et al., 2022). [Image classification](#image_classification) is sometimes used interchangeably with “image tagging.”

[Image tagging](#image_tagging) is the process of characterizing wildlife species, other entities (e.g., human, vehicle), or conditions within an image. [Image tagging](#image_tagging) may follow [image classification](#image_classification)to further describe characteristics of individuals (e.g., [Age Class](#age_class), [Sex Class](#sex_class), [Behaviour](#behaviour)), entities within the image, or information about the conditions of the [camera location](#camera_location) (e.g., the [FOV](#field_of_view), presence of [bait](#baitlure_bait) or [lure](#baitlure_scent_lure)) or the environment (e.g., weather).

A single [Analyst](#analyst) (“observer,” “interpreter” or “tagger”) should [tag](#image_tagging) all images from a [deployment](#deployment). At a minimum, the [Analyst](#analyst) should record the species, number of individuals (count), [Age Class](#age_class) and [Sex Class](#sex_class) of wildlife, as well as other entities of interest (e.g., humans).

Refer to the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) and [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019) for more information.

### Use of artificial intelligence (MegaDetector)

Artificial intelligence (AI) has improved the efficiency and precision of [classifying camera images](#image_classification) (Fennell et al., 2022; Norouzzadeh et al., 2020; Tabak et al., 2018). [Microsoft's MegaDetector](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md) (Beery et al., 2019) is the most used AI platform for this purpose. [MegaDetector](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md) (Beery et al., 2019) is a free, open-source platform that [classifies images](#image_classification) as [false triggers](#false_trigger) (“EMPTY”), humans, vehicles or animals based on probability distributions. It indicates the [classification confidence](#image_classification_confidence) for each image, which can be used to filter [false triggers](#false_trigger) (or other unwanted) images from view based on the [confidence level](#image_classification_confidence). The remaining images can then be [tagged](#image_tagging) more efficiently. Studies of [MegaDetector](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md)’s performance in [classifying](#image_classification) images with humans and animals found it to have a higher accuracy rate than [classification](#image_classification) by human observers (99% *vs.* 82%, respectively) and significantly faster processing times (500% higher and 8.4x less time) (e.g., Fennell et al., 2022). MegaDetector also had higher precision and recall when classifying images as ‘empty’ or ‘animal’ than some other AI platforms (Velez et al., 2023). Refer to Velez et al. (2023) for a comprehensive review of the requirements and advantages/disadvantages of MegaDetector relative to other platforms.

Before filtering out images, however, it is important to manually verify the [classification](#image_classification) of a sub-sample of images within each [classification](#image_classification) category ([false triggers](#false_trigger), humans, animals, vehicles). At least 5,000 auto-tagged images should be reviewed each year for each [classification](#image_classification) category.

The online version of [MegaDetector](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md) online does not currently [classify](#image_classification) animals according to species. However, researchers have developed models using [Megadetector](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md) to “train” machine learning algorithms to [classify](#image_classification) species in some regions. Tabak et al. (2018) reported that their models were very accurate for a few more common species (over 97.7%) in their area-of-interest but markedly less accurate for rare species. Since species and ecosystems differ by region, pre-trained models are only applicable to the area in which they were developed.

[MegaDetector](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md) can also be downloaded and run on a Windows-based machine (most simply using [EcoAssist](https://github.com/PetervanLunteren/EcoAssist#windows-installation) (https://github.com/PetervanLunteren/EcoAssist#windows-installation), or images can be submitted to Dan Morris (see https://saul.cpsc.ucalgary.ca/timelapse/pmwiki.php?n=Main.DownloadMegadetector for more information).

Some software, such as [Timelapse](http://saul.cpsc.ucalgary.ca/timelapse/)2 or [WildTrax](https://www.wildtrax.ca/home), can then be used to further [classify](#image_classification) the [MegaDetector](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md) image files by human observers (see Greenberg [2020] for a primer). [WildTrax](https://www.wildtrax.ca/home) automatically uses Megadetector to filter out blank images when data is uploaded to the platform. Some software can incorporate the outputs from Megadetector for species identification (e.g., [Timelapse](http://saul.cpsc.ucalgary.ca/timelapse/)2 [Greenberg, 2018]).

Refer to [Microsoft’s MegaDetector GitHub page](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md) (Beery et al., 2019) or [WILDLABS Tech Tutors tutorial](https://www.wildlabs.net/event/how-do-i-get-started-megadetector) for more information on how to get started.

### Human images

Images that allow for the identification of people (e.g., faces or vehicle license plates) should not be uploaded to some databases for privacy reasons. Detections of humans can be managed locally using specific “face-blurring” tools that are available using some R-scripts (e.g., [WildCoLab’s FaceBlur R-script](https://github.com/WildCoLab/WildCo_Face_Blur) (WildCo Lab, 2021a) or databases (e.g., [WildTrax](https://www.wildtrax.ca/home)). Users should follow the Freedom of Information and Protection of Privacy Act and any other relevant Acts (e.g., British Columbia’s Personal Information Protection Act (PIPA) and Federal Personal Information Protection and Electronic Documents Act (PIPEDA) when collecting and managing data on people.

## Data analysis

There are many analytical resources available online, such as the [step-by-step guide to data exploration and analysis "best" way to explore or analyse your data bookdown](https://bookdown.org/c_w_beirne/wildCo-Data-Analysis/) produced by the WildCo Lab (2021), which includes many helpful examples and tips. New camera users may also find Sollman’s (2018) introduction to the analysis of remote camera data useful.

As well, Wearn and Glover-Kapfer (2017) contains a detailed summary of analytical software (including R packages) for camera users (see pg. 160–162 in Wearn & Glover-Kapfer, 2017). Some software packages (e.g., [eMammal](https://emammal.si.edu/) [McShea et al., 2015], [Wildlife Insights](https://www.wildlifeinsights.org/) [Ahumada et al., 2019]) provide useful data analytics (summary tables or dashboards) for a variety of metrics (e.g., number of cameras, species richness, [occupancy](#occupancy) estimates).

See [Table 1](#_heading=h.pv6qcq) for useful software platforms and tools for data analysis/ analytics, as well as data storage and [image processing](#image_processing).

## Useful websites

##### **Table 1.** A subset of software platforms and tools for data storage, [image processing](#image_processing), and data analysis / analytics. Refer to <https://wildcams.ca/library/camera-trap-software-and-data-management/> for a comprehensive comparison of commonly used software platforms.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Software / tool** | **Data storage** | [**Image processing**](#image_processing) | **Data analysis / analytics** | **Reference** | **Link** |
| **Software** | | | | | |
| [MegaDetector](https://github.com/microsoft/CameraTraps/blob/main/megadetector.md) | No | Yes | No | Beery et al., 2019 | https://github.com/microsoft/CameraTraps/blob/main/megadetector.md |
| [Timelapse2](http://saul.cpsc.ucalgary.ca/timelapse/) | No | Yes | Yes | Greenberg, 2018 | http://saul.cpsc.ucalgary.ca/timelapse/ |
| [WildTrax](https://www.wildtrax.ca/home.html) | Yes | Yes | Yes | - | https://www.wildtrax.ca/home |
| [eMammal](https://emammal.si.edu/) | Yes | Yes | Yes | McShea et al., 2015 | https://emammal.si.edu/ |
| [Wildlife Insights](https://www.wildlifeinsights.org/) | Yes | Yes | Yes | Ahumada et al., 2019 | https://www.wildlifeinsights.org/ |
| [Reconyx MapView](http://www.reconyx.com/software/mapview) | No | Yes | No | Reconyx Inc., 2021 | http://www.reconyx.com/software/mapview |
| [WildCo Lab’s Renamer](https://github.com/WildCoLab/WildCo_Image_Renamer) | No | Yes | No | WildCo Lab, 2021b | https://github.com/WildCoLab/WildCo\_Image\_Renamer |
| [WildCoLab’s FaceBlur R-script](https://github.com/WildCoLab/WildCo_Face_Blur) | No | Yes | No | WildCo Lab, 2021a | https://github.com/WildCoLab/WildCo-FaceBlur |
| **Tools** | | | | | |
| [WILDLABS Tech Tutors tutorial](https://www.wildlabs.net/event/how-do-i-get-started-megadetector) | Yes | Yes | Yes | The WILDLABS Partnership, 2021 | https://www.wildlabs.net/event/how-do-i-get-started-megadetector |
| [Step-by-step guide to the "best" way to explore or analyse your data bookdown](https://bookdown.org/c_w_beirne/wildCo-Data-Analysis/) | No | No | Yes | Dr. Chris Beirne; WildCo Lab, 2021 | https://bookdown.org/c\_w\_beirne/wildCo-Data-Analysis/ |
| Chris Beirne’s [Tips and Tricks for the Organization and Analysis of Camera Trap Data](https://www.youtube.com/watch?v=VadXgBMhiTY) | No | No | Yes | Canadian Mountain Network, CMN 2020 | https://www.youtube.com/watch?v=VadXgBMhiTY |
| [Secrdesignapp](https://www.stats.otago.ac.nz/secrdesignapp/) | No | No | Yes | Efford & Boulanger, 2019 | https://www.stats.otago.ac.nz/secrdesignapp/ |
| [Everything I know about machine learning and camera traps](https://agentmorris.github.io/camera-trap-ml-survey/) | No | Yes | Yes | Morris, 2022 | https://agentmorris.github.io/camera-trap-ml-survey/ |

# 

# References

Ahumada, J. A., Fegraus, E., Birch, T., Flores, N., Kays, R., O’Brien, T. G., Palmer, J., Schuttler, S., Zhao, J. Y., Jetz, W., Kinnaird, M., Kulkarni, S., Lyet, A., Thau, D., Duong, M., Oliver, R., & Dancer, A. (2019). Wildlife Insights: A Platform to Maximize the Potential of Camera Trap and Other Passive Sensor Wildlife Data for the Planet. *Environmental Conservation*, 47(1), 1–6. <https://doi.org/10.1017/s0376892919000298>

Ahumada, J. A., Silva, C. E. F., Gajapersad, K., Hallam, C., Hurtado, J., Martin, E., McWilliam, A., Mugerwa, B., O’Brien, T., Rovero, F., Sheil, D., Spironello, W. R., Winarni, N., & Andelman, S. J. (2011). Community Structure and Diversity of Tropical Forest Mammals: Data from a Global Camera Trap Network. *Philosophical Transactions: Biological Sciences, 366*(1578), 2703–2711. <https://doi.org/10.1098/rstb.2011.0115>

Alberta Biodiversity Monitoring Institute [ABMI] (2021). *Terrestrial ARU and Remote Camera Trap Protocols:* Edmonton, Alberta. <https://abmi.ca/home/publications/551-600/599>

Alberta Remote Camera Steering Committee (RCSC). 2024. Remote Camera Metadata Standards: Standards for Alberta. Version 2.0. Edmonton, Alberta. <https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html>

Alonso, R. S., McClintock, B. T., Lyren, L. M., Boydston, E. E., & Crooks, K. R. (2015). Mark-recapture and Mark-resight Methods for Estimating Abundance with Remote Cameras: A Carnivore Case Study. *PLoS One, 10*(3), e0123032. <https://doi.org/10.1371/journal.pone.0123032>

Anile, S., & Devillard, S. (2016). Study Design and Body Mass Influence RAIs from Camera Trap Studies: Evidence from the Felidae. *Animal Conservation, 19*(1), 35–45. <https://doi.org/10.1111/acv.12214>

Apps, P. J., & McNutt, J. W. (2018). How Camera Traps work and how to work them. *African Journal of Ecology, 56*(4), 702–709. <https://doi.org/10.1111/aje.12563>

Arnason, A. N., Schwarz, C. J. & Gerrard, J. M. (1991). Estimating Closed Population Size and Number of Marked Animals from Sighting Data. *Journal of Wildlife Management, 55*(4), 716–730. <https://doi.org/10.2307/3809524>

Augustine, B. C., Royle, J. A., Kelly, M. J., Satter, C. B., Alonso, R. S., Boydston, E. E., & Crooks, K. R. (2018). Spatial Capture–Recapture with Partial Identity: An Application to Camera Traps. *The Annals of Applied Statistics, 12*(1), 67-95. <https://doi.org/10.1214/17AOAS1091>

Augustine, B. C., Royle, J. A., Murphy, S. M. Chandler, R. B., Cox, J. J., & Kelly, M. J. (2019). Spatial Capture–Recapture for Categorically Marked Populations with an Application to Genetic Capture–Recapture. *Ecosphere, 10*(4) e02627-n/a. <https://doi.org/10.1002/ecs2.2627>

Bayne, E., Dennett, J., Dooley, J., Kohler, M., Ball, J., Bidwell, M., Braid, A., Chetelat, J., Dillegeard, E., Farr, D., Fisher, J., Freemark, M., Foster, K., Godwin, C., Hebert, C., Huggard, D., McIssac, D., Narwani, T., Nielsen, S., Pauli, B., Prasad, S., Roberts, D., Slater, S., Song, S., Swanson, S., Thomas, P., Toms, J., Twitchell, C., White, S., Wyatt,& F., Mundy, L. (2021). *Oil Sands Monitoring Program: A Before-After Dose- Response Terrestrial Biological Monitoring Framework for the Oil Sands*. (OSM Technical Report Series No. 7). <https://open.alberta.ca/publications/9781460151341>

Becker, M., Huggard, D. J., Dickie, M., Warbington, C., Schieck, J., Herdman, E., Serrouya, R., & Boutin, S. (2022). Applying and Testing a Novel Method to Estimate Animal Density from Motion-Triggered Cameras. *Ecosphere, 13*(4), 1-14. <https://doi.org/10.1002/ecs2.4005>

Beery, S., Morris, D., & Yang, S. (2019). Efficient Pipeline for Camera Trap Image Review. *Microsoft AI for Earth*. <https://doi.org/10.48550/arXiv.1907.06772>

Bessone, M., Kühl, H. S., Hohmann, G., Herbinger, I., N'Goran, K. P., Asanzi, P., Da Costa, P. B., Dérozier, V., Fotsing, E. D. B., Beka, B. I., Iyomi, M. D., Iyatshi, I. B., Kafando, P., Kambere, M. A., Moundzoho, D. B., Wanzalire, M. L. K., Fruth, B., & Michalski, F. (2020). Drawn out of the Shadows: Surveying Secretive Forest Species with Camera Trap Distance Sampling. *Journal of Applied Ecology, 57*(5), 963–974. <https://doi.org/10.1111/1365-2664.13602>

Bischof, R., Dupont, P., Milleret, C., ChipperfIeld, J., & Royle, J.A. (2020). Consequences of Ignoring Group Association in Spatial Capture-Recapture Analysis. *Wildlife Biology, 2020*(1). <https://doi.org/10.2981/wlb.00649>

Blanc, L., Marboutin, E., Gatti, S. & Gimenez, O. (2013). Abundance of Rare and Elusive Species: Empirical Investigation of Closed versus Spatially Explicit Capture-Recapture Models with Lynx as a Case Study. *Journal of Wildlife Management, 77*(2), 372–78. <https://doi.org/10.1002/jwmg.453>

Blasco‐Moreno, A., Pérez‐Casany, M., Puig, P., Morante, M., Castells, E., & O'Hara, R. B. (2019). What Does a Zero Mean? Understanding False, Random and Structural Zeros in Ecology. *Methods in Ecology and Evolution, 10*(7), 949-959. <https://doi.org/10.1111/2041-210x.13185>

Bliss, C. I., & Fisher, R. A. (1953). Fitting the Negative Binomial Distribution to Biological Data. *Biometrics, 9*(2), 176-200. <https://doi.org/10.2307/3001850>

Borchers, D. L., & Efford, M. G. (2008). Spatially Explicit Maximum Likelihood Methods for Capture-Recapture Studies. *Biometrics, 64*(2), 377–385. <https://doi.org/10.1111/j.1541-0420.2007.00927.x>

Borcher, D.L. & Marques, T.A. (2017). From Distance Sampling to Spatial Capture–Recapture. Asta Advances In Statistical Analysis, *101*, 475–494. <https://link.springer.com/article/10.1007/s10182-016-0287-7>

Bowkett, A. E., Rovero, F., & Marshall, A. R. (2008). The use of camera-trap data to model habitat use by antelope species in the udzungwa mountain forests, tanzania. *African Journal of Ecology, 46*(4), 479–487. <https://doi.org/10.1111/j.1365-2028.2007.00881.x>

Bridges, A. S., & Noss, A. J. (2011). Behavior and Activity Patterns. In A. F. O'Connell, J. D. Nichols, & K. U. Karanth (Eds.), *Camera Traps In Animal Ecology: Methods and Analyses* (pp. 57–70). Springer. <https://doi.org/10.1007/978-4-431-99495-4>

Burgar, J. M. (2021). Counting Elk Amongst the Trees: Improving the Accuracy of Roosevelt Elk Inventory via Modelling, Preliminary Report 2021. Terrestrial Wildlife Resources, South Coast Resource Management, FLNRORD. (available upon request).

Burgar, J. M., Stewart, F. E. C., Volpe, J. P., Fisher, J. T., & Burton, A. C. (2018). Estimating density for species conservation: comparing camera trap spatial count models to genetic spatial capture-recapture models. *Global Ecology and Conservation*, *15*, Article e00411. <https://doi.org/10.1016/j.gecco.2018.e00411>

Burton, A. C., Neilson, E., Moreira, D., Ladle, A., Steenweg, R., Fisher, J. T., Bayne, E., Boutin, S., & Stephens, P. (2015). Camera trap Trapping: A Review and Recommendations for Linkingsurveys to Ecological Processes. *Journal of Applied Ecology*, *52*(3), 675–685. <https://doi.org/10.1111/1365-2664.12432>

Cappelle, N., Howe, E. J., Boesch, C., & Kühl, H. S. (2021). Estimating Animal Abundance and Effort–Precision Relationship with Camera Trap Distance Sampling. *Ecosphere, 12*(1). <https://doi.org/10.1002/ecs2.3299>

Caravaggi, A., Burton, A. C., Clark, D. A., Fisher, J. T., Grass, A., Green, S., Hobaiter, C., Hofmeester, T. R., Kalan, A. K., Rabaiotti, D., & Rivet, D. (2020). A Review of Factors To Consider When Using Camera Traps To Study Animal Behavior To Inform Wildlife Ecology And Conservation. *Conservation Science and Practice, 2*(8). <https://doi.org/10.1111/csp2.239>

Carbone, C., Christie, S., Conforti, K., Coulson, T., Franklin, N., Ginsberg, J. R., Griffiths, M., Holden, J., Kawanishi, K., Kinnaird, M., Laidlaw, R., Lynam, A., Macdonald, D. W., Martyr, D., McDougal, C., Nath, L., O’Brien, T., Seidensticker, J., Smith, D. J. L., Wan Shahruddin, W. N. (2001). The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation, 4*(1), 75–79. <https://doi.org/10.1017/S1367943001001081>

Caughley, G. (1977). Analysis of Vertebrate Populations (pp. 234). Wiley.

Chandler, R. B., & Royle, J. A. (2013). Spatially explicit models for inference about density in unmarked or partially marked populations. *The Annals of Applied Statistics, 7*(2), 936–954. <https://doi.org/10.1214/12-aoas610>

Chatterjee, N., Schuttler, T. G., Nigam, P., & Habib, B. (2021). Deciphering the rarity–detectability continuum: optimizingsurvey design for terrestrial mammalian community. *Ecosphere 12*(9), e03748. <https://doi.org/10.1002/ecs2.3748>

Clark, T. G., Bradburn, M. J., Love, S. B., & Altman, D. G. (2003). Survival Analysis Part I: Basic Concepts and First Analyses. *British Journal of Cancer, 89*(2), 232–38. <https://doi.org/10.1038/sj.bjc.6601118>

Clarke, J. D. (2019). Comparing Clustered Sampling Designs for Spatially Explicit Estimation of Population Density. *Population Ecology, 61*, 93–101. <https://doi.org/10.1002/1438-390X.1011>

Clarke, J. & Bohm, H. & Burton, C. & Constantinou, A. (2023). *Using Camera Traps to Estimate Medium and Large Mammal Density: Comparison of Methods and Recommendations for Wildlife Managers*. <https://doi.org/10.13140/RG.2.2.18364.72320>

Columbia Mountains Institute of Applied Ecology (CMI). (2020) *Chris Beirne: Tips and Tricks for the Organization and Analysis of Camera Trap Data*. <https://www.youtube.com/watch?v=VadXgBMhiTY>

Colyn, R. B., Radloff, F., & O’Riain, M. J. (2018). Camera trapping mammals in the scrubland’s of the cape floristic kingdom - the importance of effort, spacing and trap placement. *Biodiversity and Conservation, 27*(2), 503–520. <https://doi.org/10.1007/s10531-017-1448-z>

Cusack, J. Dickman, A. J., Rowcliffe, J. M., Carbone, C., Macdonald, D. W., & Coulson, T. (2015). Random versus Game Trail-based Camera trap Placement Strategy for Monitoring Terrestrial Mammal Communities. *PloS One*,*10*(5), e0126373. <https://doi.org/10.1371/journal.pone.0126373>

Davis, R. S., E. L. Stone, L. K. Gentle, W. O. Mgoola, A. Uzal, and R. W. Yarnell. (2021). Spatial Partial Identity Model Reveals Low Densities of Leopard and Spotted Hyaena in a Miombo Woodland. *Journal of Zoology*, *313*, 43-53. <https://zslpublications.onlinelibrary.wiley.com/doi/epdf/10.1111/jzo.12838>

Dénes, F. V., Silveira, L. F., Beissinger, S. R., & Isaac, N. (2015). Estimating Abundance of Unmarked Animal Populations: Accounting for Imperfect Detection and Other Sources of Zero Inflation. *Methods in Ecology and Evolution, 6*(5), 543–556. <https://doi.org/10.1111/2041-210x.12333>

Dillon, A., & Kelly, M. J. (2008). Ocelot Home Range, Overlap and Density: Comparing Radio Telemetry with Camera Trapping. *Journal of Zoology, 275*, 391–398. <https://doi.org/10.1111/j.1469-7998.2008.00452.x>

Doran-Myers, D. (2018). *Methodological Comparison of Canada Lynx Density Estimation* [Master of Science in Ecology thesis, University of Alberta]. ERA: Education and Research Archive. <https://doi.org/10.7939/R3Q815805>

Duquette, J. F., Belant, J. L., Svoboda, N. J., Beyer Jr., D. E., & Albright, C.A. (2014). Comparison of occupancy modeling and radiotelemetry to estimate ungulate population dynamics. *Population Ecology, 56,* 481-492. [https://www.academia.edu/23421255/](https://www.academia.edu/23421255/Comparison_of_occupancy_modeling_and_radiotelemetry_to_estimate_ungulate_population_dynamics).

Efford, M. (2004). Density Estimation in Live-Trapping Studies. *Oikos, 106*(3), 598–610. <http://www.jstor.org.login.ezproxy.library.ualberta.ca/stable/3548382>

Efford, M. G. (2022). Mark–resight in secr 4.5. 1–20. <https://www.otago.ac.nz/density/pdfs/secr-markresight.pdf>

Efford, M. G., Borchers, D. L., & Byrom, A. E. (2009a). Density Estimation by Spatially Explicit Capture-Recapture: Likelihood-Based Methods. *In* D. L. Thomson, E. G. Cooch, & M. J. Conroy (Eds.), *Modeling Demographic Processes In Marked Populations* (pp. 255–269). <https://doi.org/10.1007/978-0-387-78151-8_11>

Efford, M. G., & Boulanger, J. (2019). Fast Evaluation of Study Designs for Spatially Explicit Capture–Recapture. *Methods in Ecology and Evolution*, 10(9), 1529–1535. <https://doi.org/10.1111/2041-210X.13239>

Efford, M. G., Dawson, D. K., & Borchers, D. L. (2009b). Population density estimated from locations of individuals on a passive detector array. *Ecology, 90*(10), 2676–2682. <https://doi.org/10.1890/08-1735.1>

Efford, M. G., & Hunter, C. M. (2018). Spatial Capture-mark-resight Estimation of Animal Population Density. *Biometrics, 74*(2), 411–420. <https://doi.org/10.1111/biom.12766>

Espartosa, K. D., Pinotti, B. T. & Pardini, R. (2011). Performance of Camera Trapping and Track Counts for Surveying Large Mammals in Rainforest Remnants. *Biodiversity Conservation, 20*(12), 2815–2829. <https://doi.org/10.1007/s10531-011-0110-4>

Fancourt, B. A. (2016). Avoiding the subject: The implications of avoidance behaviour for detecting predators. *Behavioral Ecology and Sociobiology, 70*(9), 1535–1546. <https://doi.org/10.1007/s00265-016-2162-7>

Fennell, M., Beirne, C., & Burton, A. C. (2022). Use of object detection in camera trap image identification: Assessing a method to rapidly and accurately classify human and animal detections for research and application in recreation ecology. *Global Ecology and Conservation, 35*. <https://doi.org/10.1016/j.gecco.2022.e02104>

Findlay, M. A., Briers, R. A. & White, P. J. C. (2020). Component processes of detection probability in camera-trap studies: understanding the occurrence of false-negatives. *Mammal Research, 65*, 167–180. <https://doi.org/10.1007/s13364-020-00478-y>

Fisher, J. T., & Burton, C. (2012). *Monitoring Mammals in Alberta: Recommendations for Remote Camera Trapping*. Alberta Innovates - Technology Futures & Alberta Biodiversity Monitoring Institute. <https://doi.org/0.13140/RG.2.1.3944.3680>

Fisher, J. T., Wheatley, M., & Mackenzie, D. (2014). Spatial Patterns of Breeding Success of Grizzly Bears derived from Hierarchical Multistate Models. *Conservation Biology, 28*(5), 1249–1259. <https://doi.org/10.1111/cobi.12302>

Forrester, T., O’Brien, T., Fegraus, E., Jansen, P. A., Palmer, J., Kays, R., Ahumada, J., Stern, B., & McShea, W. (2016). An Open Standard for Camera Trap Data. *Biodiversity Data Journal, 4*, e10197. <https://doi.org/10.3897/BDJ.4.e10197>

Foster R. J., & Harmsen, B. J. (2012). A Critique of Density Estimation from Camera Trap Data. *Journal of* *Wildlife Management, 76*(2), 224–36. <https://doi.org/10.1002/jwmg.275>

Found, R., & Patterson, B. R. (2020). Assessing Ungulate Populations in Temperate North America. *Canadian Wildlife Biology and Management, 9*(1), 21–42. <https://cwbm.ca/wp-content/uploads/2020/05/Found-Patterson.pdf>

Frey, S., Fisher, J.T., Burton, A.C., & Volpe, J.P. (2017). Investigating Animal Activity Patterns and Temporal Niche Partitioning using Camera-Trap Data: Challenges and Opportunities. *Remote Sensing in Ecology and Conservation*, *3* (3), 123–132. <https://zslpublications.onlinelibrary.wiley.com/doi/10.1002/rse2.60>

Gallo, T., Fidino, M., Gerber, B., Ahlers, A. A., Angstmann, J. L., Amaya, M., Concilio, A. L., Drake, D., Gay, D., Lehrer, E. W., Murray, M. H., Ryan, T. J., St Clair, C. C., Salsbury, C. M., Sander, H. A., Stankowich, T., Williamson, J., Belaire, J. A., Simon, K., & Magle, S. B. (2022). Mammals Adjust Diel Activity across Gradients of Urbanization. *Elife, 11*. <https://doi.org/10.7554/eLife.74756>

Gálvez, N., Guillera-Arroita, G., Morgan, B.J.T. & Davies, Z.G. (2016). Cost-Efficient Effort Allocation for Camera-Trap OccupancySurveys of Mammals. *Biological Conservation*, *204*(B), 350–359. <https://doi.org/10.1016/j.biocon.2016.10.019>

Ganskopp, D. C., & Johnson, D. D. (2007). GPS Error in Studies Addressing Animal Movements and Activities. *Rangeland Ecology and Management, 60*, 350–358. [https://doi.org/10.2111/1551-5028(2007)60[350:GEISAA]2.0.CO;2](https://doi.org/10.2111/1551-5028(2007)60%5b350:GEISAA%5d2.0.CO;2)

Gerber, B., Karpanty, S.S.M., Crawford, C., Kotschwar, M. & Randrianantenaina, J. (2010). An assessment of carnivore relative abundance and density in the eastern rainforests of Madagascar using remotely-triggered camera traps. *Oryx, 44*(2), 219–222. <https://doi.org/10.1017/S0030605309991037>

Gilbert, N. A., Clare, J. D. J., Stenglein, J. L., & Zuckerberg, B. (2021). Abundance Estimation of Unmarked Animals based on Camera-Trap Data. *Conservation Biology, 35*(1), 88-100. <https://doi.org/10.1111/cobi.13517>

Gillespie, G. R., Brennan, K., Gentles, T., Hill, B., Low Choy, J., Mahney, T., Stevens, A., & Stokeld, D. (2015). *A Guide for the use of Remote Cameras for Wildlife**Survey in Northern Australia*. Darwin: Charles Darwin University. <https://nesplandscapes.edu.au/wp-content/uploads/2015/10/5.2.4_a_guide_to_use_of_remote_cameras_for_wildlife_surveys_final_web2.pdf>

Glen, A. S., Cockburn, S. Nichols, M. Ekanayake, J., & Warburton, B. (2013) Optimising Camera Traps for Monitoring Small Mammals. *PloS one,* 8(6), Article e67940. <https://doi.org/10.1371/journal.pone.0067940>

Government of Alberta (2023a) *Proponent-led Indigenous consultations.* Edmonton, Alberta. <https://www.alberta.ca/proponent-led-indigenous-consultations.aspx>

Government of Alberta (2023a) *LAT Overview.* Edmonton, Alberta. <https://www.alberta.ca/lat-overview.aspx>

Green, A. M., Chynoweth, M. W., & Şekercioğlu, Ç. H. (2020). Spatially Explicit Capture-Recapture Through Camera Trapping: A Review of Benchmark Analyses for Wildlife Density Estimation. *Frontiers in Ecology and Evolution*, 8, Article 563477. <https://doi.org/10.3389/fevo.2020.563477>

Greenberg, S. (2018).*Timelapse: An Image Analyser for Camera Traps.* University of Calgary. <https://saul.cpsc.ucalgary.ca/timelapse/pmwiki.php?n=Main.Download2./>

Greenberg, S. (2020). *Automated Image Recognition for Wildlife Camera Traps: Making it Work for You*. Research report, University of Calgary: Prism Digital Repository, August 21, 15 pages, <https://prism.ucalgary.ca/items/f68a0c27-8502-4fe4-a3b9-3a3c2d994762>

Guillera-Arroita, G., Ridout, M. S. & Morgan, B. J. T. (2010). Design of Occupancy Studies with Imperfect Detection. *Methods in Ecology and Evolution, 1*, 131–139. <https://doi.org/10.1111/j.2041-210X.2010.00017.x>

Hall, K. W., Cooper, J. K., & Lawton, D. C. (2008). GPS accuracy: Hand-held versus RTK. *CREWES Research Report, 20*. <https://www.crewes.org/Documents/ResearchReports/2008/2008-15.pdf>

Harrison, X. A., Donaldson, L., Correa-Cano, M. E., Evans, J., Fisher, D. N., Goodwin, C. E. D., Robinson, B. S., Hodgson, D. J., & Inger, R. (2018). A Brief Introduction to Mixed Effects Modelling and Multi-Model Inference in Ecology. *PeerJ, 6*, Article e4794. <https://doi.org/10.7717/peerj.4794>

Heilbron, D. C. (1994). Zero-Altered and other Regression Models for Count Data with Added Zeros. *Biometrical Journal, 36*(5), 531-547. <https://doi.org/https://doi.org/10.1002/bimj.4710360505>

Huggard, D. (2018). *Animal Density from Camera Data*. Alberta Biodiversity Monitoring Institute. <https://www.abmi.ca/home/publications/501-550/516>

Hurlbert, S. (1984). Pseudoreplication and the design of ecological field experiments. *Ecological Monographs, 54*(2), 187–211. <https://doi.org/10.2307/1942661>

Hofmeester, T. R., Cromsigt, J. P. G. M., Odden, J., Andrén, H., Kindberg, J., & Linnell, J. D. C. (2019). Framing Pictures: A Conceptual Framework to Identify and Correct for Biases in Detection Probability of Camera Traps Enabling Multi-Species Comparison. *Ecology and Evolution, 9*(4), 2320–2336. <https://doi.org/10.1002/ece3.4878>

Holinda, D., Burgar, J. M., & Burton, A. C. (2020). Effects of scent lure on camera trap detections vary across mammalian predator and prey species. *PLoS One, 15*(5), e0229055. <https://doi.org/10.1371/journal.pone.0229055>

Howe, E. J., Buckland, S. T., Després-Einspenner, M.-L., & Kühl, H. S. (2017). Distance sampling with camera traps. *Methods in Ecology and Evolution, 8*(11), 1558–1565. <https://doi.org/https://doi.org/10.1111/2041-210X.12790>

Iknayan, K. J., Tingley, M. W., Furnas, B. J., & Beissinger, S. R. (2014). Detecting Diversity: Emerging Methods to Estimate Species Diversity. *Trends in Ecology & Evolution, 29*(2), 97–106. <https://doi.org/10.1016/j.tree.2013.10.012>

Jennelle, C. S., Runge, M. C., & MacKenzie, D. I. (2002). The Use of Photographic Rates to Estimate Densities of Tigers and Other Cryptic Mammals: A Comment on Misleading Conclusions. *Animal Conservation, 5*(2), 119–120. <https://doi.org/10.1017/s1367943002002160>

Jennrich, R. I., & Turner, F. B. (1969). Measurement of non-circular home range. *Journal of Theoretical Biology, 22*(2), 227–237. <https://doi.org/https://doi.org/10.1016/0022-5193(69)90002-2>

Johanns, P, Haucke, T., & Steinhage, V. (2022) Automated Distance Estimation and Animal Tracking for Wildlife Camera Trapping. *Ecological Informatics, 70,* arXiv:2202.04613. <https://doi.org/10.48550/arXiv.2202.04613>

Junker, J., Kühl, H., Orth, L., Smith, R., Petrovan, S., & Sutherland, W. (2021). *7. Primate Conservation.* In (pp. 435–486). <https://doi.org/10.11647/obp.0267.07>

Karanth, K. U. (1995). Estimating tiger Panthera tigris populations from camera-trap data using capture-recapture models. *Biological Conservation, 71*(3), 333–338. <https://doi.org/10.1016/0006-3207(94)00057-W>

Karanth, K. U., Nichols, J. D., & Kumar, N. S. (2011). Estimating tiger abundance from camera trap data: field surveys and analytical issues. In A. F. O'Connell, J. D. Nichols, & K. U. Karanth (Eds.), *Camera Traps In Animal Ecology: Methods and Analyses* (pp. 9–117). Springer. <https://doi.org/10.1007/978-4-431-99495-4>

Karanth, K. U., & Nichols, J. D. (1998). Estimation of tiger densities in India using photographic captures and recaptures. *Ecology*, *79*(8), 2852–2862. [https://doi.org/10.1890/0012-9658(1998)079[2852:EOTDII]2.0.CO;2](https://doi.org/10.1890/0012-9658(1998)079%5b2852:EOTDII%5d2.0.CO;2)

Karanth, K. U., Nichols, J. D., Kumar, N. S., & Hines, J. E. (2006). Assessing Tiger Population Dynamics Using Photographic Capture–Recapture Sampling. *Ecology, 87*(11), 2925–2937. [https://doi.org/10.1890/0012-9658(2006)87[2925:ATPDUP]2.0.CO;2](https://doi.org/10.1890/0012-9658(2006)87%5b2925:ATPDUP%5d2.0.CO;2)

Kays, R., Hody, A., Jachowski, D. S., & Parsons, A. W. (2021). Empirical Evaluation of the Spatial Scale and Detection Process of Camera Trapsurveys. *Movement Ecology, 9*, 41. <https://doi.org/10.1186/s40462-021-00277-3>.

Kays, R., Arbogast, B. S., Baker‐Whatton, M., Beirne, C., Boone, H. M., Bowler, M., Burneo, S. F., Cove, M. V., Ding, P., Espinosa, S., Gonçalves, A. L. S., Hansen, C. P., Jansen, P. A., Kolowski, J. M., Knowles, T. W., Lima, M. G. M., Millspaugh, J., McShea, W. J., Pacifici, K., & Spironello, W. R. (2020). An Empirical Evaluation of Camera Trap Study Design: How Many, How Long and When? *Methods in Ecology and Evolution*, *11*(6), 700–713. <https://doi.org/10.1111/2041-210x.13370>

Kays, R., Tilak, S., Kranstauber, B., Jansen, P. A., Carbone, C., Rowcliffe, M. J., & He, Z. (2010). Monitoring wild animal communities with arrays of motion sensitive camera traps. *arXiv Preprint*, arXiv:1009.5718. <https://arxiv.org/pdf/1009.5718>

Kelejian, H. H., & Prucha, I.R., (1998). A generalized spatial two-stage least squares procedure for estimating a spatial autoregressive model with autoregressive disturbances. The Journal of Real Estate Finance and Economics,17:99-121.

Kelly, M. J., Noss, A. J., Bitetti, M. S., Maffei, L., Arispe, R. L., Paviolo, A., Angelo, C. D. D., & Di Blanco, Y. E. (2008). Estimating Puma Densities from Camera Trapping Across Three Study Sites: Bolivia, Argentina, And Belize. *Journal of Mammalogy, 89*(2), 408–418. <https://doi.org/10.1644/06-MAMM-A-424R.1>

Keim, J. L., DeWitt, P. D., Wilson, S. F., Fitzpatrick, J. J., Jenni, N. S., & Lele, S. R. (2021). Managing animal movement conserves predator–prey dynamics. *Frontiers in Ecology and the Environment, 19*(7), 379-385. <https://esajournals.onlinelibrary.wiley.com/doi/10.1002/fee.2358>

Keim, J. L., Lele, S. R., DeWitt, P. D., Fitzpatrick, J. J., Jenni, N. S. (2019). Estimating the intensity of use by interacting predators and prey using camera traps. *Journal of Animal Ecology, 88:* 690–701. <https://doi.org/10.1111/1365-2656.12960>

Kinnaird, M. F., & O'Brien, T. G. (2011). Density estimation of sympatric carnivores using spatially explicit capture–recapture methods and standard trapping grid. *Ecological Applications, 21*(8), 2908–2916. <https://www.jstor.org/stable/41417102>

Kitamura, S., Thong-Aree, S., Madsri, S., & Poonswad, P. (2010). Mammal diversity and conservation in a small isolated forest of southern Thailand. *Raffles Bulletin of Zoology, 58*(1), 145–156. <https://www.pangolinsg.org/wp-content/uploads/sites/4/2018/06/Kitamura-et-al._2010_Mammal-diversity-in-small-forest-of-Southern-Thailand.pdf>

Kucera, T. E., & R. H. Barrett. (2011). A History of Camera Trapping. In A. F. O’Connell, J. D. Nichols, & K. U. Karanth (Eds.), *Camera Traps In Animal Ecology: Methods and Analyses* (pp. 9–26). Springer. <https://doi.org/10.1007/978-4-431-99495-4_6>

Kusi, N., Sillero‐Zubiri, C., Macdonald, D. W., Johnson, P. J., & Werhahn, G. (2019). Perspectives of traditional Himalayan communities on fostering coexistence with Himalayan wolf and snow leopard. *Conservation Science and Practice, 2*(3). <https://doi.org/10.1111/csp2.165>

Krebs, C. J., Boonstra, R., Gilbert, S., Reid, D., Kenney, A. J., Hofer, E. J., & an Vuren, D. H. (2011). Density estimation for small mammals from livetrapping grids: rodents in northern Canada. *Journal of Mammalogy, 92*(5), 974–981. <https://doi.org/10.1644/10-M>

Kruger, H., Vaananen, V.-M., Holopainen, S., & Nummi, P. (2018). The new faces of nest predation in agricultural landscapes - a camera trap survey with artificial nests. European *Journal of Wildlife Research, 64*(6), 76. <https://doi.org/10.1007/s10344-018-1233-7>

Lahoz-Monfort, J. J., & Magrath, M. J. L. (2021). A Comprehensive Overview of Technologies for Species and Habitat Monitoring and Conservation. *Bioscience, 71*(10), 1038–1062. <https://doi.org/10.1093/biosci/biab073>

Lambert, D. (1992). Zero-Inflated Poisson Regression, with an application to Defects in Manufacturing. *Technometrics, 34*(1), 1–14. <https://doi.org/10.2307/1269547>

Lazenby, B. T., Mooney, N. J., & Dickman, C. R. (2015). Detecting species interactions using remote cameras: Effects on small mammals of predators, conspecifics, and climate. *Ecosphere, 6*(12), 1–18. <https://doi.org/10.1890/ES14-00522.1>

Linden, D. W., Fuller, A. K., Royle, J. A., & Hare, M. P. (2017). Examining the occupancy–density relationship for a low‐density carnivore. *Journal of Applied Ecology, 54*(6), 2043–2052. <https://doi.org/10.1111/1365-2664.12883>

Li, S., McShea, W. J., Wang, D. J., Huang, J. Z., & Shao, L. K. (2012). A Direct Comparison of Camera-Trapping and Sign Transects for Monitoring Wildlife in the Wanglang National Nature Reserve, China. *Wildlife Society Bulletin, 36*(3), 538–545. <https://doi.org/10.1002/wsb.161>

Loonam, K. E., Lukacs, P. M., Ausband, D. E., Mitchell, M. S., & Robinson, H. S. (2021). Assessing the robustness of time-to-event models for estimating unmarked wildlife abundance using remote cameras. *Ecological Applications, 31*(6), Article e02388. <https://doi.org/10.1002/eap.2388>

Lynch, T. P., Alderman, R., & Hobday, A. J. (2015). A high-resolution panorama camera system for monitoring colony-wide seabird nesting behaviour. *Methods in Ecology and Evolution, 6*(5), 491–499. <https://doi.org/10.1111/2041-210X.12339>

MacKenzie, D. I., Nichols, J. D., Hines, J. E., Knutson, M. G., & Franklin, A. B. (2003). Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology, 84*(8), 2200–2207. <https://doi.org/10.1890/02-3090>

MacKenzie, D. I., Bailey, L. L., & Nichols, J. D. (2004). Investigating Species Co-Occurrence Patterns When Species Are Detected Imperfectly. *Journal of Animal Ecology, 73*(3), 546–555. <https://doi.org/10.1111/j.0021-8790.2004.00828.x>

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A., & Langtimm, C. A. (2002). Estimating Site Occupancy Rates When Detection Probabilities Are Less Than One. *Ecology, 83*(8), 2248–2255. <https://doi.org/10.2307/3072056>

MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. L., & Hines, J. E. (2006). *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*. Academic Press, USA.

MacKenzie, D. I., & Kendall, W. L. (2002) How Should Detection Probability Be Incorporated into Estimates of Relative Abundance? *Ecology, 83*(9), 2387–93. [https://doi.org/10.1890/0012-9658(2002)083[2387:HSDPBI]2.0.CO;2](https://doi.org/10.1890/0012-9658(2002)083%5B2387:HSDPBI%5D2.0.CO;2)

Mackenzie, D. I., & Royle, J. A. (2005). Designing occupancy studies: general advice and allocatingsurvey effort. *Journal of Applied Ecology, 42*, 1105–1114. <https://doi.org/10.1111/j.1365-2664.2005.01098.x>

Maffei, L., & Noss, A. J. (2008). How Small Is Too Small? Camera Trap Survey Areas and Density Estimates for Ocelots in the Bolivian Chaco. *Biotropica, 40*(1), 71-75. <https://doi.org/10.1111/j.1744-7429.2007.00341.x>

Manly, B.F.J., McDonald, L.L., & Thomas, D.L. (1993). Resource Selection by Animals: Statistical Design and Analysis for Field Studies. Chapman & Hall, London, p. 177.

Martin, T. G., Wintle, B. A., Rhodes, J. R., Kuhnert, P. M., Field, S. A., Low-Choy, S. J., Tyre, A. J., & Possingham, H. P. (2005). Zero Tolerance Ecology: Improving Ecological Inference by Modelling the Source of Zero Observations. *Ecology Letters, 8*(11), 1235-1246. <https://doi.org/10.1111/j.1461-0248.2005.00826.x>

McClintock, B. T., White, G. C., Antolin, M. F. & Tripp, D. W. (2009). Estimating abundance using mark-resight when sampling is with replacement or the number of marked individuals is unknown. *Biometrics, 65*(1), 237–246. <https://doi.org/10.1111/j.1541-0420.2008.01047.x>

McCullagh, P., & Nelder, J. A. (1989). *Generalised Linear Models,* 2nd edn. Chapman and Hall, London. <http://dx.doi.org/10.1007/978-1-4899-3242-6>

McShea, W. J., Forrester, T., Costello, R., He, Z., & Kays, R. (2015). Volunteer-Run Cameras as Distributed Sensors for Macrosystem Mammal Research. *Landscape Ecology, 31,* 1–13. <https://doi.org/10.1007/s10980-015-0262-9>

Meek, P. D., Ballard, G. A., & Falzon, G. (2016). The Higher You Go the Less You Will Know: Placing Camera Traps High to Avoid Theft Will Affect Detection. Remote Sensing in Ecology and Conservation, 2(4), 204–211. <https://doi.org/10.1002/rse2.28>

Meek, P. D., Ballard, G.-A., Fleming, P. J. S., Schaefer, M., Williams, W., & Falzon, G. (2014a). Camera Traps Can Be Heard and Seen by Animals. *PLoS One*, *9*(10), e110832. <https://doi.org/10.1371/journal.pone.0110832>

Meek, P. D., Ballard, G., Claridge, A., Kays, R., Moseby, K., O’Brien, T., O’Connell, A., Sanderson, J., Swann, D. E., Tobler, M., & Townsend, S. (2014b). Recommended Guiding Principles for Reporting on Camera trap Trapping Research. *Biodiversity and Conservation*, *23*(9), 2321–2343. <https://doi.org/10.1007/s10531-014-0712-8>

Mills, C. A., Godley, B. J., & Hodgson, D. J. (2016). Take Only Photographs, Leave Only Footprints: Novel Applications of Non-Invasive survey Methods for Rapid Detection of Small, Arboreal Animals. *PloS One, 11*(1), e0146142. <https://doi.org/10.1371/journal.pone.0146142>

Mills, D., Fattebert, J., Hunter, L. & Slotow, R. (2019). Maximising camera trap data: Using

attractants to improve detection of elusive species in multi-species surveys. *PLoS ONE, 14(5)*, e0216447. <https://doi.org/10.1371/journal.pone.0216447>

Moeller, A. K., Waller, S. J., DeCesare, N. J., Chitwood, M. C., & Lukacs, P. M. (2023). Best practices to account for capture probability and viewable area in camera‐based abundance estimation. *Remote Sensing in Ecology and Conservation.* <https://doi.org/10.1002/rse2.300>

Moeller, A. K., Lukacs, P. M., & Horne, J. S. (2018). Three Novel Methods to Estimate Abundance of Unmarked Animals using Remote Cameras. *Ecosphere, 9*(8), Article e02331. <https://doi.org/10.1002/ecs2.2331>

Moll, R. J., Ortiz-Calo, W., Cepek, J. D., Lorch, P. D., Dennis, P. M., Robison, T., & Montgomery, R. A. (2020). The effect of camera-trap viewshed obstruction on wildlife detection: implications for inference. *Wildlife Research, 47*(2). <https://doi.org/10.1071/wr19004>

Moqanaki, E.S., Milleret, C., Tourani, M., Dupont, P., & Bischof, R. (2021). Consequences of ignoring variable and spatially autocorrelated detection probability in spatial capture- recapture. *Landscape Ecology, 36, 2879–2895*. <https://doi.org/10.1007/s10980-021-01283-x>

Morin, D. J., Boulanger, J., Bischof, R., Lee, D. C., Ngoprasert, D., Fuller, A. K., McLellan, B., Steinmetz, R., Sharma, S., Garshelis, D., Gopalaswamy, A., Nawaz, M. A., & Karanth, U. (2022). Comparison of methods for estimating density and population trends for low-density Asian bears. *Global Ecology and Conservation, 35*, e02058 <https://doi.org/10.1016/j.gecco.2022.e02058>

Morris, D. (2022). *Everything I know about machine learning and camera traps.* <https://agentmorris.github.io/camera-trap-ml-survey/>

Mullahy, J. (1986). Specification and Testing of Some Modified Count Data Models. *Journal of Econometrics, 3*3(3), 341–365. <https://doi.org/10.1016/0304-4076(86)90002-3>

Murray, M. H., Hill J., Whyte, P., St Clair, C. C. (2016) Urban Compost Attracts Coyotes, Contains Toxins, and may Promote Disease in Urban-Adapted Wildlife. *EcoHealth, 13*(2):285–92. <https://www.ncbi.nlm.nih.gov/pubmed/27106524>

Nakashima, Y., Fukasawa, & K., Samejima, H. (2018). Estimating Animal Density Without Individual Recognition Using Information Derivable Exclusively from Camera Traps. *Journal of Applied Ecology, 55*(2), 735–744. <https://doi.org/10.1111/1365-2664.13059>

Neilson, E. W., Avgar, T., Burton, A. C., Broadley, K., & Boutin, S. (2018). Animal movement affects interpretation of occupancy models from camera‐trapsurveys of unmarked animals. *Ecosphere, 9*(1). <https://doi.org/10.1002/ecs2.2092>

Newbold, H. G. & King, C. M. (2009). Can a predator see invisible light? Infrared vision in ferrets (*Mustelo furo*). *Wildlife Research, 36*(4), 309–318. <https://doi.org/10.1071/WR08083>

Norouzzadeh, M. S., Morris, D., Beery, S., Joshi, N., Jojic, N., Clune, J., & Schofield, M. (2020). A deep active learning system for species identification and counting in camera trap images. *Methods in Ecology and Evolution, 12*(1), 150–161. <https://doi.org/10.1111/2041-210x.1350>

Noss, A., Cuéllar, R., Barrientos, J., Maffei, L., Cuéllar, E., Arispe, R., Rumiz, D., & Rivero, K. (2003). A Camera trapping and radio telemetry study of lowland tapir (*Tapirus terrestris*) in Bolivian dry forests. *Tapir Conservation*, *12*, 24–32. [https://www.researchgate.net/publication/228541823\_A\_Camera\_trapping\_and\_radio\_telemetry\_study\_of\_lowland\_tapir\_Tapirus\_terrestris\_in\_Bolivian\_dry\_forests](https://www.researchgate.net/publication/228541823_A_camera_trapping_and_radio_telemetry_study_of_lowland_tapir_Tapirus_terrestris_in_Bolivian_dry_forests)

Noss, A. J., Gardner, B., Maffei, L., Cuéllar, E., Montaño, R., Romero-Muñoz, A., Sollman, R., O'Connell, A. F., & Altwegg, R. (2012). Comparison of density estimation methods for mammal populations with camera traps in the Kaa-Iya del Gran Chaco landscape. *Animal Conservation, 15*(5), 527–535. <https://doi.org/10.1111/j.1469-1795.2012.00545.x>

Obbard, M.E., Howe, E.J. & Kyle, C.J. (2010). Empirical Comparison of Density Estimators for Large Carnivores. *Journal of Applied Ecology*, 47(1), 76–84. <https://doi.org/10.1111/j.1365-2664.2009.01758.x>

O’Brien, T. G., Kinnaird, M. F. & Wibisono, H. T. (2003). Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation, 6*(2), 131-139. <https://doi.org/10.1017/s1367943003003172>

O’Brien, T. G. (2011). Abundance, Density and Relative Abundance: A Conceptual Framework. In A. F. O’Connell, J. D. Nichols, & K. U. Karanth (Eds.), *Camera Traps In Animal Ecology: Methods and Analyses* (pp. 71–96). Springer. <https://doi.org/10.1007/978-4-431-99495-4_6>

O’Brien, T. (2010). *Wildlife Picture Index: Implementation Manual Version 1.0.* WCS Working Paper No. 39. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.538.8335&rep=rep1&type=pdf>

O’Brien, T. G., Kinnaird, M. F., & Wibisono, H. T. (2011). Estimation of Species Richness of Large Vertebrates Using Camera Traps: An Example from an Indonesian Rainforest. In A. F. O’Connell, J. D. Nichols, & K. U. Karanth (Eds.), *Camera Traps In Animal Ecology: Methods and Analyses* (pp. 233–252). Springer. <https://doi.org/10.1007/978-4-431-99495-4_6>

O’Brien, T. G., & Kinnaird, M. F. (2011). Density estimation of sympatric carnivores using spatially explicit capture–recapture methods and standard trapping grid. *Ecological Applications, 21*(8), 2908–2916. <https://www.jstor.org/stable/41417102>

O’Connell, A. F., & Bailey, L. L. (2011a). Inference for Occupancy and Occupancy Dynamics. In O’Connell, A. F. Nichols, J. D. & Karanth, K. U. (Eds.), *Camera Traps In Animal Ecology: Methods and Analyses* (pp. 191–206). Springer. <https://doi.org/10.1007/978-4-431-99495-4_6>

O’Connor, K. M., Nathan, L. R., Liberati, M. R., Tingley, M. W., Vokoun, J. C., & Rittenhouse, T. A. G. (2017). Camera trap arrays improve detection probability of wildlife: Investigating study design considerations using an empirical dataset. PloS One, 12(4), e0175684. <https://doi.org/10.1371/journal.pone.0175684>

Pacifici, K., Reich, B. J., Dorazio, R. M., Conroy, M. J., & McPherson, J. (2016). Occupancy estimation for rare species using a spatially‐adaptive sampling design. *Methods in Ecology and Evolution, 7*(3), 285–293. <https://doi.org/10.1111/2041-210x.12499>

Palencia, P., Rowcliffe, J. M., Vicente, J., & Acevedo, P. (2021). Assessing the camera trap methodologies used to estimate density of unmarked populations. *Journal of Applied Ecology, 58*(8), 1583–1592. <https://doi.org/10.1111/1365-2664.13913>

Palencia, P., Vicente, J., Soriguer, R. C., & Acevedo, P. (2022). Towards a best‐practices guide for camera trapping: assessing differences among camera trap models and settings under field conditions. *Journal of Zoology, 316*(3), 197–208. <https://doi.org/10.1111/jzo.12945>

Palmer, M.S., Swanson, A., Kosmala, M., Arnold, T. & Packer, C. (2018). Evaluating relative abundance indices for terrestrial herbivores from large‐scale camera trap surveys. *African Journal of Ecology*, 56, 791-803. <https://onlinelibrary.wiley.com/doi/abs/10.1111/aje.12566>

Parmenter, R. R., Yates, T. L., Anderson, D. R., Burnham, K. P., Dunnum, J. L., Franklin, A. B., Friggens, M. T., Lubow, B. C., Miller, M., Olson, G. S., Parmenter, C. A., Pollard, J., Rexstad, E., Shenk, T. M., Stanley, T. R., & White, G. C. (2003). Small-mammal density estimation: A field comparison of grid-based vs. web-based density estimators. *Ecological Monographs, 73*(1), 1-26. [https://doi.org/10.1890/0012-9615(2003)073[0001:Smdeaf]2.0.Co;2](https://doi.org/10.1890/0012-9615(2003)073%5b0001:Smdeaf%5d2.0.Co;2)

Pease, B. S., Nielsen, C. K., & Holzmueller, E. J. (2016). Single-Camera TrapSurvey Designs Miss Detections: Impacts on Estimates of Occupancy and Community Metrics. *PloS One, 11*(11), e0166689. <https://doi.org/10.1371/journal.pone.0166689>

Powell, R. A., & Mitchell, M. S. (2012). What is a home range? *Journal of Mammalogy, 93*(4), 948-958. <https://doi.org/10.1644/11-mamm-s-177.1>

Ramage, B. S., Sheil, D., Salim, H. M. W., Fletcher, C., Mustafa, N.-Z. A., Luruthusamay, J. C., Harrison, R. D., Butod, E., Dzulkiply, A. D., Kassim, A. R., & Potts, M. D. (2013). Pseudoreplication in tropical forests and the resulting effects on biodiversity conservation. *Conservation Biology, 27*(2), 364–372. <https://www.jstor.org/stable/23525262>

Randler, C. and Kalb, N. (2018). Distance and size matters: A comparison of six wildlife camera traps and their usefulness for wild birds. *Ecology and Evolution*, 1-13. <https://onlinelibrary.wiley.com/doi/pdf/10.1002/ece3.4240>

Reconyx Inc. (2018). Hyperfire Professional/Outdoor Instruction Manual. Holmen, WI, USA. <https://www.reconyx.com/img/file/HyperFire_2_User_Guide_2018_07_05_v5.pdf>

Resources Information Standards Committee (RISC). (2019). *Camera trap Metadata Protocol: Standards for Components of British Columbia’s Biodiversity No. 44*. Province of British Columbia Knowledge Management Branch, Ministry of Environment and Climate Change Strategy, and Ministry of Forests, Lands, Natural Resource Operations and Rural Development. Victoria, B.C. [https://www2.gov.bc.ca/assets/download/DABCE3A5C7934410A8307285070C24EA](about:blank)

Rich, L. N., Kelly, M. J., Sollmann, R., Noss, A. J., Maffei, L., Arispe, R. L., Paviolo, A., De Angelo, C. D., Di Blanco, Y. E., & Di Bitetti, M. S. (2014). Comparing capture-recapture, mark-resight, and spatial mark-resight models for estimating puma densities via camera traps. *Journal of Mammalogy, 95*(2), 382–391. <https://doi.org/10.1644/13-mamm-a-126>

Ridout, M. S., & Linkie, M. (2009). Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics, 14*(3), 322–337. <https://doi.org/10.1198/jabes.2009.08038>

Robinson, S. G., Weithman, C. E., Bellman, H. A., Prisley, S. P., Fraser, J. D., Catlin, D. H., & Karpanty, S. M. (2020). Assessing Error in Locations of Conspicuous Wildlife Using Handheld GPS Units and Location Offset Methods. *Wildlife Society Bulletin, 44*(1), 163-172. <https://doi.org/10.1002/wsb.1055>

Rovero, F., & Marshall, A. R. (2009). Camera Trapping Photographic Rate as an Index of Density in Forest Ungulates. *Journal of Applied Ecology*, *46*(5), 1011–1017. <https://www.jstor.org/stable/25623081>

Rovero, F., Zimmermann, F., Berzi, D., & Meek, P. (2013). Which camera trap type and how many do I need? A review of camera features and study designs for a range of wildlife research applications. *Hystrix, the Italian Journal of Mammalogy*, *24*(2), 148–156. <https://doi.org/10.4404/hystrix-24.2-6316>

Rovero, F., & Zimmermann, F. (2016). *Camera Trapping for Wildlife Research*. Exeter: Pelagic Publishing, UK.

Rowcliffe, J. M., & C. Carbone. (2008). Surveys Using Camera Traps: Are We Looking to a Brighter Future?” *Animal Conservation, 11*(3), 185–86. <https://doi.org/10.1111/j.1469-1795.2008.00180.x>

Rowcliffe, M. J., Carbone, C., Jansen, P. A., Kays, R., & Kranstauber, B. (2011). Quantifying the sensitivity of camera traps: an adapted distance sampling approach. *Methods in Ecology and Evolution, 2*(5), 464–476. <https://doi.org/10.1111/j.2041-210X.2011.00094.x>

Rowcliffe, J. M., Field, J., Turvey, S. T., & Carbone, C. (2008). Estimating animal density using camera traps without the need for individual recognition. *Journal of Applied Ecology*, *45*(4), 1228–1236. <https://doi.org/10.1111/j.1365-2664.2008.01473.x>

Rowcliffe, J. M., Kays, R., Carbone, C., & Jansen, P. A. (2013). Clarifying assumptions behind the estimation of animal density from camera trap rates. *The Journal of Wildlife Management, 77*(5), 876–876. <https://doi.org/10.1002/jwmg.533>

Rowcliffe, J. M., Kays, R., Kranstauber, B., Carbone, C., Jansen, P. A., & Fisher, D. (2014). Quantifying levels of animal activity using camera trap data. *Methods in Ecology and Evolution*, *5*(11), 1170–1179. <https://doi.org/10.1111/2041-210x.12278>

Rowcliffe, J. M., Jansen, P. A., Kays, R., Kranstauber, B. & Carbone, C. (2016). Wildlife speed cameras: measuring animal travel speed and day range using camera traps. *Remote Sensing in Ecology and Conservation, 2*, 84–94. <https://doi.org/10.1002/rse2.17>

Royle, J. A. (2004). N-mixture Models for estimating population size from spatially Repeated Counts. *International Biometric Society, 60*(1), 108–115. <https://www.jstor.org/stable/3695558>

Royle, J. A., Converse, S. J., & Freckleton, R. (2014). Hierarchical spatial capture-recapture models: modelling population density in stratified populations. *Methods in Ecology and Evolution, 5*(1), 37-43. <https://doi.org/10.1111/2041-210x.12135>

Royle, J. A., & Nichols, J. D. (2003). Estimating abundance from repeated presence–absence data or point counts. *Ecology, 84*, 777–790. [https://doi.org/10.1890/0012-9658(2003)084[0777:EAFRPA]2.0.CO;2](https://doi.org/10.1890/0012-9658(2003)084%5b0777:EAFRPA%5d2.0.CO;2)

Royle, J. A., Nichols, J. D., Karanth, K. U., & Gopalaswamy, A. M. (2009). A hierarchical model for estimating density in camera-trap studies. *Journal of Applied Ecology, 46*(1), 118–127. <https://doi.org/10.1111/j.1365-2664.2008.01578.x>

Royle, J. A., & Young, K. V. (2008). A hierarchical model for spatial capture-recapture data. *Ecology, 89*(8), 2281–2289. <https://doi.org/10.1890/07-0601.1>

Samejima, H., Ong, R., Lagan, P. & Kitayama, K. (2012). Camera-trapping rates of mammals and birds in a Bornean tropical rainforest under sustainable forest management. *Forest Ecology and Management, 270*, 248–256. <https://doi.org/10.1016/j.foreco.2012.01.013>

Schlexer, F. V. (2008). Attracting Animals to Detection Devices. In R. A. Long, P. MacKay, W. J. Zielinski, & J. C. Ray (Eds.), *Noninvasive Survey Methods for Carnivores* (pp. 263–292). Island Press. <https://www.gwern.net/docs/cat/biology/2008-schlexer.pdf>

Schenider, S., Taylor, G.W., Linquist, S., & Kremer, S.C. (2018). Past, Present, and Future Approaches Using Computer Vision for Animal Re-Identification from Camera Trap Data. *Methods in Ecology and Evolution, 10, 461-47*0. https://besjournals.onlinelibrary.wiley.com/doi/epdf/10.1111/2041-210X.13133

Schweiger, A. K. (2020). Spectral Field Campaigns: Planning and Data Collection. In *Remote Sensing of Plant Biodiversity* (pp. 385–423). <https://doi.org/10.1007/978-3-030-33157-3_15>

Scotson, L., Johnston, L. R., Lannarilli, F., Wearn, O. R., Mohd‐Azlan, J., Wong, W. M., Gray, T. N. E., Dinata, Y., Suzuki, A., Willard, C. E., Frechette, J., Loken, B., Steinmetz, R., Moßbrucker, A. M., Clements, G. R., & Fieberg, J. (2017). Best Practices and Software for the Management and Sharing of Camera Trap Data for Small and Large Scales Studies. *Remote Sensing in Ecology and Conservation*, 3(3), 158–172. <https://doi.org/10.1002/rse2.54>

Shannon, G., Lewis, J. S. & Gerber, B. D. (2014). RecommendedSurvey Designs for Occupancy Modelling using Motion-activated Cameras: Insights from Empirical Wildlife Data. *PeerJ, 2*, e532. <https://doi.org/10.7717/peerj.532>

Seccombe, S. (2017). *ZSL Trail Camera Comparison Testing.* Zoological Society of London: Conservation Technology Unit. <https://www.wildlabs.net/sites/default/files/community/files/zsl_trail_camera_comparison_for_external_use.pdf>

Séquin E. S., Jaeger M. M., Brussard P. F., & Barrett R. H. (2003). Wariness of Coyotes to Camera Traps Relative to Social Status and Territory Boundaries. Lincoln, NE, USA: University of Nebraska–Lincoln. <https://doi.org/10.1139/z03-204>

Si, X., Kays, R., & Ding, P. (2014). How long is enough to detect terrestrial animals? Estimating the minimum trapping effort on camera traps. *PeerJ, 2*, e374. <https://doi.org/10.7717/peerj.374>

Sirén, A. P. K., Somos‐Valenzuela, M., Callahan, C., Kilborn, J. R., Duclos, T., Tragert, C., & Morelli., T. L. (2018) Looking beyond Wildlife: Using Remote Cameras to Evaluate Accuracy of Gridded Snow Data. Edited by Marcus Rowcliffe and Sadie Ryan. *Remote Sensing in Ecology and Conservation, 4*(4), 375–86. <https://doi.org/10.1002/rse2.85>

Sollmann, R. (2018). A gentle introduction to camera‐trap data analysis. *African Journal of Ecology,* 56, 740–749. <https://doi.org/10.1111/aje.12557>

Sollmann, R., Furtado, M.M., Gardner, B., Hofer, H., Jácomo, A.T.A., Tôrres, N.M. & Silveira, L. (2011). Improving Density Estimates for Elusive Carnivores: Accounting for Sex-Specific Detection and Movements Using Spatial Capture–Recapture Models for Jaguars in Central Brazil. *Biological Conservation*,144(3), 1017–24. <https://doi.org/10.1016/j.biocon.2010.12.011>

Sollmann, R., Gardner, B. & Belant, J. L. (2012). How does Spatial Study Design Influence Density Estimates from Spatial capture-recapture models? *PLoS One, 7*, e34575. <https://doi.org/10.1371/journal.pone.0034575>

Sollmann, R., Gardner, B., Chandler, R. B., Shindle, D. B., Onorato, D. P., Royle, J. A., O'Connell, A. F., & Lukacs, P. (2013a). Using multiple data sources provides density estimates for endangered Florida panther. *Journal of Applied Ecology, 50*(4), 961–968. <https://doi.org/10.1111/1365-2664.12098>

Sollmann, R., Gardner, B., Parsons, A. W., Stocking, J. J., McClintock, B. T., Simons, T. R., Pollock, K. H., & O'Connell, A. F. (2013b). A Spatial Mark-Resight Model Augmented with Telemetry Data. *Ecology, 94*(3), 553–559. <https://doi.org/10.1890/12-1256.1>

Sollmann, R., Mohamed, A., Samejima, H., & Wilting, A. (2013c). Risky Business or Simple Solution – Relative Abundance Indices from Camera-Trapping. *Biological Conservation, 159*, 405–412. <https://doi.org/10.1016/j.biocon.2012.12.025>

Soria-Díaz, L., Monroy-Vilchis, O., Rodríguez-Soto, C., Zarco-González, M., & Urios, V. (2010). Variation of Abundance and Density of *Puma concolor* in Zones of High and Low Concentration of Camera Traps in Central Mexico. *Animal Biology, 60*(4), 361-371. <https://doi.org/10.1163/157075610X523251>

Steenweg, R., Hebblewhite, M., Kays, R., Ahumada, J., Fisher, J. T., Burton, C., Townsend, S. E., Carbone, C., Rowcliffe, J. M., Whittington, J., Brodie, J., Royle, J. A., Switalski, A., Clevenger, A. P., Heim, N., & Rich, L. N. (2017). Scaling‐up Camera Traps: Monitoring the Planet’s Biodiversity with Networks of Remote Sensors. *Frontiers in Ecology and the Environment*, *15*(1), 26–34. <https://doi.org/10.1002/fee.l448>

Steenweg, R., Hebblewhite, M., Whittington, J., Lukacs, P., & McKelvey, K. (2018). Sampling scales define occupancy and underlying occupancy–abundance relationships in animals. *Ecology*, *99*(1), 172–183. <https://doi.org/10.1002/ecy.2054>

Steenweg, R., Hebblewhite, M., Whittington, J., & Mckelvey, K. (2019). Species‐specific Differences in Detection and Occupancy Probabilities Help Drive Ability to Detect Trends in Occupancy. *Ecosphere, 10*(4), Article e02639. <https://doi.org/10.1002/ecs2.2639>

Steenweg, R., Whittington, J., & Hebblewhite, M. (2015). *Canadian Rockies remote camera multi-species occupancy project: Examining trends in carnivore populations and their prey*. University of Montana. <http://parkscanadahistory.com/wildlife/steenweg-2015.pdf>

Steinbeiser, C. M., Kioko, J., Maresi, A., Kaitilia, R., & Kiffner, C. (2019). Relative Abundance and Activity Patterns Explain Method-Related Differences in Mammalian Species Richness Estimates. *Journal of Mammalogy, 100*(1), 192–201. <https://doi.org/10.1093/jmammal/gyy175>

Stokeld, D., Frank, A. S., Hill, B., Choy, J. L., Mahney, T., Stevens, A., & Gillespie, G. R. (2016). Multiple Cameras Required to Reliably Detect Feral Cats in Northern Australian Tropical Savannah: An Evaluation of Sampling Design When Using Camera Traps. *Wildlife Research, 42*(8), 642–649. <https://doi.org/10.1071/WR15083>

Sun, C., Beirne, C., Burgar, J. M., Howey, T., Fisher, J. T., Burton, A. C., Rowcliffe, M., & Hofmeester, T. (2021). Simultaneous Monitoring of Vegetation Dynamics and Wildlife Activity with Camera Traps to Assess Habitat Change. *Remote Sensing in Ecology and Conservation, 7*(4), 666-684. <https://doi.org/10.1002/rse2.222>

Sun, C., Burgar, J. M., Fisher, J. T., & Burton, A. C. (2022). A Cautionary Tale Comparing Spatial Count and Partial Identity Models for Estimating Densities of Threatened and Unmarked Populations. *Global Ecology and Conservation, 38*, e02268. <https://doi.org/10.1016/j.gecco.2022.e02268>

Sun, C. C., Fuller, A. K., & Royle., J. A. (2014). Trap Configuration and Spacing Influences Parameter Estimates in Spatial Capture-Recapture Models. *PLoS One, 9*(2): e88025. <https://doi.org/10.1371/journal.pone.0088025>.

Suwanrat, S., Ngoprasert, D., Sutherland, C., Suwanwareea, P., Savini, T. 2015. Estimating density of secretive terrestrial birds (Siamese Fireback) in pristine and degraded forest using camera traps and distance sampling. *Global Ecology and Conservation, 3*, 596–606. <https://www.sciencedirect.com/science/article/pii/S2351989415000116>

Tabak, M. A., Norouzzadeh, M. S., Wolfson, D. W., Sweeney, S. J., Vercauteren, K. C., Snow, N. P., Halseth, J. M., Di Salvo, P. A., Lewis, J. S., White, M. D., Teton, B., Beasley, J. C., Schlichting, P. E., Boughton, R. K., Wight, B., Newkirk, E. S., Ivan, J. S., Odell, E. A., Brook, R. K., . . . Photopoulou, T. (2018). Machine Learning to Classify Animal Species in Camera Trap Images: Applications in Ecology. *Methods in Ecology and Evolution, 10*(4), 585–590. <https://doi.org/10.1111/2041-210x.13120>

The WILDLABS Partnership (2021). *How do I get started with Megadetector?* Siyu Y. <https://www.wildlabs.net/event/how-do-i-get-started-megadetector>

Thorn, M., Scott, D. M., Green, M., Bateman, P. W. & Cameron, E. Z. (2009). Estimating Brown Hyaena Occupancy using Baited Camera Traps. *South African Journal of Wildlife Research, 39*(1), 1–10. <https://doi.org/10.3957/056.039.0101>

Tobler, M. W., Pitman, R. L., Mares, R. & Powell, G. (2008). An Evaluation of Camera Traps for Inventorying Large- and Medium-Sized Terrestrial Rainforest Mammals. *Animal Conservation, 11*, 169–178. <https://doi.org/10.1111/j.1469-1795.2008.00169.x>

Tobler, M. W. & Powell, G. V. N. (2013). Estimating jaguar densities with camera traps: problems with current designs and recommendations for future studies. *Biological Conservation, 159*, 109–118. <https://doi.org/10.1016/j.biocon.2012.12.009>

Twining, J. P., McFarlane, C., O’Meara, D., O’Reilly, C., Reyne, M., Montgomery, W. I. Helyar, S., Tosh, D. G., & Augustine, B. C. (2022) A Comparison of Density Estimation Methods for Monitoring Marked and Unmarked Animal Populations. *Ecosphere, 13*(10), e4165. <https://doi.org/10.1002/ecs2.4165>

Van Wilgenburg, S.L., Mahon, C.L., Campbell, G., McLeod, L., Campbell, M., Evans, D., Easton, W., Francis, C.M., Hache´, S., Machtans, C.S., Mader, C., Pankratz, R.F., Russell, R., Smith, A.C., Thomas, P., Toms, J.D., Tremblay, J.A. (2020). A Cost Efficient Spatially Balanced Hierarchical Sampling Design for Monitoring Boreal Birds Incorporating Access Costs and Habitat Stratification. *PLoS ONE, 15(6).* <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0234494>

Velez, J., McShea, W., Shamon, H., Castiblanco-Camacho, P.J., Tabak, M.A., Chalmers, C., Fergus, P. & Fieberg, J. (2023). An Evaluation of Platforms for Processing Camera-Trap Data using Artificial Intelligence. *Methods in Ecology and Evolution, 145*, 459-477. <https://doi.org/10.1111/2041-210X.14044>

Vidal, M., Wolf, N., Rosenberg, B., Harris, B.P. & Mathis, A. (2021). Perspectives on Individual Animal Identification from Biology and Computer Vision. *Integrative and Comparative Biology, 61(3),* 900-916. <https://academic.oup.com/icb/article/61/3/900/6288456>

Warbington, C. H., & Boyce, M. S. (2020). Population density of sitatunga in riverine wetland habitats. *Global Ecology and Conservation*, *24*. <https://doi.org/10.1016/j.gecco.2020.e01212>

Wearn, O. R., Carbone, C., Rowcliffe, J. M., Bernard, H. & Ewers, R. M. (2016). Grain-dependent responses of mammalian diversity to land-use and the implications for conservation set-aside. *Ecological Applications, 26*(5), 1409–1420. <https://doi.org/10.1890/15-1363>

Wearn, O. R., & Glover-Kapfer, P. (2017). Camera-Trapping for Conservation: A Guide to Best-ractices. *WWF conservation technology series*, *1*, 1–181. <http://dx.doi.org/10.13140/RG.2.2.23409.17767>

Wearn, O. R., Rowcliffe, J. M., Carbone, C., Bernard, H., & Ewers, R. M. (2013). Assessing the status of wild felids in a highly-disturbed commercial forest reserve in Borneo and the implications for camera trap survey design. *PLoS One, 8*(11), e77598. <https://doi.org/10.1371/journal.pone.0077598>

Wegge, P., C. P. Pokheral, & Jnawali, S. R. (2004). Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. *Animal Conservation 7*, 251–256. <https://doi.org/10.1017/S1367943004001441>

Welbourne, D.J., Claridge, A.W., Paul, D.J. & Lambert, A. (2016). How do passive infrared triggered camera traps operate and why does it matter? Breaking down common misconceptions. *Remote Sensing in Ecology and Conservation*, 77-83. <https://doi.or/10.1002/rse2.20>

Wellington, K., Bottom, C., Merrill, C., & Litvaitis, J. A. (2014). Identifying performance differences among trail cameras used to monitor forest mammals. *Wildlife Society Bulletin, 38*(3), 634–638. <https://doi.org/10.1002/wsb.425>

Whittington, J., Hebblewhite, M., Chandler, R. B., & Lentini, P. (2018). Generalized spatial mark-resight models with an application to grizzly bears. *Journal of Applied Ecology, 55*(1), 157–168. <https://doi.org/10.1111/1365-2664.12954>

WildCAM Network (2019). *WildCAM Network Camera Trapping Best Practices Literature Synthesis.* <https://wildcams.ca/site/assets/files/1390/wildcam_network_camera_trapping_best_practices_literature_synthesis.pdf>

WildCo Lab (2020). *WildCo\_Image\_Renamer.* <https://github.com/WildCoLab/WildCo_Image_Renamer>

WildCo Lab (2021a). *WildCo-FaceBlur.* <https://github.com/WildCoLab/WildCo_Face_Blur>

WildCo Lab (2021b). *WildCo: Reproducible camera trap data exploration and analysis examples in R*. University of British Columbia. <https://bookdown.org/c_w_beirne/wildCo-Data-Analysis/#what-this-guide-is>

Young, S., Rode-Margono, J., & Amin, R. (2018). Software to facilitate and streamline camera trap data management: A review. *Ecology and Evolution*, *8*(19), 9947–9957. <https://doi.org/10.1002/ece3.4464>

Zorn, C. J. W. (1998). An Analytic and Empirical Examination of Zero-inflated and Hurdle Poisson Specifications. *Sociological Methods and Research 26*(3), 368-400. <https://doi.org/10.1177/0049124198026003004>

Zuur, A. K., Ieno, E. N., & Smith, G. M. (2007). Generalised linear modelling. In, M. Gail, K. Krickeberg, J. Samet, A. Tsiatis, & W. Wong (Eds.), *Analysing Ecological Data* (pp 79-96). Springer. <https://doi.org/10.1111/j.1751-5823.2007.00030_17.x>

# Glossary

|  |  |
| --- | --- |
| **Field name** | **Definition** |
| **\*Access Method** | The method used to reach the camera location (e.g., on "Foot," "ATV," "Helicopter," etc.). |
| **Age Class** | The age classification of individual(s) being categorized (e.g., "Adult," "Juvenile," "Subadult," "Subadult - Young of Year," "Subadult - Yearling,” or "Unknown"). |
| **Analyst** | The first and last names of the individual who provided the observation data point (species identification and associated information). If there are multiple analysts for an observation, enter the primary analyst. |
| Audible lure | Sounds imitating noises of prey or conspecifics that draw animals closer by eliciting curiosity (Schlexer, 2008). |
| Bait | A food item (or other substance) that is placed to attract animals via the sense of taste and olfactory cues (Schlexer, 2008). |
| **Bait/Lure Type** | The type of bait or lure used at a camera location. Record “None” if a Bait/Lure Type was not used and "Unknown" if not known. If “Other,” describe in the Deployment Comments. |
| **\*Batteries Replaced** | Whether the camera's batteries were replaced. |
| **\*Behaviour** | The behaviour of the individual(s) being categorized (e.g., "Standing," "Drinking," "Vigilant," etc.). |
| **\*Camera Active On Arrival** | Whether a camera was functional upon arrival. |
| **\*Camera Active On Departure** | Whether a camera was functional upon departure. |
| Camera angle | The degree at which the camera is pointed toward the FOV Target Feature relative to the horizontal ground surface (with respect to slope, if applicable). |
| **\*Camera Attachment** | The method/tools used to attach the camera (e.g., attached to a tree with a bungee cord; reported as codes such as "Tree + Bungee/Strap"). If “Other,” describe in the Camera Location Comments. |
| **\*Camera Damaged** | Whether the camera was damaged or malfunctioning; if there is any damage to the device (physical or mechanical), the crew should describe the damage in the Service/Retrieval Comments. |
| Camera days per camera location | The number of days each camera was active and functioning during the period it was deployed (e.g., 24-hour periods or the difference in days between the Deployment Start Date Time and the Deployment End Date Time if there were no interruptions). |
| **\*Camera Direction (degrees)** | The cardinal direction that a camera faces. Ideally, cameras should face north (N; i.e. "0" degrees), or south (S; i.e. "180" degrees) if north is not possible. The Camera Direction should be chosen to ensure the field of view (FOV) is of the original FOV target feature. |
| **Camera Height (m)** | The height from the ground (below snow) to the bottom of the lens (metres; to the nearest 0.05 m). |
| **Camera ID** | A unique alphanumeric ID for the camera that distinguishes it from other cameras of the same make or model. |
| Camera location | The location where a single camera was placed (recorded as "Camera Location Name"). |
| **\*Camera Location Characteristic(s)** | Any significant features around the camera at the time of the visit. This may include for example, manmade or natural linear features (e.g., trails), habitat types (e.g., wetlands), wildlife structure (e.g., beaver dam). If “Other,” describe in the Camera Location Comments.  Camera Location Characteristics differ from FOV Target Features in that Camera Location Characteristics could include those not in the camera's Field of View. If “Other,” describe in the Camera Location Comments. |
| **\*Camera Location Comments** | Comments describing additional details about a camera location. |
| **Camera Location Name** | A unique alphanumeric identifier for the location where a single camera was placed (e.g., "bh1," "bh2"). |
| **Camera Make** | The make of a particular camera (i.e., the manufacturer, e.g., "Reconyx" or "Bushnell”). |
| **Camera Model** | The model number or name of a particular camera (e.g., "PC900" or "Trophy Cam HD"). |
| **Camera Serial Number** | The serial number of a particular camera, which is usually found inside the camera cover (e.g., "P900FF04152022"). |
| Camera spacing | The distance between cameras (i.e., also referred to as "inter-trap distance"). This will be influenced by the chosen sampling design, the Survey Objectives, the Target Species and data analysis. |
| Capture-recapture (CR) model /  Capture-mark-recapture (CMR) model (Karanth, 1995; Karanth & Nichols, 1998) | A method of estimating the abundance or density of marked populations using the number of animals detected and the likelihood animals will be detected (detection probability). CR (Karanth, 1995; Karanth & Nichols, 1998) can be used to estimate vital rates where all newly detected unmarked animals become marked and are distinguishable in future (Efford, 2022). Spatially explicit capture-recapture (SECR; Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008) models have largely replaced CR and CMR models and provide more accurate density estimates (Blanc et al., 2013, Obbard et al., 2010, Sollmann et al., 2011). |
| Categorical partial identity model (catSPIM) (Augustine et al., 2019; Sun et al., 2022) | A method used to estimate the density of partially marked populations in which the "spatial locations of where partial identity samples are captured to probabilistically resolve their complete identities" (Augustine et al., 2018, 2019). catSPIM models use partial identity traits (e.g., sex class, antler points) to help infer individual identities (Augustine et al., 2019; Sun et al., 2022). catSPIM is an extension of the SC model (Chandler & Royle, 2013). |
| Clustered design | Multiple cameras are deployed at a sample station (Figure 3d). A clustered design can be used within a systematic or stratified approach (i.e., systematic clustered design or as a clustered random design [Wearn & Glover-Kapfer, 2017]). |
| Convenience design | Camera locations or sample stations are chosen based on logistic considerations (e.g., remoteness, access constraints, and/or costs). |
| Crew | The first and last names of all the individuals who collected data during the deployment visit ("Deployment Crew") and service/retrieval visit ("Service/Retrieval Crew"). |
| Cumulative detection probability | The probability of detecting a species at least once during the entire survey (Steenweg et al., 2019). |
| Density | The number of individuals per unit area. |
| Deployment | A unique placement of a camera in space and time (recorded as "Deployment Name"). There may be multiple deployments for one camera location. Deployments are often considered as the time between visits (i.e., deployment to service, service to service, and service to retrieval). Any change to camera location, sampling period, camera equipment (e.g., Trigger Sensitivity setting, becomes non-functioning), and/or conditions (e.g., not baited then baited later; camera SD card replaced) should be documented as a unique deployment. |
| **\*Deployment Area Photo Numbers** | The image numbers for the deployment area photos (if collected, e.g., "DSC100"). These are optionally documented on a Camera Deployment Field Datasheet for each set of camera deployment area photos. Leave blank if not applicable. |
| Deployment area photos | Photos of the area around the camera location, collected as a permanent, visual record of the FOV Target Features, Camera Location Characteristics, environmental conditions (e.g., vegetation, ecosite, weather) or other variables of interest. The recommendation includes collecting four photos taken from the centre of the target detection zone (Figure 5), facing each of the four cardinal directions. The documentation of the collection of these photos is recorded as "Deployment Area Photos Taken" (Y/N). |
| **\*Deployment Area Photos Taken** | Whether deployment area photos were taken (yes/no; optional). The recommendation includes collecting four photos taken from the centre of the target detection zone (Figure 5), facing each of the four cardinal directions. |
| **\*Deployment Comments** | Comments describing additional details about the deployment. |
| **Deployment Crew** | The first and last names of the individuals who collected data during the deployment visit. |
| **Deployment End Date Time (DD-MMM-YYYY HH:MM:SS)** | The date and time that the data was retrieved for a specific deployment (e.g., 27-Jan-2019 23:00:00). The Deployment End Date Time may not coincide with when the last image or video was collected (i.e., the Image Set End Date Time). Recording this field allows users to account for deployments where no images were captured and to confirm the last date and time that the camera was active. |
| Deployment metadata | Metadata that is collected each time a camera is deployed. Each deployment event should have its own Camera Deployment Field Datasheet. The relevant metadata fields that should be collected differ when a camera is deployed vs. serviced or retrieved.  Refer to Appendix A - Table A5 and Camera Deployment Field Datasheet. |
| **Deployment Name** | A unique alphanumeric identifier for a unique camera deployed during a specific survey period (ideally recorded as: “Camera Location Name”\_“Deployment Start Date” (or …\_”Deployment End Date”) (e.g., “bh1\_17-Jul-2018" or “bh1\_17-Jul-2018\_21-Jan-2019”).  Alternative naming conventions may be used, but the goal should be to minimize duplicate Image Names. |
| **Deployment Start Date Time (DD-MMM-YYYY HH:MM:SS)** | The date and time that a camera was placed for a specific deployment (e.g., 17-Jan-2018 10:34:22).  The Deployment Start Date Time may not coincide with when the first image or video was collected (i.e., the Image Set Start Date Time). Recording this field allows users to account for deployments where no images were captured and to confirm the first date and time a camera was active. |
| Deployment visit | When a crew has gone to a location to deploy a remote camera. |
| Detection “event” | A group of images or video clips that are considered independent from other images or video clips based on a certain time threshold (or “inter-detection interval”). For example, 30 minutes (O’Brien et al., 2003; Gerber et al., 2010; Kitamura et al., 2010; Samejima et al., 2012) or 1 hour (e.g., Tobler et al., 2008; Rovero & Marshall, 2009). |
| Detection distance | "The maximum distance that a sensor can detect a target" (Wearn and Glover-Kapfer, 2017). |
| Detection probability (aka detectability) | The probability (likelihood) that an individual of the population of interest is included in the count at time or location *i*. |
| Detection rate | The frequency of independent detections within a specified time period. |
| Detection zone | The area (conical in shape) in which a remote camera can detect the heat signature and motion of an object (Rovero & Zimmermann, 2016) (Figure 5). |
| Distance sampling (DS) model (Howe et al., 2017) | A method to estimate abundance by using distances at which animals are detected (from survey lines or points) to model abundance as a function of decreasing detection probability with animal distance from the camera (using a decay function) (Cappelle et al., 2021; Howe et al., 2017). |
| **Easting Camera Location** | The easting UTM coordinate of the camera location (e.g., "337875"). Record using the NAD83 datum. Leave blank if recording the Longitude instead. |
| Effective detection distance | The distance from a camera that would give the same number of detections if all animals up to that distance are perfectly detected, and no animals that are farther away are detected; Buckland, 1987, Becker et al., 2022). |
| False trigger | Blank images (no wildlife or human present). These images commonly occur when a camera is triggered by vegetation blowing in the wind. |
| Field of View (FOV) | The extent of a scene that is visible in an image (Figure 5); a large FOV is obtained by "zooming out" from a scene, whilst "zooming in" will result in a smaller FOV (Wearn & Glover-Kapfer, 2017). |
| Flash output | The camera setting that provides the level of intensity of the flash (if enabled). |
| **FOV Target Feature** | A specific man-made or natural feature at which the camera is aimed to maximize the detection of wildlife species or to measure the use of that feature. Record “None” if a FOV Target Feature was not used and "Unknown" if not known. If “Other,” describe in the Camera Location Comments. |
| **\*FOV Target Feature Distance (m)** | The distance from the camera to the FOV Target Feature (in metres; to the nearest 0.5 m). Leave blank if not applicable. |
| **GPS Unit Accuracy (m)** | The margin of error of the GPS unit used to record spatial information (e.g., "5" [m]), such as the coordinates of the camera location. On most GPS units (e.g., "Garmin") this information is provided on the unit’s satellite information page. |
| Hurdle model (Mullahy, 1986; Heilbron 1994) | A regression model used in the setting of excess zeros (zero-inflation) and overdispersion (Mullahy, 1986). Hurdle models (aka "zero-altered" models) differ from zero-inflation models in that they are two-part models, and the zero and non-zero counts are modelling separately (thus, they are only adequate when the counting process cannot generate a zero value) (Blasco-Moreno et al., 2019). [relative abundance indices] |
| Image | An individual image captured by a camera, which may be part of a multi-image sequence (recorded as "Image Name"). |
| Image classification | The process of assigning class labels to an image according to the wildlife species, other entities (e.g., human, vehicle), or conditions within the image. Image classification can be performed manually or automatically by an artificial intelligence (AI) algorithm. Image classification is sometimes used interchangeably with "image tagging." |
| Image classification confidence | The likelihood of an image containing an object of a certain class (Fennell et al., 2022). |
| **Image Name** | A unique alphanumeric identifier for the image. It is important to include (at a minimum) the camera location, date, time, and image number when generating an Image Name to avoid duplicate file names (e.g., "bh1\_17-Jul-2018\_P900FF04152022\_22-Jul-2018 10:34:22\_img\_100" or "bh1\_17-Jul-2018\_22-Jul-2018\_10:34:22\_img\_100"). |
| Image processing | The series of operations that are taken to extract information from images. In the case of remote camera data, it can include loading the images into a processing platform, extracting information from the image metadata (e.g., the date and time the image was taken), running an artificial intelligence (AI) algorithm to identify empty images, classifying animals or other entities within the image. |
| **Image Set End Date Time (DD-MMM-YYYY HH:MM:SS)** | The date and time of the last image or video collected during a specific deployment (e.g., "17-Jan-2018 22:10:05").  The Image Set End Date Time may not coincide with the deployment end date time. Recording this field allows users to account for deployments that were conducted but for which no data was found and to confirm the last date and time a camera was active (if functioning) if no images or videos were captured prior to Service/Retrieval (especially valuable if users did not collect Time-lapse images or if the camera malfunctioned). |
| **Image Set Start Date Time (DD-MMM-YYYY HH:MM:SS)** | The date and time of the first image or video collected during a specific deployment (e.g., “17-Jan-2018 12:00:02”).  The Image Set Start Date Time may not coincide with the Deployment Start Date Time. Recording this field allows users to confirm the first date and time a camera was active (reliable if Time-lapse images were collected; especially valuable if the user scheduled a start delay). |
| Image tagging | The process of classifying an image according to the wildlife species, other entities (e.g., human, vehicle), or conditions within the image. Image tagging may follow image classification to further classify characteristics of the individuals (e.g., age class, sex class, or behaviour) or entities within the image. |
| Imperfect detection | Species are often detected "imperfectly," meaning that they are not always detected when they are present (e.g., due to cover of vegetation, cryptic nature or small size) (MacKenzie et al., 2004). |
| Independent detections | Detections that are deemed to be independent based on a user-defined threshold (e.g., 30 minutes). |
| **Individual Count** | The number of unique individuals being categorized. Depending on the Event Type, this may be recorded as the total number of individuals, or according to Age Class and/or Sex Class. |
| Infrared illuminator | The camera setting that can be enabled (if applicable to the camera make and camera model) to obtain greater visibility at night by producing infrared light. This field is categorical; leave blank if not applicable and record "Unknown" if not known. |
| Instantaneous sampling (IS) (Moeller et al., 2018) | A method used to estimate abundance or density from time-lapse images from randomly deployed cameras; the number of unique individuals (the count) is needed (Moeller et al., 2018). |
| Intensity of use (Keim et al., 2019) | "The expected number of use events of a specific resource unit during a unit of time… [which characterizes] how frequently a particular resource unit is used" (Keim et al., 2019). The intensity of use differs from the probability of use (which characterizes "the probability of at least one use event of that resource unit during a unit of time"; Keim et al., 2019). |
| Inter-detection interval | A user-defined threshold used to define a single "detection event" (i.e., independent "events") for group of images or video clips (e.g., 30 minutes or 1 hour). The threshold should be recorded in the Survey Design Description. |
| Inventory | Rapid assessment surveys to determine what species are present in a given area at a given point in time; there is no attempt made to quantify aspects of communities or populations (Wearn & Glover-Kapfer, 2017). |
| Kernel density estimator | The probability of "utilization" (Jennrich & Turner, 1969); describes the relative probability of use (Powell & Mitchell, 2012). |
| **\*Key ID** | The unique ID for the specific key or set of keys used to lock/secure the camera to the post, tree, etc. |
| **Latitude Camera Location** | The latitude of the camera location in decimal degrees to five decimal places (e.g., "53.78136"). Leave blank if recording Northing instead. |
| **Longitude Camera Location** | The longitude of the camera location in decimal degrees to five decimal places (e.g., "-113.46067"). Leave blank if recording Easting instead. |
| Lure | Any substance that draws animals closer; lures include scent (olfactory) lure, visual lure and audible lure (Schlexer, 2008). |
| Marked individuals / populations / species | Individuals, populations, or species (varies with modelling approach and context) that can be identified using natural or artificial markings (e.g., coat patterns, scars, tags, collars). |
| Mark-resight (MR) model (Arnason et al., 1991; McClintock et al., 2009) | A method used to estimate the abundance of partially marked populations using the number of marked individuals, the number of unmarked individuals, and the detection probability from marked animals (Wearn & Glover-Kapfer, 2017). MR is similar to capture-recapture (CR; Karanth, 1995; Karanth & Nichols, 1998) models, except only a portion of animals are individually identified. |
| Metadata | Data that provides information about other data (e.g., the number of images on an SD card). |
| Model assumption | Explicitly stated (or implicitly premised) conventions, choices and other specifications (e.g., about the data, wildlife ecology/behaviour, the relationships between variables, etc.) on which a particular modelling approach is based that allows the model to provide valid inference. |
| Modelling approach | The method used to analyze the camera data, which should depend on the state variable, e.g., occupancy models [MacKenzie et al., 2002], spatially explicit capture recapture (SECR) for density estimation [Chandler and Royle, 2013], etc. and the Target Species. |
| **Motion Image Interval (seconds)** | The time (in seconds) between images within a multi-image sequence that occur due to motion, heat, or activation of external detector devices. The Motion Image Interval is pre-set in the camera’s settings by the user, but the time at which the camera collects images because of this setting is influenced by the presence of movement or heat. For example, if the camera was set to take 3 images per event at a Motion Image Interval of 3 seconds when the camera detects motion or heat, the first image will be collected (e.g., at 09:00:00), the second image will be collected 3 seconds later (09:00:03), and the third will be collected 3 seconds after that (09:00:06).  This setting differs from the Quiet Period in that the delay occurs between images contained within a multi-image sequence, rather than between multi-image sequences (as in Quiet Period). If a Motion Image Interval was not set, enter "0" seconds (i.e., instantaneous). |
| Negative binomial (NB) regression (Mullahy, 1986) | A regression model used for count data with overdispersion but without zero-inflation. [relative abundance indices] |
| N-mixture models | A class of models for estimating absolute abundance using replicated counts of animals from several different sites; site-specific counts are treated as independent random variables to estimate the number of animals available for capture at each site; detection is imperfect (Royle, 2004). N-mixture models are a type of site-structured model (i.e., that "treat each camera as though it samples... [a] distinct population within a larger meta-population" [Clarke et al., 2023]). |
| **Northing Camera Location** | The northing UTM coordinate of the camera location (e.g., "5962006"). Record using the NAD83 datum. Leave blank if recording the Latitude instead. |
| **\*# Of Images** | The number of images on an SD card. |
| Occupancy | The probability a site is occupied by the species. |
| Occupancy model (MacKenzie et al., 2002) | A modelling approach used to account for imperfect detection by first evaluating the detection probability of a species via detection histories (i.e., present or absent) to determine the probability of the true presence or absence of a species at a site (MacKenzie et al., 2002). |
| Overdispersion | A variance significantly larger than the mean (Bliss & Fisher, 1953); greater variability in a set of data than predicted by the error structure of the model (Harrison et al., 2018); excess variability can be caused by zero inflation, non-independence of counts, or both (Zuur et al., 2009). |
| Paired design | A form of “clustered design” where two cameras that are placed closely together to increase detection probability ("paired cameras"), to evaluate certain conditions ("paired sites,” e.g., on- or off trails), etc. Paired placements can help to account for other variability that might occur (i.e., variation in habitat quality). For some objectives, pairs of cameras might be considered subsamples within another sampling design (e.g., simple random, stratified random, systematic). |
| Partially marked individuals / populations / species | Individuals, populations, or species (varies with modelling approach and context) that have a suite of partially identifying traits (e.g., antler points, sex class, age class). For populations/species, those in which a proportion of individuals carry marks or in which individuals themselves are partially marked. |
| **Photos Per Trigger** | The camera setting that describes the number of photos taken each time the camera is triggered. |
| Poisson regression | A regression model for count data used when data are not overdispersed or zero-inflated (Lambert, 1992). [relative abundance indices] |
| Project | A scientific study, inventory or monitoring program that has a certain objective, defined methods, and a defined boundary in space and time (recorded as "Project Name"). |
| **Project Name** | A unique alphanumeric identifier for each project. Ideally, the Project Name should include an abbreviation for the organization, a brief project name, and the year the project began (e.g., "uofa\_oilsands\_2018"). |
| Pseudoreplication | When observations are not statistically independent (spatially or temporally) but are treated as if they are independent. |
| **Purpose of Visit** | The reason for visiting the camera location (i.e. to deploy the camera ["Deployment"], retrieve the camera ["Retrieve"] or to change batteries/SD card or replace the camera ["Service"]). |
| **Quiet Period (seconds)** | The user-defined camera setting which provides the time (in seconds) between shutter "triggers" if the camera was programmed to pause between firing initially and firing a second time. If a Quiet Period was not set, enter "0."  Also known as "time lag" (depending on the Camera Make and Camera Model; Palmer et al., 2018). The Quiet Period differs from the Motion Image Interval in that the delay occurs between multi-image sequences rather than between the images contained within multi-image sequences (as in the Motion Image Interval). |
| Random (or “simple random”) design | Cameras occur at randomized camera locations (or sample stations) across the area of interest, sometimes with a predetermined minimum distance between camera locations (or sample stations). |
| Random encounter and staying time (REST) model (Nakashima et al., 2018) | A recent modification of the REM (Nakashima et al., 2018) that substitutes staying time (i.e., the cumulative time in the cameras' detection zone) for movement speed (staying time and movement speed are inversely proportional) (Cappelle et al., 2021). |
| Random encounter model (REM) (Rowcliffe et al., 2008, 2013) | A method used to estimate the density of unmarked populations; uses the rate of independent captures, an estimate of movement rate, average group size, and the area sampled by the remote camera. |
| Recovery time | The time necessary for the camera to prepare to capture the next photo after the previous one has been recorded (Trolliet et al., 2014). |
| Registration area | The area in which an animal entering has at least some probability of being captured on the image. |
| Relative abundance indices | An index of relative abundance. When observational data is converted to a detection rate (i.e., the frequency [count] of independent detections of a species within a distinct time period). An index can be a count of animals or any sign that is expected to vary with population size (Caughley, 1977; O'Brien, 2011). |
| **\*Remaining Battery (%)** | The remaining battery power (%) of batteries within a camera. |
| Royle-Nichols model (Royle & Nichols, 2003; MacKenzie et al., 2006) | A method used to estimate population abundance or density, which assumes that individuals are counted only once per sampling occasion (Royle, 2004), but that does not require all individuals to be marked. Royle-Nichols models are a type of site-structured model (i.e., that "treat each camera as though it samples... [a] distinct population within a larger meta-population" [Clarke et al., 2023]). |
| Sample station | A grouping of two or more non-independent camera locations, such as when cameras are clustered or paired (recorded as "Sample Station Name"). |
| **Sample Station Name** | A sequential alphanumeric identifier for each grouping of two more non-independent camera locations (when cameras are deployed in clusters, pairs, or arrays; e.g., “ss1” in “ss1\_bh1,” “ss1\_bh2,” “ss1\_bh3” etc.). Leave blank if not applicable. |
| Scent lure | Any material that draws animals closer via their sense of smell (Schlexer, 2008). |
| **\*SD Card ID** | The ID label on an SD card (e.g., "cmu\_100"). |
| **\*SD Card Replaced** | Whether the SD card was replaced. |
| **\*SD Card Status (% Full)** | The remaining storage capacity on an SD card; collected during a camera service or retrieval. |
| **\*Security** | The equipment used to secure the camera (e.g., "Security box," "Bracket," "Bracket + Screws," or "None"). |
| Sequence | A user-defined group of images or video clips considered as a single “detection event“ (recorded as "Sequence Name"); often users choose a certain time threshold (or “inter-detection interval“) to define independent “events“; e.g., 30 minutes or 1 hour. The threshold should be recorded in the Survey Design Description). |
| **Sequence Name** | A unique alphanumeric identifier for a multi-image sequence. The Sequence Name should ideally consist of the Deployment Name and the names of the first and last images and videos in the sequence (separated by "\_") (i.e., "Deployment Name"\_"img\_#[name of first image in sequence]"\_"img\_#[name of last image in sequence] (e.g., "bh1\_22-Jul-2018\_img\_001-img\_005"). Leave blank if not applicable. |
| Service/Retrieval | When a crew has gone to a location to service or retrieve a remote camera. |
| **\*Service/Retrieval Comments** | Comments describing additional details about the service/retrieval. |
| **Service/Retrieval Crew** | The first and last names of the individuals who collected data during the service/retrieval visit. |
| Service/retrieval metadata | Metadata that should be collected each time a camera location is visited to service or retrieve a camera, including data on any change to the camera location, sampling period, and/or setting type (e.g., not baited and then baited later). The relevant metadata fields that should be collected differ when a camera is deployed vs. serviced or retrieved.  Refer to Appendix - Table A5 and the Camera Service/Retrieval Field Datasheet. |
| Service/Retrieval visit | When a crew has gone to a location to service or retrieve a remote camera. |
| **Sex Class** | The sex classification of individual(s) being categorized (e.g., "Male," "Female," or "Unknown"). |
| Space-to-event (STE) model (Moeller et al., 2018) | A method used to estimate abundance or density that accounts for variable detection probability through the use of time-lapse images and is unaffected by animal movement rates (collapses sampling intervals to an instant in time, and thus estimates are unaffected by animal movement rates) (Moeller et al., 2018). |
| Spatial autocorrelation | The tendency for locations that are closer together to be more similar. |
| Spatial count (SC) model / Unmarked spatial capture-recapture (Chandler & Royle, 2013) | A method used to estimate the density of unmarked populations; similar to SECR (Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008; Royle et al., 2009); however, SC models account for individuals' unknown identities using the spatial pattern of detections (Chandler & Royle, 2013; Sun et al., 2022). SC uses trap-specific counts to estimate the location and number of activity centres to estimate density. |
| Spatial mark-resight (SMR) (Chandler & Royle, 2013; Sollmann et al., 2013a, 2013b) | A method used to estimate the density of "partially marked populations by combining... [detection] histories of marked [individuals] and counts of unmarked [individuals]" (Doran-Myers, 2018) over several occasions (Sollman et al., 2013a; Rich et al., 2014; Whittington et al., 2018). SMR models can be implemented using different statistical frameworks, including Bayesian estimation (Royle and Young, 2008; Morin et al., 2022). |
| Spatial partial identity model (2-flank SPIM) (Augustine et al., 2018) | A method used to estimate the density of partially marked populations in which the “spatial locations of where partial identity samples are captured to probabilistically resolve their complete identities” (Augustine et al., 2018). Paired sampling design is commonly used to capture both the right and left flanks of an animal to resolve individual identities (Augustine et al., 2018). 2-flank SPIM is an extension of the SCR model (Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008; Royle et al., 2009). |
| Spatially explicit capture-recapture (SECR) / Spatial capture-recapture (SCR) (Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008; Royle et al., 2009) | The SECR (or SCR) method is used to estimate the density of marked populations; an extension of traditional capture-recapture (CR; Karanth, 1995; Karanth & Nichols, 1998) models (Karanth, 1995; Karanth & Nichols, 1998) that explicitly accounts for camera location and animal movement (Burgar et al., 2018). SECR models use spatially referenced individual capture histories to infer where animals' home range centres are, assuming that detection probability decreases with increasing distance between cameras and home range centres (Clarke et al., 2023). SECR models can be implemented using different statistical frameworks, including Bayesian estimation (Royle and Young, 2008; Morin et al., 2022). |
| **\*Stake Distance (m)** | The distance from the camera to a stake (in metres to the nearest 0.05 m). Leave blank if not applicable. |
| State variable | A formal measure that summarizes the state of a community or population at a particular time (Wearn & Glover-Kapfer, 2017), e.g., species richness or population abundance. |
| Stratified design | The area of interest is divided into smaller strata (e.g., habitat type, disturbance levels), and cameras are placed within each stratum (e.g., 15%, 35% and 50% of sites within high, medium, and low disturbance strata). |
| Stratified random design | The area of interest is divided into smaller strata (e.g., habitat type, disturbance levels), and then a proportional random sample of sites is selected within each stratum (e.g., 15%, 35% and 50% of sites within high, medium and low disturbance strata). |
| Study area | A unique research, inventory or monitoring area (spatial boundary) within a project (there may be multiple study areas within a single project) (recorded as "Study Area Name"). |
| **Study Area Name** | A unique alphanumeric identifier for each study area (e.g.,"oilsands\_ref1”). If only one area was surveyed, the Project Name and Study Area Name should be the same. |
| Survey | A unique deployment period (temporal extent) within a project (recorded as "Survey Name"). |
| **Survey Design** | The spatial arrangement of remote cameras within the study area for an individual survey. If “Hierarchical (multiple)\*,” include additional details in the Survey Design Description.  Note that we refer to different configurations of cameras more generally as study design and sampling design; however, the term “Survey Design“ refers to study design as it applies to an individual survey. There may be multiple Survey Designs for surveys within a project; if this occurs, the Survey Design should be reported separately for each survey. |
| **\*Survey Design Description** | A description of any additional details about the Survey Design. |
| **Survey Name** | A unique alphanumeric identifier for each survey period (e.g., "fortmc\_001"). |
| **Survey Objectives** | The specific objectives of each survey within a project, including the Target Species, the state variables (e.g., occupancy, density), and proposed modelling approach(es). Survey Objectives should be specific, measurable, achievable, relevant, and time-bound (i.e., SMART). |
| Systematic design | Camera locations occur in a regular pattern (e.g., a grid pattern) across the study area. |
| Systematic random design | Camera locations are selected using a two-stage approach. Firstly, girds are selected systematically (to occur within a regular pattern) across the study area. The location of the camera within each grid is then selected randomly. |
| **Target Species** | The common name(s) of the species that the survey was designed to detect. |
| Targeted design | Camera locations or sample stations are placed in areas that are known or suspected to have higher activity levels (e.g., game trails, mineral licks). |
| Test image | An image taken from a camera after it has been set up to provide a permanent record of the visit metadata (e.g., Sample Station Name, Camera Location Name, Deployment Name, Crew, and Deployment Start Date Time [DD-MMM-YYYY HH:MM:SS]). Taking a test image can be useful to compare the information from the image to that of which was collected on the Camera Service/Retrieval Field Datasheet after retrieval and can help in reducing recording errors. |
| **\*Test Image Taken** | Whether a test image (i.e., an image taken from a camera after it has been set up to provide a permanent record of the visit metadata) was taken. Arm the camera, from ~5 m in front, walk towards the camera while holding the Test Image Sheet. |
| Time in front of the camera (TIFC) (Huggard, 2018; Warbington & Boyce, 2020; tested in Becker et al., 2022) | A method used to estimate density that treats camera image data as quadrat samples (Becker et al., 2022). |
| Time-lapse image | Images that are taken at regular intervals (e.g., hourly or daily, on the hour). It is critical to take a minimum of one time-lapse image per day at a consistent time (e.g., 12:00 pm [noon]) to create a record of camera functionality and local environmental conditions (e.g., snow cover, plant growth, etc.). Time-lapse images may always be useful for modelling approaches that require estimation of the "viewshed" ("viewshed density estimators" such as REM or time-to-event (TTE) models; see Moeller et al., [2018] for advantages and disadvantages). |
| Time-to-event (TTE) model (Moeller et al., 2018) | A method used to estimate abundance or density from the detection rate while accounting for animal movement rates (Moeller et al., 2018). The TTE model assumes perfect detection (though there is a model extension to account for imperfect detection that requires further testing). |
| Total number of camera days | The number of days that all cameras were active during the survey. |
| Trigger “event” | An activation of the camera detector(s) that initiates the capture of a single or multiple images, or the recording of video. |
| **Trigger Mode(s)** (camera settings) | The camera setting(s) that determine how the camera will trigger: by motion ("Motion Image"), at set intervals ("Time-lapse image"), and/or by video ("Video"; possible with newer camera models, such as Reconyx HP2X). |
| **Trigger Sensitivity** | The camera setting responsible for how sensitive a camera is to activation (to "triggering") via the infrared and/or heat detectors (if applicable, e.g., Reconyx HyperFire cameras have a choice between "Low," "Low/Med," "Med," "Med/High," "High," "Very high" and "Unknown"). |
| Trigger speed | The time delay necessary for the camera to shoot a photo once an animal has interrupted the infrared beam within the camera's detection zone (Trolliet et al., 2014). Trigger speed differs from Motion Image Interval (a camera setting specified by the user) in that the trigger speed is inherent to the Camera Make and Camera Model (e.g., two different cameras, models both with a Motion Image Interval set to "no delay," may not be able to capture images at the same speed). |
| Unmarked individuals / populations / species | Individuals, populations, or species (varies with modelling approach and context) that cannot be identified using natural or artificial markings (e.g., coat patterns, scars, tags, collars). Unmarked population models rely on supplementary data (e.g., animal movement speed) and/or assumptions as a surrogate for individual identification; that is, to distinguish between multiple detections of the same individual from detections of multiple individuals when individuals do not have unique features (Gilbert et al., 2020; Morin et al., 2022). |
| User label | A label (up to 16 characters) that can be programmed in the camera’s settings, and that will be visible in the data band of all photos and videos taken by the camera (Reconyx, 2018). It is recommended that users program the Sample Station Name/Camera Location Name as the user label, which serves as a means to confirm which Sample Station Name/Camera Location Name is associated with the images/videos. |
| **UTM Zone Camera Location** | The number corresponding to the Universal Transverse Mercator (UTM) grid zone where the camera was placed (e.g., “12”). UTM is a coordinate system that divides the earth into grid zones that are identified with a number (representing a width of latitude) and letter (representing the hemisphere).  In Alberta the UTM zones are either 11, 12, or TTM. Enter all other UTM zones in the Camera Location Comments field (e.g., zones 7-10 for British Columbia), or use Latitude and Longitude instead of UTM coordinates. |
| **\*Video Length (seconds)** | If applicable, describes the camera setting that specifies the minimum video duration (in seconds) that the camera will record when triggered. Leave blank if not applicable. |
| Viewshed | The area visible to the camera as determined by its lens angle (in degrees) and trigger distance (Moeller et al., 2023). |
| Viewshed density estimators | Methods used to estimate the abundance of unmarked populations from observations of animals that relate animal observations to the space directly sampled by each camera’s viewshed (Moeller et al., 2023); they result in viewshed density estimates that can be extrapolated to abundance within broader sampling frames (Gilbert et al., 2020; Moeller et al., 2023). |
| Visit | When a crew has gone to a location to deploy, service, or retrieve a remote camera. |
| Visit metadata | Metadata that should be collected each time a camera location is visited to deploy, service or retrieve a camera. Other relevant metadata fields that should be collected differ when a camera is deployed vs. serviced or retrieved.  Refer to Appendix A - Table A5, Camera Deployment Field Datasheet, and Camera Service/Retrieval Field Datasheet. |
| Visual lure | Any material that draws animals closer via their sense of sight (Schlexer, 2008). |
| Walktest | A test performed to ensure the camera height, tilt, etc., adequately captures the desired detection zone. The user will 1) activate the walktest mode, 2) attach the camera at the desired height / angle, 3) walk in front of the camera to a specified distance (i.e., the "Walktest Distance," e.g., 5 m), and 4) wave their hand in front of the camera (usually at ground level and a chosen height [i.e., the "Walktest Height," e.g., 0.8 m]) to determine if the camera is activating (a light on the camera will flash). |
| **\*Walktest Complete** | Whether a walktest was performed to ensure the camera height, tilt, etc., adequately captures the desired detection zone. The user will 1) activate the walktest mode, 2) attach the camera at the desired height / angle, 3) walk in front of the camera to a specified distance (i.e., the "Walktest Distance," e.g., 5 m), and 4) wave their hand in front of the camera (usually at ground level and a chosen height [i.e., the "Walktest Height," e.g., 0.8 m]) to determine if the camera is activating (a light on the camera will flash). |
| **Walktest Distance (m)** | The horizontal distance from the camera at which the crew performs the walktest (metres; to the nearest 0.05 m). Leave blank if not applicable. |
| **Walktest Height (m)** | The vertical distance from the camera at which the crew performs the walktest (metres; to the nearest 0.05 m). Leave blank if not applicable. |
| Zero-inflated negative binomial (ZINB) regression (McCullagh & Nelder, 1989) | A regression model used in the setting of excess zeros (zero-inflation) and overdispersion. This approach is a two-part model, where the zero-inflation is modelled separately from the counts and assumes that the count (abundance) is "conditional" on the zero-inflation model (occurrence) model. [relative abundance indices] |
| Zero-inflated Poisson (ZIP) regression (Lambert, 1992) | A regression model for count data that both follows the Poisson distribution and contains excess zeros (Lambert, 1992). ZIP models are only appropriate for data for which the overdispersion is not solely due to zero-inflation. [relative abundance indices] |
| Zero-inflation | An excess of zeros that is "so large that those expected in standard distributions (e.g., normal, Poisson, binomial, negative binomial and beta)" (Heilbron, 1994) violate the assumptions of such distributions (Martin et al., 2005). Excess zeroes can be a result of ecological effects ("true" zeros) or due to sampling or observer error ("false zeros") (Martin et al., 2005). Excess zeroes contribute to overdispersion, but they don't necessarily account for all excess variability (Blasco-Moreno et al., 2019). |

# Appendix A

##### **Appendix A - Table A1.** Summary of the [assumption](#mods_modelling_assumption)s and pros/cons of the different [modelling approach](#mods_modelling_approach)es (adapted from Wearn & Glover-Kapfer [2017] and Clarke et al. [2022]).

| [**Objective**](#survey_objectives) | [**Approach**](#mods_modelling_approach) | [**Assumption**](#mods_modelling_assumption)**s** | **Pros** | **Cons** | **References** |
| --- | --- | --- | --- | --- | --- |
| [Species inventory](#mods_inventory) | [Species inventory](#mods_inventory) | * No formal [assumption](#mods_modelling_assumption)s1 | * Maximum flexibility for [study](#survey) design (e.g., [camera days per camera location](#camera_days_per_camera_location) or use of [lure](#baitlure_lure)2)1 | * Not reliable estimates for inference ("considered as unfinished, working drafts")1 | 1 Wearn & Glover-Kapfer, 2017  2 Rovero et al., 2013  3 MacKenzie et al., 2002  4 MacKenzie et al., 2006  5 Rowcliffe & Carbone, 2008  6 Lambert, 1992  7 Mullahy, 1986  8 McCullagh & Nelder, 1989  9 Heilbron 1994  10 Karanth & Nichols, 1998  11 Karanth, 1995  12 Clarke et al., 2023  13 Noss et al., 2003  14 Kelly et al., 2008  15 Moeller et al., 2018  16 Chandler & Royle, 2013  17 Royle et al., 2009  18 Borchers & Efford, 2008  19 Efford, 2004  20 Royle & Young, 2008  21 O’Brien et al., 2011  22 Doran-Myers, 2018  23 Morin et al., 2022  24 Green et al., 2020  25 Parmenter et al., 2003  26 Noss et al., 2012  27 Sollmann et al., 2013a  28 Sollmann et al., 2013b  29 Rich et al., 2014  30 Whittington et al., 2018  31 Royle & Nichols, 2003  32 Efford et al., 2009b  33 Royle et al., 2014  34 Augustine et al., 2019  35 Burgar et al., 2018  36 Sun et al., 2022  37 Sollmann, 2018  38 Augustine et al., 2018  39 Davis et al., 2021  40 Rowcliffe et al., 2008  41 Rowcliffe et al., 2013  42 Rowcliffe et al., 2014  43 Rowcliffe et al., 2016  44 Rowcliffe et al., 2011  45 Cusack et al., 2015  46 Nakashima et al., 2018  47 Meek et al., 2016  48 Anile & Devillard, 2016  49 Huggard, 2018  50 Becker et al., 2022  51 Warbington & Boyce, 2020  52 Howe et al., 2017  53 Borchers & Marques, 2017  54 Palencia et al., 2021  55 Gilbert et al., 2021  56 Twining et al., 2022  57 Bessone et al., 2020  58 Loonam et al., 2021  59 Bridges & Noss, 2011  60 Rovero & Zimmermann, 2016 |
| Species richness | Species richness | * [Camera location](#camera_location)s are [randomly placed](#sampledesign_random)1 * [Camera location](#camera_location)s are independent1 * [Detection probability](#detection_probability) of different species remains the same1 ("true" species richness estimation involves attempting to correct for “[imperfect detection](#imperfect_detection)“1) * Sampling effort is comparable between [camera location](#camera_location)s31 | * Fundamental to ecological theory and often a key metric used in management1 * Simple to analyze, interpret and communicate1 * Models exist to estimate asymptotic species richness, including unseen species (simple versions of these models - “EstimateS” and the “vegan” R-packages)1 | * Dependent on the scale (as captured in the species-area relationship)1 * All species have equal weight in calculations, and community evenness is disregarded1 * Insensitive to changes in abundance, community structure and community composition1 |  |
| Species diversity | Species diversity | * [Camera location](#camera_location)s are [randomly placed](#sampledesign_random)1 * [Camera location](#camera_location)s are independent1 * [Detection probability](#detection_probability) of different species remains the same1 | * Captures evenness and richness (although some indices only reflect evenness)1 * Most indices are easy to calculate and widely implemented in software packages (e.g., “EstimateS” and “vegan” in R)1 | * Many indices exist, and it can be difficult to choose the most appropriate1 * Comparing measures across space, time and studies can be very difficult1 * Insensitive to changes in community composition1 (however, this may be conditional on study design) |  |
| Species diversity | β-diversity | * [Camera location](#camera_location)s are [randomly placed](#sampledesign_random)1 * Randomness and independence1 * Samples are assumed to have been taken at random from the broader population of sites1 | * Can be used to track changes in community composition1 * Plays a critical role in effective conservation prioritization (e.g., designing reserve networks)1 * Important for detecting changes in the fundamental processes1 | * No single best measure for all purposes1 * Interpretation/communication not always straightforward1 * Scale-dependent (i.e., influenced by the size of the communities that are being included)1 |  |
| [Occupancy](#occupancy)3 | [Occupancy models](#mods_occupancy)3 | * [Occupancy](#occupancy) is constant[3] (abundance is constant)4 * [Camera location](#camera_location)s are independent4 * Detections are [independent](#independent_detections)4 * The probability of [occupancy](#occupancy) and detection are constant across all [camera location](#camera_location)s within a stratum or can be modelled using covariates4 * Species are not misidentified4 | * Does not require individual identification4 * Only requires detection/non-detection data for each site1 * Relatively easy-to-use software exists for fitting models (PRESENCE, MARK, and the “unmarked” R package)1 * “Open” models exist that allow for the estimation of site colonization and extinction rates1,4 * Multi-species [occupancy models](#mods_occupancy)[3] allow the inclusion of interactions among species while controlling for [imperfect detection](#imperfect_detection)1 | * [Occupancy](#occupancy)[3] only measures distribution; it may be a misleading indicator of changes in abundance1 * Interpretation/communication of results may not be straightforward (if the scale of movement is much larger than the [camera spacing](#camera_spacing) the results should be interpreted as “probability of use” rather than [occupancy](#occupancy))1 |  |
| [Relative abundance indices](#mods_relative_abundance) | [Poisson](#mods_poisson) | * Many [assumption](#mods_modelling_assumption)s exist(since used for many approaches)1 | * Simple to calculate and technically possible (even with small sample sizes when robust methods might fail)1 * [Relative abundance indices](#mods_relative_abundance) often do correlate with abundance1 * Calibration with independent [density](#density) estimates is possible1 | * Difficult to draw inferences (a large number of [assumptions](#mods_modelling_assumption)); comparisons across space, time, species, and studies are difficult1 * Requires stringent [study design](#survey) (e.g., random sampling, standardized methods)1 * Detection rates from remote cameras cannot be used as an index to compare relative abundance across species5 |  |
|  | [Zero-inflated Poisson (ZIP)](#Mods_zip)6 |  |  |  |  |
|  | [Negative binomial (NB)](#mods_negative_binomial)7 |  |  |  |  |
|  | [Zero-inflated negative binomial (ZINB)](#mods_zinb)8 |  |  |  |  |
|  | [Hurdle models](#mods_hurdle)7,9 |  |  |  |  |
|  | Other |  |  |  |  |
| Population size / Absolute abundance / vital rates / [Density](#density); [Marked population](#typeid_marked) | [Capture-recapture (CR) / capture-mark-recapture (CMR)](#mods_cr_cmr)10,11 | * Demographic closure (i.e., no births or deaths)1 * Geographic closure (i.e., no immigration or emigration)1 * All individuals have at least some probability of being detected2 * Sampled area encompasses the full extent of individuals’ movements2,10 * Activity centres are randomly dispersed12 * Activity centres are stationary12 | * May be used as a [relative abundance index](#mods_relative_abundance) that controls for [imperfect detection](#imperfect_detection)1 * Easy-to-use software exists to implement (e.g., CAPTURE); MARK Implements more complicated models with covariates (and must be used for [mark-resight modelling](#Mods_marked__resight))1 * Can use the robust design with “open” models to obtain recruitment and survival rate estimates1 | * Requires that individuals are distinguishable.1 However, CR[10,11] has also been used to estimate abundance of species that lack natural markers but that have phenotypic and/or environment-induced characteristics2,13,14 * When the sample size is large enough to reliably estimate [density](#density) with CR, [10,11] individuals are unlikely to have a unique marker2,13,14 * Dependent on the surveyed area, which is difficult to track and calculate1 * Requires a minimum number of captures and recaptures1 * Relatively stringent requirements for [study design](#survey) (e.g., no “holes” in the trapping grid)1 * Geographic closure at the plot level, which is often unrealistic1 * Assumes a specific relationship between abundance and detection1 * [Density](#density) cannot be explicitly estimated because the true area animals occupy is never measured (only approximated)16 |  |
| [Density](#density) / population size; [Marked population](#typeid_marked) | [Spatially explicit capture recapture (SECR)](#mods_scr_secr)17–20 (also referred to as [Spatial capture-recapture [SCR])](#mods_scr_secr) | * Demographic closure (i.e., no births or deaths)1 * [Detection probability](#detection_probability) of different individuals is equal1   + or, for SECR, individuals have equal [detection probability](#detection_probability) at a given distance from the centre of their home range1 * Detections of different individuals are [independent](#independent_detections)1 * Behaviour is unaffected by cameras and marking1 * Individuals do not lose marks1 * Individuals are not misidentified1 * Surveys are independent1 * For conventional models, geographic closure (i.e., no immigration or emigration)1 * Spatially explicit models have further [assumption](#mods_modelling_assumption)s about animal movement1,17,21; these include:   + Home ranges are stable1   + Movement is unaffected by cameras1   + [Camera location](#camera_location)s are [randomly placed](#sampledesign_random) with respect to the distribution and orientation of home ranges1   + Distribution of home range centres follows a defined distribution ([Poisson](#mods_poisson), or other, e.g.,negative binomial)1 | * Produces direct estimates of [density](#density) or population size for explicit spatial regions16 * Allows researchers to mark a subset of the population/to take advantage of natural markings1 * Estimates are fully comparable across space, time, species and studies1 * [Density](#density) estimates obtained in a single model, fully incorporate spatial information of locations and individuals1 * Both likelihood-based and Bayesian versions of the model have been implemented in relatively easy-to-use software (DENSITY and SPACECAP, respectively, as well as associated R packages)1 * Flexibility in [study](#survey) design (e.g., “holes” in the trapping grid)1 * “Open” [SECR](#mods_scr_secr)[17–20] models exist that allow for estimation of recruitment and survival rates1 * “Avoid ad-hoc definitions of [study area](#study_area) and edge effects”22 * [SECR](#mods_scr_secr)[17–20] accounts for variation in individual [detection probability](#detection_probability); can produce spatial variation in [density](#density); [SECR](#mods_scr_secr)[17–20] more sensitive “to detect moderate-to-major populations changes” (+/-20-80%)12,23 | * Requires that individuals are identifiable1 * Requires that a minimum number of individuals are trapped (each recaptured multiple times ideally)1 * Requires that each individual is captured at a number of [camera locations](#camera_location)1 * Multiple cameras per station may be required to identify individuals; difficult to implement at large spatial scales as it requires a high density of cameras12,23 * May not be precise enough for long-term monitoring24 * Cameras must be close enough that animals are detected at multiple [camera location](#camera_location)s1 (may be challenging to implement at large scales as many cameras are needed)”16 * ½ MMDM (Mean Maximum Distance Moved) will usually lead to an under -estimation of home range size and thus overestimation of [density](#density)1,25,26 |  |
| [Density](#density); [Marked population](#typeid_marked) | [Spatial mark-resight (SMR)](#mods_smr)(type of SCR model)16,27,28 | * Demographic closure (i.e., no births or deaths)12,16 * Geographic closure (i.e., no immigration or emigration)12,16 * Individuals do not lose marks1 (for maximum precision), but [SMR](#mods_smr)[16,27,28] does allow for inclusion of [marked](#typeid_marked) but unidentified resighting detections27,29 * Individuals are not misidentified1 * Failure to identify marked individuals is random12,30 * [Marked animals](#typeid_marked) are a random sample of the population with home ranges located inside the state space28,29 * Detections are [independent](#independent_detections)12,16 * Individuals have equal [detection probability](#detection_probability) at a given distance from the centre of their home range1 * Detections of different individuals are [independent](#independent_detections)1 * Movement is unaffected by cameras1 * Behaviour is unaffected by cameras and marking1 * [Camera location](#camera_location)s are [randomly placed](#sampledesign_random) relative to the distribution and orientation of home ranges1 * [Camera location](#camera_location)s are close enough together that animals are detected at multiple cameras12,16 * Surveys are independent1 * Home ranges are stable1 * Distribution of home range centres follows a defined distribution ([Poisson](#mods_poisson), or other, e.g.,negative binomial)1 * Animals’ activity centres are randomly dispersed12,16 * Animals’ activity centres are stationary12,16 * All animals have stable activity centres within home ranges where detection probability is greatest27,31,32 | * Estimates are fully comparable to [SECR](#mods_scr_secr)[17–20] of [marked](#typeid_marked) species1 * Can be applied to a broader range of species than [SECR](#mods_scr_secr)[17–20]1 * Allows researcher to take advantage of natural markings1 * Allows researcher to mark a subset of the population (note - precision is dependent on number of [marked](#typeid_marked) individuals in a population)1 | * Animals may have to be physically captured and [marked](#typeid_marked) if natural marks do not exist on enough individuals1 * All individuals must be identifiable1 * Allows for [density](#density) estimation for a [unmarked population](#typeid_unmarked), but the precision of the [density](#density) estimates are likely to be very low value1 * Remains poorly tested with camera data, although it offers promise1 * [Density](#density) estimates are likely less precise than with [SECR](#mods_scr_secr)[17–20] or [REM](#mods_rem), unless a large proportion of the population have marks1 * Requires sampling points to be close enough that individuals encounter multiple cameras1 |  |
| [Density](#density); [Unmarked population](#typeid_unmarked) | [Spatial count (SC)](#mods_sc) / Unmarked spatial capture-recapture (type of SCR model)16,33 | * [Camera location](#camera_location)s are close enough together that animals are detected at multiple cameras12,16 * Demographic closure (i.e., no births or deaths)12,16 * Geographic closure (i.e., no immigration or emigration)12,16 * Detections are [independent](#independent_detections)12,16 * Animals’ activity centres are randomly dispersed12,16 * Animals’ activity centres are stationary12,16 | * Does not require individual identification12 | * Produces imprecise estimates even under ideal circumstances unless supplemented with auxiliary data (e.g., telemetry)16,22,27,28 * Precision decreases with an increasing number of individuals detected at a camera”23 (as overlap of individuals’ home ranges increases) 12,34 * Not appropriate for low [density](#density) or elusive species when recaptures too few to confidently infer the number and location of activity centres”12,35 * Not appropriate for high-[density](#density) populations with evenly spaced activity centres (camera[-specific] counts will be too similar and impair activity centre inference)”12 * Ill-suited to populations that exhibit group-travelling behaviour”12,36 * Study design (camera arrangement) can dramatically affect the accuracy and precision of [density](#density) estimates”12,37 * Cameras must be close enough that animals are detected at multiple [camera location](#camera_location)s (may be challenging at large scales as many cameras are needed)”12,16 |  |
| [Density](#density) / population size; [Partially Marked population](#typeid_partially_marked) | [Spatial Partial Identity Model (Categorical SPIM; catSPIM)](#mods_catspim)34,36  (Extension of [SC](#mods_sc) model using animal traits (e.g., [Sex Class](#sex_class), antler points) and model parameters) | * Same as [SC](#mods_sc)12,34,36   + Camera must be close enough together that animals are detected at multiple cameras12,16   + Demographic closure (i.e., no births or deaths)12,16   + Geographic closure (i.e., no immigration or emigration)12,16   + Detections are independent12,16 * Activity centres are randomly dispersed12,16 * Activity centres are stationary12,16 * Each categorical identifier (e.g., male/female, collared/not collared, etc) has fixed number of possibilities36 * All possible values of categorical identifiers occur in the population with probabilities that can be estimated12,34,36 * Every individual is assigned “full categorical identity” (i.e., “set of traits given all categorical identifiers and possibilities”)12,34 * Individuals' identifying traits do not change during the survey (e.g., antlers present/absent)34 | * May produce more precise and less biased [density](#density) estimates than [SC](#mods_sc) with less information12,36 | * Sensitive to non-independent movement (e.g., group-travel; can cause over-dispersion and bias estimates12,36); may limit application to solitary species only12,36 * May produce be less reliable/accurate estimates for high-[density](#density) populations12,36 * Too few categorical identifiers/ possibilities can result in mis-assignments and overestimating [density](#density)12,25,34 |  |
| [Density](#density) / population size; [Partially Marked population](#typeid_partially_marked) | [Spatial Partial Identity Model (2-flank SPIM)](#mods_2flankspim)38 (extension of [SCR](#mods_scr_secr) model augmented with data from partially-identifying images) | * Same as [SCR](#mods_scr_secr)12,38 * Capture processes for left-side, right-side and both-side images are independent12,38 | * Same as [SCR](#mods_scr_secr)12,38 * Improved precision of [density](#density) estimates relative to [SCR](#mods_scr_secr)12,38,39 * Many study designs can be used ([paired](#sampledesign_paired) [sample stations](#sample_station), single [camera location](#camera_location)s, and hybrids of both [paired](#sampledesign_paired)- and single [camera location](#camera_location)s12,38,39 * Can be used with single-camera and hybrid sampling designs, and therefore requires fewer cameras (or sample more area) than [SCR](#mods_scr_secr)12,38 * May be more robust to non-independence than [SC](#mods_sc)12,38 | * Computationally intensive12,38 * Increased precision is less pronounced in high-[density](#density) populations12,38 |  |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Random encounter models (REM)](#mods_rem)40,41 | * Demographic closure22,40 (i.e., no births or deaths) * Geographic closure22,40 (i.e., no immigration or emigration) * [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed relative to animal movement1,40 * Animal movement is unaffected by the cameras1,40 * Accurate counts of independent “contacts” [camera location](#camera_location)s1,40 * Unbiased estimates of animal activity levels and speed1,42,43 * Camera’s [detection zone](#detection_zone) can be approximated well using a 2D cone shape, defined by the radius and angle parameters44 * If activity and speed are to be estimated from camera data, two additional [assumption](#mods_modelling_assumption)s: * All animals are active during the peak daily activity42 * Animals moving quickly past a camera are not missed43 | * Flexible study design (e.g., “holes” in grids allowed, [camera spacing](#camera_spacing) less important)1 * Can be applied to [unmarked](#typeid_unmarked) species1 * Allows community-wide [density](#density) estimation1 * Outputs also include informative parameter estimates (i.e., animal speed and activity levels, and [detection zone](#detection_zone) parameters)1 * Comparable estimates to [SECR](#mods_scr_secr)[17–20]1 * Does not require [marked animals](#typeid_marked) or identification of individuals22,40 * Can use [camera spacing](#camera_spacing) without regard to population home range size22,40 * Direct estimation of [density](#density); avoids ad-hoc definitions of [study area](#study_area)40 | * Requires relatively stringent study design, particularly (e.g., random sampling and use of [bait](#baitlure_bait) or [lure](#baitlure_lure))1 * Requires independent estimates of animal speed or measurement of animal speed within videos1 * No dedicated, simple software1 * Random relative to animal movement, grid preferred, avoid multiple captures of same individual, area coverage important for abundance estimation2 * Possible sources of error include inaccurate measurement of [detection zone](#detection_zone) and movement rate41,45 |  |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Random encounter and staying time (REST)](#mods_rest)46 | * Demographic closure (i.e., no births or deaths) and geographic closure (i.e., no immigration or emigration) (animal [density](#density) is constant during the [survey](#survey))40 * Detection is perfect1 ([detection probability](#detection_probability) “p” = 1) unless otherwise modelled46 * [Camera location](#camera_location)s are representative of the available habitat46 * [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed relative to the spatial distribution of animals46 * Animal movement and behaviour are not affected by cameras46 * Detections are [independent](#independent_detections)46 * The observed distribution of staying time in the focal area fits the distribution of movement46 * The observed staying time must follow a given parametric distribution46 | * Provides unbiased estimates of animal [density](#density), even when animal movement speed varies, and animals travel in pairs46 | * Attraction or aversion to cameras is exhibited in some species47 and could affect the time within the [detection zone](#detection_zone) and subsequently affect estimates of [density](#density)22 * Requires accurate measurements of the area of the camera [detection zone](#detection_zone), which has been a challenge in previous studies22,44–46,48 * Mathematically challenging45 |  |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Time in front of the camera (TIFC)](#mods_tifc)49–51 | * [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed or representative relative to animal movement50 * Movement is unaffected by the cameras50 * Reliable detection of animals in part of the camera’s [FOV](#field_of_view) (at least)50 | * Does not require individual identification51 * Makes no [assumption](#mods_modelling_assumption) about home range51 * Comparable to estimates from [SECR](#mods_scr_secr)[17–20]51 | * Requires careful calculation of the effective area of detection51 * A high level of measurement error50 |  |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Distance sampling (DS)](#mods_distance_sampling)52,53 | * [Random](#sampledesign_random) or [systematic random](#sampledesign_systematic_random) placements (consistent with the [assumption](#mods_modelling_assumption) that points are placed independently of animal locations)52 * [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed relative to animal movement54 * Detection is perfect ([detection probability](#detection_probability) “p” = 1) at focal area /distance 054 * Demographic closure (i.e., no births or deaths) and geographic closure (i.e., no immigration or emigration) (animal [density](#density) is constant during the [survey](#survey))54 * Animal movement and behaviour are unaffected by the cameras54 * Animals are detected at initial locations (e.g., they do not change course in response to the camera prior to detection)54 * Distances are measured exactly (however if the data from different distances will be grouped (“binned”) for analysis later, an accuracy of +/- 1m may suffice)54 * Detections are [independent](#independent_detections)54 * Snapshot moments selected independently of animal locations54 | * A shortcut to controlling for variation in [detection distances](#detection_distance) by only counting individuals within a short distance with an unobstructed view, and well sampled across cameras and species1 * [Density](#density) estimates are unbiased by animal movement “since camera-animal distance is measured at a certain instant in time (intervals of duration *t* apart)”12,52 * Can be applied to low-[density](#density) populations12,52 * Does not require individual identification52 | * May require discarding a portion of the dataset (when the best fitting model truncates the dataset)1 * Biased by movement speed54 * Best suited to larger animals; the smaller the focal species, the lower remote cameras must be set, which reduces the depth of the [viewshed](#fov_viewshed), and thus sampling size and the flexibility of the model”12,52 * Does not permit inference about spatial variation in abundance (unless using hierarchical distance which can model spatial variation as a function of covariates)12,55 * “Calculating camera-animal distances can be labour-intensive and time-consuming (However, recently developed techniques (e.g., Johanns et al., 2022) show promise for simplifying and automating the process)”12 * Requires a good understanding of the focal populations’ activity patterns; [density](#density) estimates can be biased (e.g., under-estimated) when regular periods of inactivity are not accounted for (using detection times to infer periods of activity may help overcome this limitation)”12,52,54 * Tends to underestimate [density](#density)12,52,56 * Low population [density](#density) and reactivity to cameras may be major sources of bias”12,57 |  |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Time-to-event (TTE) model](#mods_tte)15 | * Demographic closure (i.e., no births or deaths)15,58 * Geographic closure (i.e., no immigration or emigration) at the level of the sampling frame (area of interest); this assumption does not apply at the plot-level (area sampled by the camera)15,58 * Animal movement and behaviour are unaffected by the cameras54 * [Camera location](#camera_location)s placement is [random](#sampledesign_random), [systematic](#sampledesign_systematic), or [systematic random](#sampledesign_systematic_random)15 * Detections are [independent](#independent_detections)15 * Spatial counts of animals (or counts in equal subsets of the landscape) are Poisson-distributed58 * Accurate estimate of movement speed58 * Detection is perfect ([detection probability](#detection_probability) “*p*” = 1)15 | * Can be efficient for estimating abundance of common species (with a lot of images)15 | * Requires independent estimates of movement rate (difficult to obtain without telemetry data)15 * Assumes that [detection probability](#detection_probability) is 1 (or apply extension to account for [imperfect detection](#imperfect_detection))15 |  |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Space-to-event (STE)](https://ualbertaca-my.sharepoint.com/personal/cjsteven_ualberta_ca/Documents/RCSC_RC-Survey-Guidelines_AB-Metadata-Standards/mods_ste) models15 | * Demographic closure (i.e., no births or deaths)15 * Geographic closure (i.e., no immigration or emigration)15 * [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed15 * Detections are [independent](#independent_detections)15 * Spatial counts of animals in a small area (or counts in equal subsets of the landscape) are Poisson-distributed58 * Detection is perfect ([detection probability](#detection_probability) “*p*” = 1)15 | * Can be efficient for estimating abundance of common species (with a lot of images)15 * Does not require estimate of movement rate15 | * Assumes that [detection probability](#detection_probability) is 115 |  |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Instantaneous sampling (IS)](#mods_instantaneous_sampling)15 | * Demographic closure (i.e., no births or deaths)15 * Geographic closure (i.e., no immigration or emigration)15 * [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed15 * Detections are [independent](#independent_detections)15 * Detection is perfect ([detection probability](#detection_probability) “*p*” = 1)15 | * Can be efficient for estimating abundance of common species (with a lot of images)15 * Flexible [assumption](#mods_modelling_assumption) of animals’ distribution15 | * Requires accurate counts of animals15 * Assumes that perfect ([detection probability](#detection_probability) “*p*” = 1)15 * Reduced precision15 |  |
| Behaviour  (diel activity patterns, mating, boldness, etc.) | | * [Assumption](#mods_modelling_assumption)s vary depending on the behavioural metric1 * For studies of activity patterns and temporal interactions of species: activity level is the only factor determining [detection rates](#detection_rate); animals are active when camera [detection rate](#detection_rate) reaches its maximum in daily cycle33,60 | * Can detect difficult to observe behaviours (i.e., boldness, or mating)59 * Long-term data on behavioural changes that would be difficult to obtain otherwise (i.e., time-limited human observers, or costly GPS collars)59 * Can monitor behaviour in response to specific locations (i.e., compost sites, which might be more difficult using GPS collars for example)60 * Can evaluate interactions between species60 | * Behavioural metrics may not reflect the behavioural state (inferred)60 * Biases associated with equipment (i.e., presence of the camera itself may change behaviour studied)60 * Difficult to consider individual variation60 |  |

##### **Appendix A - Table A2.** Summary of appropriate [study design](#survey), [camera spacing](#camera_spacing), and [survey](#survey) effort (adapted from Wearn & Glover-Kapfer [2017] with additional references included) for various [modelling approaches](#mods_modelling_approach). Note – these are guidelines only, using best available information. There is uncertainty associated with each of the different approaches. To address this, the table contains ‘minimum’, ‘ideal’ and ‘often’ used values, as well as qualifiers.

| **Approach** | **Camera arrangement** | [[[**Camera spacing**](#Camera_spacing)](#Camera_spacing)](#camera_spacing) | **Number of cameras** | [**Camera days per camera location**](#camera_days_per_camera_location) | [**Total number of camera days**](#total_number_of_camera_days) | **Survey duration** | **References** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| [Species inventory](#mods_inventory) | * [Targeted](#sampledesign_targeted)1,2 * [Random](#sampledesign_random) if species poorly known3 * Flexible4 | * No minimum1,4,5 * Ideally 1-2 km1,5,6 | * No minimum5 * Ideally ≥ 202,3 | * No minimum5 * Ideally ≥ 305 * < 30 for highly detectable5 | * No minimum2,3,5 | * No maximum2,4,5 | 1 Rovero et al., 2013  2 Tobler et al., 2008  3 Wearn et al., 2013  4 Rovero & Tobler, 2010  5 Wearn & Glover-Kapfer, 2017  6 Colyn et al., 2018  7 O'Brien, 2010  8 O'Connell & Bailey, 2011  9 Cusack et al., 2015  10 Ahumada et al., 2011  11 Kinnaird & O'Brien, 2011  12 Wearn et al., 2016  13 Li et al., 2012  14 Kays et al., 2020  15 MacKenzie et al., 2002  16 Mackenzie & Royle, 2005  17 Guillera-Arroita et al., 2010  18 Shannon et al., 2014  19 Pacifici et al., 2016  20 Rowcliffe et al., 2008  21 Rovero & Marshall, 2009  22 Karanth & Nichols, 1998  23 Karanth, 1995  24 Sollmann et al., 2012  25 Clarke et al., 2023  26 Tobler & Powell, 2013  27 Krebs et al., 2011  28 Noss et al., 2012  29 Borchers & Efford, 2008  30 Royle & Young, 2008  31 Royle et al., 2009  32 Sun et al., 2014  33 Burgar et al., 2018  34 Burgar, personal communication, April 23, 2023  35 Karanth et al., 2011  36 Foster & Harmsen, 2012  37 White et al., 1982  38 Efford, 2004  39 Dillon & Kelly, 2008  40 Chandler & Royle, 2013  41 Sollmann et al., 2013b  42 Burgar, 2021  43 Clark, 2019  44 Sun et al., 2022  45 Augustine et al., 2019  46 Augustine et al., 2018  47 Davis et al., 2021  48 Rowcliffe et al., 2013  49 Loonam et al., 2021  50 Rowcliffe et al., 2016  51 Nakashima et al., 2018  52 Moeller et al., 2023  53 Becker et al., 2022  54 Huggard, 2018  55 Warbington et al., 2020  56 Howe et al., 2017  57 Moeller et al., 2018  58 Ridout & Linkie, 2009  59 Rowcliffe et al., 2014 |
| Species diversity & richness | * Ideally, [random](#sampledesign_random)1,5 * [Stratified](#sampledesign_stratified)5 * [Stratified random](#sampledesign_stratified_random)5 * [[Clustered](#sampledesign_clustered)](#sampledesign_clustered)7,8 | * Spatially independenti,5 * Ideally ≥ 1 km, but closer may be justified2,9 * 1-2 km is often adequate (provided each camera is treated as an independent sample)2,5,10,11 | * Minimum 205 * Commonly 3010 * Ideally ≥ 505 * If stratified, 20-50 per stratum5 * 20-100 to reach species-accumulation asymptote10,12,13 * 25-35, scale-dependent14 | * Ideally ≥ 305,10 | * Generally, 600-15005 * ≥ 10005 | * Ideally < 6 months5 * 3-6 months for medium-large mammals5 |
| [Occupancy models](#mods_occupancy)15 | * Ideally [random](#sampledesign_random)7,8,16–18 * [Targeted](#sampledesign_targeted)7,16–18 * [[Clustered](#sampledesign_clustered)](#sampledesign_clustered)8,19 * [Stratified random](#sampledesign_stratified_random)5 | * If home range size known, ideally, > home range diameter5 * If home range size unknown, > 1 km5 * ≥ 1 km is typical5 | * Minimum 405 * Ideally ≥ 10016–18 * > 60; species-dependent1 * < 20 for common (occur at > 75% of camera locations)**ii,**14 * ≤ 30 if ψ > 0.8 (occur at > 80% of camera locations)**ii,**18 * > 150 for rare (occur at < 25% of camera locations)**ii,**14 * 30-60 sites for less common18 | * ≥ 30 for most16–18 * 80-100 if [detection probability](#detection_probability) is low18 | * Species-dependent5 * > 1200 for most5 * > 1,000 for most7,16–18 * > 5,000 for rare / hard to detect18 | * Species-dependent17 * Ideally < 6 months7,16–18 |
| [Relative abundance indices](#mods_relative_abundance) (RAI) | * Ideally [random](#sampledesign_random)5 * Systematic [random](#sampledesign_random)5 | * No minimum5 * Ideally ≥ 1 km3 * Ideally 1-2 km5 | * As many as possible5,20 * Minimum 205,20 * Ideally ≥ 505,20 * If stratified, 20-50 per stratum5 | * No minimum5 * Ideally ≥ 305 * As many as possible5 | * Ideally > 20005 * Enough to capture > 10 detections5 * Ideally > 20 detections5 * Usually > 2,000 for many carnivores / rare ungulates5,20 * > 250 for common5,20,21 * > 20,000 "hyper-rare" (caught 0.1% of the time)5,7 | * No maximum3 * Ideally < 12 months3 |
| [Capture-recapture (CR) / Capture-mark-recapture (CMR)](#mods_cr_cmr)22,23 | * Ideally [paired](#sampledesign_paired)iii,1,2,5 or [random](#sampledesign_random)5 * [Targeted](#sampledesign_targeted)iv,2,5,24 * [Targeted](#sampledesign_targeted) for carnivores1 * [Systematic](#sampledesign_systematic)25 | * Spatially dependentv,5 * Species-dependentvi,1 (< home range diameter) * 1-4 km is typical2,5,24 | **CR/CMR:**   * At minimum, enough to encompass the home ranges of 5-10 individuals5,26–28 * > 2-4 per smallest home range1,22   **CR/CMR / SECR/SCR:**   * Minimum 205,28,37 * > 4 per home range5,39 * If used suggested 4 camera per home range, 40-120 locations5   **SECR/SCR:**   * > 4 per home range5 * At minimum, enough to expose 10-30 individuals to sampling1,5,26–28,35 * Ideally, enough to capture > 20 individuals5,36,37 (encompass home ranges) and 20-50 total recaptures5,28,38 * 60-100if detection probability is <0.126 | * ≥ 30 for all but the most detectable5,26 * > 60 for reasonable precision for most5,26 * > 60-120 if capture probability is low5,26 | * > 1,000 for most5 * > 1200 for common5 * > 3,600 if [detection probability](#detection_probability) or species density is low5 * Enough for > 20-detections5,28,37 * > 60 recaptures1 | * As short as possible5 * Species-dependent2,24 * Ideally < 3 months2,24 |
| [Spatially explicit capture-recapture (SECR) / Spatial capture-recapture (SCR)](#mods_scr_secr)29,30 31,38 | * [Paired](#sampledesign_paired)1,5 * [[[Clustered](#sampledesign_clustered)](#sampledesign_clustered)](#sampledesign_clustered)5,32 * [Systematic](#sampledesign_systematic)25 | * Species-dependent (< home range size)5,24,32 * Ideally, 1/3 the home range radius5,24,32 (~4-7 camera per home range)5 * Maximum of 0.8 times the home range radius5,24,32 | * ≥ 30 for all but the most detectable5,26 * > 60 for reasonable precision for most5,26 * > 60-120 if [detection probability](#detection_probability) is low5,26 | * > 1,000 for most5 * > 1200 for common5 * > 3,600 if [detection probability](#detection_probability) or species density is low5 * Enough for 20-50 recaptures5,28,38 | * Minimum 1 month per [survey](#survey) (presuming multiple surveys)33,34 * Ideally > 12 months total (based on minimum for [SCR](#mods_scR) models)33,34 * Ideally 1-3 months (depending on time required to maximize detections while minimizing violation of "population closure" [assumption](#mods_modelling_assumption))33,34 |
| [Spatial mark-resight (SMR](#mods_smr)) (type of [SCR](#mods_scR) model)24,32,40 | * [Random](#sampledesign_random) relative to activity centres41 * [Systematic](#sampledesign_systematic_random) [random](#sampledesign_random)25 * [[[Clustered](#sampledesign_clustered)](#sampledesign_clustered)](#sampledesign_clustered)25 | * 1-3 sigma (related to home range size)32 | * Minimum 3034,42 * 60 (but will depend on [detection probability](#detection_probability) and resight data)34,42 | * Minimum 30 (precision dependent on number of [marked](#typeid_marked) individuals in a population)34,42 * ≥ 30 for all but the most detectable5,26 * > 60 for reasonable precision for most5,26 * > 60-120 if [detection probability](#detection_probability) is low5,26 | * 360 days34,42 |
| [Spatial count (SC)](#mods_sc)40 (type of [SCR](#mods_scR) model) | * [Systematic](#sampledesign_systematic_random) [random](#sampledesign_random)25,32,43 * [[Clustered](#sampledesign_clustered)](#sampledesign_clustered)25,32,43 | * Close enough that individuals will be detected at multiple locations25,31 | * Minimum 3033,44 * 60 (but will depend on [detection probability](#detection_probability) and resight data)33,44 | - |
| [Spatial Partial Identity Model (Categorical SPIM; catSPIM)](#mods_catspim)44,45 | * Same as [SC](#mods_sc)25,32,44,45 | * Similar to [SC](#mods_sc)25,32,44,45 | * Similar to [SC](#mods_sc) or with fewer cameras44 | * Similar to [SC](#mods_sc) or less25,32,44,45 | * Similar to [SC](#mods_sc) or less25,32,44,45 | * Similar to [SC](#mods_sc) or less (such that identity traits [e.g., antlers present/ absent] don’t change)32 |
| [Spatial Partial Identity Model (2-flank SPIM)](#mods_2flankspim)46 (extension of [SCR](#mods_scR) that uses probabilistic identities) | * Same as [SCR](#mods_scR)25,46; however, more flexible47 | * Similar to [SCR](#mods_scR) 25,46 | * Fewer cameras than [SCR](#mods_scR) (or same but larger sampling area)**viii**,46 | * Similar to [SCR](#mods_scR) or less25,46 | * Similar to [SCR](#mods_scR) or less25,46 | * Similar to [SCR](#mods_scR) or less25,46 |
| * Ideally, [systematic](#sampledesign_systematic) closely-spaced (relative to home range size)vi,46 | |
| [Random encounter models (REM)](#mods_rem)20,48 | * [Random](#sampledesign_random) relative to movementix,1,5,48,49 * [Systematic](#sampledesign_systematic)49 * [Systematic](#sampledesign_systematic_random) [random](#sampledesign_random)x**,**5 * [Stratified random](#sampledesign_stratified_random)5 * Stratified targetedxi**,**5 | * No minimum5 * Ideally ≥ 1 km5 * Spatially independent48 * > home range diameter5 * 1-2 km without home range size, closer if using mixed models5 | * Minimum 205,20 * Ideally > 505,20 * Dependent on species' [density](#density)5 | * No minimum5 * Ideally > 305 | * Minimum 10 detections1,20 * Ideally > 20 detections1,20 * Often 2,0001,20 * 1,000-10,000 for most, if estimates of activity and speed are to be reasonable precise48 * > 2000 for low-[density](#density) carnivores / rare ungulates5 | * Ideally < 12 months5 * No maximum20 |
| [Random encounter and staying time (REST)](#mods_rest)51 | * Same as [REM](#mods_rem)52 53 | | | | | |
| [Time in front of the camera (TIFC)](#mods_tifc)53–55 | * [Random](#sampledesign_random) or [stratified random](#sampledesign_stratified_random) (representative) relative to movement53 | * Same as [REM](#mods_rem)52,53 | | | | |
| [Distance sampling (DS)](#mods_distance_sampling)56 | * [Random](#sampledesign_random) relative to movement, pointing in either random or consistent direction25,49 * [Systematic](#sampledesign_systematic)49 * [Random](#sampledesign_random) or [targeted](#sampledesign_targeted) across known [density](#density) gradient52 | * Dependent on spatial extent of interest52 | | | | |
| [Time-to-event (TTE) model](#mods_tte)56 | * [Random](#sampledesign_random) relative to movement49 * [Systematic](#sampledesign_systematic)49 * [Systematic random](#sampledesign_systematic_random)49 | * No minimum if random sampling used56 | * Dependent on species [density](#density) and distribution (e.g., more cameras with lower [density](#density) and more clumped distribution)56 * Minimum 2057 * Ideally > 5057 | * No minimum56 | * Dependent on species [density](#density) and distribution57 | * None required57 * If demographic/ geographic closure [assumption](#mods_modelling_assumption)s not met the estimate will be mean abundance or [density](#density) in [study area](#study_area) during the [survey](#survey)57 |
| [Space-to-event (STE)](file:///C:\Users\cassi\Downloads\mods_ste) model56 | * None (uses instantaneous snapshots)57 |
| [Instantaneous sampling (IS)](#mods_instantaneous_sampling)56 |
| Behaviour | * Ideally, [random](#sampledesign_random)5 * [Stratified](#sampledesign_stratified)5 * Usually [targeted](#sampledesign_targeted)5 | * [Objective](#survey_objectives)-dependent5 * Ideally, independent ( > home range diameter or > 1 km)58,59 | * Activity patterns: Enough to obtain > 100 detections58,59 * If stratified, > 20 per stratum5 | - | - | * Dependent on behavioural metric (e.g., if it occurs during a certain period)5 |

**i Camera spacing to achieve spatial independence for species diversity and richness:** locations should be independent, meaning that any two locations do not sample the same community of animals. Note - this may be hard to achieve when considering the movement distances of some species, such as big cats, and in practice, a [[[camera spacing](#Camera_spacing)](#Camera_spacing)](#camera_spacing) of 1-2 km is often used (e.g., Tobler et al., 2008; Ahumada et al., 2011; Kinnaird & O’Brien, 2012)

**ii Number of cameras for occupancy models:** should based on expected occupancy probability (i.e., the expected probability that a given camera site is occupied, for a given species [Kays et al., 2020]).

**iii** [**Paired design**](#sampledesign_paired) **camera arrangement** **for CR:** due to thehigher chance of recognizing all individuals captured in a [survey](#survey); using two cameras also decreases the chances of missing captures entirely (Tobler et al., 2008).

**iv** [**Targeted**](#sampledesign_targeted) **camera arrangement** **for CR:** This design is commonly used when estimating densities of [marked populations](#typeid_marked) (e.g., [spatially explicit capture-recapture [SECR](#mods_scr_secr); Borchers & Efford, 2008; Efford, 2004; Royle & Young, 2008]) or behaviour studies. However, [targeted](#sampledesign_targeted) sampling may impede the ability to draw inferences beyond the [survey](#survey) area (Wearn & Glover-Kapfer, 2017).

**v** **Camera spacing to achieve spatial dependence for CR:** “[camera location](#camera_location)s should be sufficiently close to one another such that individuals are picked up across more than one location” (Wearn & Glover-Kapfer, 2017).

**vi Camera spacing should be species-dependent (home range size) for CR/CMR:** There is a trade-off between [density](#density) and [survey](#survey) extent: 10-30 individuals exposed with a [camera location](#camera_location) density of at least 2-4 per smallest home range.

**vii Ideally, systematic camera arrangement, closely spaced cameras for** [**2-flank SPIM**](#mods_2flankspim)**:** due to the increased likelihood of capturing both sides of the animal (Augustine et al., 2018)

**viii** **Fewer number of cameras** [**2-flank SPIM**](#mods_2flankspim) **than for** [**SCR**](#mods_scr_secr) **(or same but larger sample area):** Note - larger sampling areas preferred for [**2-flank SPIM**](#mods_2flankspim)since there will be fewer samples collected on the periphery of the sampled area and thus less uncertainty in identifying individuals (Augustine et al., 2018).

**ix** [**Random**](#sampledesign_random) **camera arrangement for** [**REM**](#mods_rem)**:** Note that species with very restricted distributions in a landscape are best sampled using a [stratified design](#sampledesign_stratified) (Wearn & Glover-Kapfer, 2017).

x[**Systematic random**](#sampledesign_systematic_random) **camera arrangement for** [**REM**](#mods_rem): to ensure a minimum separation between cameras (Wearn & Glover-Kapfer, 2017).

xi**Stratified targeted camera arrangement for** [**REM**](#mods_rem)**:** species that are highly restricted in occurrence (Wearn & Glover-Kapfer, 2017).

##### **Appendix A - Table A3.** Example of camera settings and recommended camera settings options (Reconyx Camera Models).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Field name in Reconyx camera settings** | **Setting option - Reconyx PC800/PC900** | **Setting option - Reconyx HP2X** | **Field name in Remote Camera Survey Guidelines** | **Setting option Remote Camera Survey Guidelines** | **Recommended setting option** |
| [Trigger](#trigger_event) **/ Motion** | | | | | |
| Motion Sensor | On / Off | On / Off | [Trigger Mode(s)](#settings_trigger_modes) | Motion image / [Time-lapse image](#timelapse_image)  / Video | On |
| [Sensitivity](#settings_trigger_sensitivity) | Low / Low/Medium / Med / Medium/High / High | Low / Low/Med / Med / Med/High / High / Very High | [Trigger Sensitivity](#settings_trigger_sensitivity) | Low / Low/Med / Med / Med/High / High / Very High / Unknown | High |
| Pictures per Trigger | 1 / 2 / 3 / 5 / 10 | 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 | [Photos Per Trigger](#settings_photos_per_trigger) | [numeric] | 1 |
| Picture Interval | RapidFire / 1 sec / 3 sec / 5 sec / 10 sec | RapidFire / 1 sec / 2 sec / 3 sec / 4 sec / 5 sec / 6 sec / 7 sec / 8 sec / 9 sec / 10 sec | [Motion Image Interval (seconds)](#settings_motion_image_interval) | [numeric; seconds; “0” if NA] | RapidFire |
| Quiet Period | No delay / 15 sec / 30 sec / 1 min / 3 min / 5 min | No Delay / 5 sec / 10 sec / 15 sec / 30 sec / 1 min / 2 min / 3 min / 5 min | [Quiet Period (seconds)](#settings_quiet_period) | [numeric; seconds; “0” if NA] | No delay |
| Motion videos | - | On / Off | [Trigger Mode(s)](#settings_trigger_modes) | Motion image / [Time-lapse image](#timelapse_image)  / Video | - |
| [Video length](#settings_video_length) | - | 5 sec, 10 sec, Dynamic Length | \*[Video Length (seconds)](#settings_video_length) | [numeric; seconds; blank if NA] | - |
| External trigger images | On / Off; if applicable | On / Off | [Trigger Mode(s)](#settings_trigger_modes) | Motion image / [Time-lapse image](#timelapse_image)  / Video | - |
| External trigger videos | - | On / Off; if applicable | [Trigger Mode(s)](#settings_trigger_modes) | Motion image / [Time-lapse image](#timelapse_image)  / Video | - |
| **Time-lapse** | | | | | |
| Lapse Picture |  | On / Off | [Trigger Mode(s)](#settings_trigger_modes) | [Time-lapse images](#timelapse_image) | On |
| [Time-lapse interval](#settings_Timelpase_Interval) | 1 min, 5 min, 15 min, 30 min, 1 hour | 1 min, 5 min, 15 min, 30 min, 1 hour | - | - | 2 hours |
| Lapse Schedule | One-hour increments | 24 hr, Add Solar, Add Fixed | - | - | 00:00 to 12:00 |
| AM Period | On / Off | On / Off | - | - | On |
| PM Period | On / Off | On / Off | - | - | On |
| Time-lapse videos | - | On / Off | [Trigger Mode(s)](#settings_trigger_modes) | Motion image / [Time-lapse image](#timelapse_image)  / Video | - |
| [Video length](#settings_video_length) | - | 5 sec, 10 sec, Dynamic Length | \*[Video Length (seconds)](#settings_video_length) | [numeric; seconds; blank if NA] | - |
| **Night Mode / Day/Night** | | | | | |
| Take pictures | Both / Day / Night | Both / Day / Night | - | - | Both |
| Take videos | - | Both / Day / Night | - | - | - |
| [Infrared illuminator](#settings_infrared_illum) | On / Off | On / Off | - | - | - |
| [Flash output](#settings_flash_output) | - | Low / Med / High / Off | - | - | - |
| Night Mode | Balance / High Quality / Fast Shutter / Max Range | Optimized / Fast shutter / Long Range | - | - | - |
| **Other** | | | | | |
| [User label](#settings_userlabel) | [text field] | [text field] | - | - | [text field] |
| Minimum shutter speed | - | - | - | - | 1/120th |
| Maximum ISO | - | - | - | - | ISO1600 |

##### **Appendix A - Table A4.** Recommended equipment for field deployments (checklist).

| **Category** | **Equipment** |
| --- | --- |
| Safety | * Appropriate personal protective equipment for weather and safety (e.g., sunscreen, rain jacket, etc.) * Bear spray * First aid kit (ensure contents are complete) * A communication device (e.g., satellite phone, radio, etc.) |
| Navigation | * GPS unit (NAD83, decimal degrees) * Maps * Compass (set to appropriate declination; to document the [Camera Direction](#camera_direction) (degrees)) |
| Camera equipment | * Reconyx HP2X unit (or camera of your choice) * User manual for your [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make) (for reference/troubleshooting) * Laptop case(s) (to protect the camera lens/detectors in transit) * AA lithium batteries (appropriate number make/model dependent) * spare batteries * Ziplock bags for old batteries and/or keep items dry * Sharpie for labelling * 1 SDHC memory card (16 GB or larger) * spare SD cards * Cable lock with key (labelled with the [Camera ID](#camera_id)), with adjustable straps for support as needed * extra key for cable lock (bolt cutter useful if lock jammed) * Bracket or security enclosure (e.g., lock box; optional but recommended to minimize risk of theft) * Desiccant packets * Lighter or de-icer (spray; for frozen locks in winter) |
| Camera Attachment | * Post or stake (to serve as an attachment point) * Mallet (to drive in post or stake) * Screws (for mounting cameras) * Screwdrivers * Phillips (crosshead) * Robertson (square) * Slotted (flathead) |
| Documentation | * Tablet, digital camera with SD card or a phone to view photos (if required) * Tablet or clipboard * [Camera Deployment Field Datasheet](#_camera_deployment_Field) (Rite-In-The-Rain paper with pencil, ideally). * [Camera Service/Retrieval Field Datasheet](#_camera_Service/Retrieval_Field) (Rite-In-The-Rain paper with pencil, ideally). * [Test Image Sheet](#test_image_sheet) or dry-erase board * Marker (to document [deployment](#deployment) information in [test images](#test_image)) * Measuring tape (to measure the [camera height](#camera_height), etc.) |
| Deployment of [lure](#baitlure_lure) | * Lure stakes & PVC pipes * [Lure](#baitlure_lure) * [Lure](#baitlure_lure) product Safety Data Sheet (SDS) * Nitrile gloves |
| Visibility | * Folding machete/saw/hatchet (to clear shrubs, tree branches and vegetation; gloves are also useful) * Conduit (1.3 m; painted with alternating swatches of high contrast paint [if required]) |

##### 

##### **Appendix A - Table A5.** Steps to deploy a remote camera.

| **Task** | **Instructions** |
| --- | --- |
| Select [camera locations](#camera_location) | 1. Locate the predetermined [camera locations](#camera_location) (e.g. based on [study](#survey) design and determined before camera set up; [Appendix A - Table A2](#surv_guidelines_table_a2)). 2. Select a [FOV Target Feature](#fov_target) (if applicable) to maximize [detection probability](#detection_probability) (e.g., wildlife trail). 3. Identify a suitable attachment point in the vicinity of the target area (e.g., tree, fence post) that supports:    * + a [detection zone](#detection_zone) ~3–5 m from the camera (~3–5 m from the [FOV Target Feature](#fov_target)),      + a [Field of View (FOV)](#field_of_view) at least 5 m wide and 10 m long (unobstructed by objects, shrubs or trees), and      + the camera aimed perpendicular to the expected movement path of the [Target Species](#target_species). 4. Trim vegetation as needed.   ***Note:*** It may be necessary to bring a man-made attachmentpoint (e.g., stake). The most suitable attachment point will depend on the [camera height](#camera_height), [angle](#camera_angle), and [direction](#camera_direction) because these choices will impact the [Field of View (FOV)](#field_of_view). |
| Set camera | 1. Before setting up the camera, record the [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make), [Camera Serial Number](#camera_serial_number), and optionally the [Camera ID](#camera_id), [SD Card ID](#sd_card_id), [key ID](#key_id) (for python or cable lock), attachment and the equipment that will be used to secure the camera. 2. Ensure the SD card is inserted, the batteries are fresh and turn the camera on. 3. Check (and record) the camera settings (e.g., [Trigger Mode(s)](#settings_trigger_modes), [Video Length (seconds)](#settings_video_length), [Trigger Sensitivity](#settings_trigger_sensitivity), # of [Photos Per Trigger](#settings_photos_per_trigger), [Motion Image Interval (seconds)](#settings_motion_image_interval), [Quiet Period (seconds)](#settings_quiet_period) , etc.) to ensure they match the predetermined choices and that the date time is correct. Record the [Deployment Start Date Time](#deployment_start_date_time) (in the format: “DD-MMM-YY HH:MM:SS”) |
| [Walktest](#walktest) | Perform a [walktest](#walktest) to confirm that the [Field of View (FOV)](#field_of_view) is satisfactory (see [section 7.4.5](#_Field_of_View)). See the camera’s user manual for instructions on how to perform the [walktest](#walktest) for your particular [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make).   1. Ensure the camera detects motion 5 m in front of the camera, at both 0 m and 0.5–1 m height. Trim vegetation as needed. 2. Activate the walktest mode. 3. Attach the camera at the desired [camera height](#camera_height), [angle](#camera_angle), and [[direction](#Camera_direction)](#camera_direction). 4. Walk in front of the camera to a specified distance (i.e., the "[Walktest Distance](#walktest_distance)," e.g., 5 m). 5. Wave your hand in front of the camera (usually at ground level and at a chosen height [i.e., the "[Walktest Height](#walktest_height)," e.g., 0.8 m]) to determine if the camera is activating. If the camera is set correctly (based on the user’s criteria), an indicator light will flash to signal that the sensor is detecting heat and motion (thus indicating the camera’s [detection zone](#detection_zone)). 6. Arm the camera or wait for the camera to arm itself (~2 minutes of inactivity). 7. Note whether a [walktest](#walktest) was performed on the field datasheets and if so, optionally record the [Walktest Distance (m)](#walktest_distance) and [Walktest Height (m)](#walktest_height). |
| Attach and secure the camera | 1. Attach and secure the camera to the tree/post (e.g., security box or bracket, cable lock and lock box, as needed). Security / lock boxes are recommended to avoid theft.    * + Cameras should be angled slightly downward. 2. Record the [camera height](#camera_height) (m).    * + In general, cameras should be ~0.5–1 m from the base of the tree to the bottom of the camera lens. 3. Record the [Camera Direction](#camera_direction) (degrees).    * + Cameras should ideally face north (if not, south). |
| [Test images](#test_image) | 1. Write the [deployment metadata](#deployment_metadata) (specifically, [[[[[[[[[Sample Station Name](#ID_Sample_Station)](#ID_Sample_station_ID)](#ID_Sample_Station)](#ID_Sample_station_ID)](#ID_Sample_station_ID)](#ID_Sample_station_ID)](#ID_Sample_Station)](#ID_Sample_station_ID)](#sample_station_name), [[[[Camera Location Name](#ID_Camera_location)](#ID_Camera_location)](#Heirch_Camera_location)](#camera_location_name), [Deployment Name](#deployment_name), [Deployment Crew](#deployment_crew), and [Deployment Start Date Time](#deployment_start_date_time) (in the format “DD-MMM-YYYY HH:MM:SS”) on either a [Test Image Sheet](#test_image_sheet) or a dry-erase board with a marker. This is important in case of the situation that the camera does not properly record the [user label](#settings_userlabel). 2. Walk ~5 m in front of the camera. 3. Face the [Test Image Sheet](#test_image_sheet)/dry-erase board towards the camera, and slowly walk towards the camera. If the [Test Image Sheet](#test_image_sheet) is laminated, tilt it slightly downward to avoid sun glare on the shiny surface. 4. Allow the camera to take a series of images. |
| Document [deployment metadata](#deployment_metadata) | Relevant [deployment metadata](#deployment_metadata) should be documented each time a camera is **deployed** (see full list below). Each event should have its own [Camera Deployment Field Datasheet](#_camera_deployment_Field).  ***Note:*** If a camera is deployed for more than one [survey](#survey), the field [crew](#crew)s will need to revisit the [camera location](#camera_location) to “**service**” the camera and/or equipment (e.g., to refresh batteries or swap out SD cards. If the field [crew](#crew) visits the [camera location](#camera_location) to collect the camera and other equipment (“[Service/Retrieval Crew](#service_retrieval_crew)“; i.e., the [camera location](#camera_location) will no longer be used and cameras, SD cards, and batteries are not replaced), this is referred to as a “**retrieval**.” Whether the [Service/Retrieval Crew](#service_retrieval_crew) services or retrieves a camera, additional [metadata](#metadata) should be collected that is not included in the [deployment metadata](#deployment_metadata) (see “[service/retrieval metadata](#service_retrieval_metadata)“ below).  Pertinent [deployment metadata](#deployment_metadata)collection fields include those in the [[Camera Deployment Field Datasheet](#_camera_deployment_Field)]. Additional information may be collected as needed. Data can be input into a tablet interface or recorded on a paper field datasheet. |
| Camera service or retrieval | 1. Approach the camera from the front so that the camera will collect images of the field [crew](#crew), thus serving as backup documentation of the [Deployment End Date Time](#deployment_end_date_time) (in the format “DD-MMM-YYYY HH:MM:SS”) in case that field sheets are lost, destroyed, etc. |
| Document [service/retrieval metadata](#service_retrieval_metadata) | Relevant [Service/Retrieval metadata](#service_retrieval_metadata) should be collected each time a camera is **serviced** (e.g., revisited to refresh batteries or swap out SD cards) or **retrieved** (e.g., revisited to collect the camera and other equipment, i.e., the [camera location](#camera_location) will no longer be used and the camera, SD card, and batteries are not being replaced) if there have been any changes to [[camera location](#Heirch_Camera_location)](#camera_location), sampling period, and/or setting type (e.g., not [baited](#baitlure_bait) and then [baited](#baitlure_bait) later) (see below for a full list). Whether the [crew](#crew) services or retrieves a camera, additional [metadata](#metadata) fields should be collected that are not included in the [deployment metadata](#deployment_metadata). Each event should have its own [Camera Service/Retrieval Field Datasheet](#_camera_Service/Retrieval_Field).   * + - Be sure to record the “[Purpose Of Visit](#purpose_of_visit)” (i.e., to service or retrieve the camera) as well as whether the camera was active or incurred damage, as this can provide context if there are no photos taken after a certain date.     - If the camera was damaged/is not functioning - before setting up the camera, record the new [[Camera Make](#Camera_make) and [Camera Model](#Camera_model)](#camera_make), new [Camera Serial Number](#camera_serial_number), and optionally the New [Camera ID](#camera_id), Key ID, and/or SD Card ID (if applicable; if python or cable lock damaged).     - Be sure to record whether the batteries were replaced (under “[Batteries Replaced](#batteries_replaced)”). If using lithium batteries, the camera’s battery level indicator may not decline evenly (but rather indicate full battery until a sudden drop-off). If you expect to leave your camera for a long period of time before checking it again, it is best to refresh the batteries.     - Record other relevant [metadata](#metadata) below.     - Ensure you collect whatever material you used to attach the camera to the tree, post, etc. and any other equipment you brought with you.   Pertinent [service/retrieval metadata](#service_retrieval_metadata) collection fields include those in the [[Camera Service/Retrieval Field Datasheet](#_camera_Service/Retrieval_Field)]. Additional information may be collected as needed. Data can be input into a tablet interface or recorded on a paper [field](#_camera_Service/Retrieval_Field) datasheet. |

***Notes:*** An asterisk (\*) indicates the field is optional and not required by the [AB Metadata Standards](https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/2_metadata-standards/2_0.1_Citation-and-Info.html) (RCSC, 2024) and [B.C. Metadata Standards](https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/wcmp_v1.pdf) (RISC, 2019).

##### Camera Deployment Field Datasheet

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Visit metadata** | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Project Name** | | | | | | |  | | | | **GPS Unit Accuracy (m)** | | | | | | |  | | | | | | | |
| [[[[[[**Sample Station Name**](#ID_Sample_station_ID)](#ID_Sample_Station)](#ID_Sample_station_ID)](#ID_Sample_station_ID)](#ID_Sample_station_ID)](#ID_sample_Station) | | | | | | |  | | | | **\*Access Method** | | | Foot / ATV / Argo / Truck / Snowmobile / Horse / Helicopter / Boat / Unknown | | | | | | | | | | | |
| **Camera Location Name** | | | | | | |  | | | |
|  | **Latitude or Northing** | | | | | |  | | | | **Deployment Crew**  (list full names) | | | | |  | | | | | | | | | |
|  | **Longitude or Easting** | | | | | |  | | | |
|  | **UTM zone** | | | | | |  | | | | **Deployment Start Date Time** | | | | | | | | DD-MMM-YYYY HH:MM:SS | | | | | | |
| **Equipment information** | | | | | | | | | | | **Placement** | | | | | | | | | | | | | | |
| **Camera ID** | | | |  | | | | | | | **Camera Height (m)** (0.5-1 m; to the nearest 0.05 m) | | | | | | | | | | | | |  | |
| **Camera Make** | | | |  | | | | | | | **\*Camera Direction (degrees)**  (Ideally north, if other explain in comments) | | | | | | | | |  | | | | | |
| **Camera Model** | | | |  | | | | | | |
| **Camera Serial Number** | | | | | | |  | | | | **\*Camera Attachment** | | | | Tree / Post / Tree + Bungee/Strap / Tree + Screws / Post + Bungee/Strap / Post + Screws / Other† | | | | | | | | | | |
| **\*SD Card ID** | | |  | | | | **\*Key ID** | | |  |
| **\*Security** | | | Security Box / Bracket / Bracket + Screws / None | | | | | | | |
| **\*Stake Distance (m)** | | | | |  | | | | | | | | | |
| **Camera settings** | | | | | | | | | | | **FOV Target Feature**  (circle one) | | Game Trail / Hiking Trail / Off-Highway Vehicle Trail / Paved Road / Dirt/Gravel Road / Road Crossing1 / Railway / Cutline/Seismic Line / Transmission Line / Pipeline / Wellsite / Culvert / Beaver Dam / Burrow/Den / Nest / Carcass2 / Natural Mineral Lick / Rub Post / Other† / None / Unknown | | | | | | | | | | | | |
| **Trigger Mode(s)**  (circle all that apply) | | | | | Motion / Time-lapse / Video | | | | | |
| **\*Video Length (seconds)** | | | | | | | | |  | |
| **Trigger Sensitivity**  (circle one) | | Low / Low/Med / Med / Med/High / High / Very High / Unknown | | | | | | | | |
| **Photos Per Trigger** | | | | | | | |  | | | **FOV Target Feature Distance (m)** (to the nearest 0.05 m) | | | | | | | | | | | | | |  |
| **Motion Image Interval (seconds)** | | | | | | | |  | | | **Bait/lure Type**  (circle one) | | | | | Scent / Meal3 / Bait Tree / Visual / Acoustic / Other‡ / None / Unknown | | | | | | | | | |
| **Quiet Period (seconds)** | | | | | | | |  | | |
| **Site characteristics** | | | | | | | | | | | | | | | | | | | | | | | | | |
| **\*Camera Location Characteristic(s)**  (circle all that apply) | | | | | | Trail / Road / Railway/Pipeline/Transmission Line / Cutline/Seismic Line / Wellsite / Clearcut / Building / Forest - Deciduous / Forest - Mixedwood / Forest - Conifer / Forest - Undefined / Meadow / Burn / Agriculture / Shrubland / Beaver Dam / Wetland / Lentic / Lotic / Other† / Unknown | | | | | | | | | | | **\*Deployment Area Photos Taken**  (circle one; photo order: datasheet, N, E, S, W) | | | | | | Y / N | | |
| **\*Deployment Area Photo Numbers** (list photo numbers) | | | |  | | | | |
| **Equipment checks** | | | | | | | | | | | | | | | | | | | | | | | | | |
| **\*Test Image Taken**  (circle one; see Test Image Sheet next page) | | | | | | | | | | Y / N | | **\*Walktest Distance (m)** (to the nearest 0.05 m) | | | | | | | | | |  | | | |
| **\*Walktest Height (m)** (to the nearest 0.05 m) | | | | | | | | | |  | | | |
| **\*Walktest Complete** (circle one) | | | | | | | | | | Y / N | | **\*Camera Active On Departure** (circle one) | | | | | | | | | | Y / N | | | |
|  | | | | | | | | | | | | | | | | | | | | | | | | | |
| **\*Camera Location Comments** | | | | | | | |  | | | | | | | | | | | | | | | | | |
| **\*Deployment Comments** | | | | | | | |  | | | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | | | | | | | | | |

\*Optional and not required by the Remote Camera Metadata: Standards for Alberta (RCSC, 2024)

**†** The option should be described in the Camera Location Comments

**‡** The option should be described in the Deployment Comments.

**Notes:** Abbreviations: Y = yes; N = no.

**\*Access Method:** record the method used to reach the camera location.

**Bait/lure Type:** record the type of bait or lure used at the camera location. If “Other,” describe in the Deployment Comments.

**2Carcass [FOV Target Feature]:** not placed by the crew as bait/lure.

**\*Camera Active On Departure:** record whether a camera was functional upon departure.

**\*Camera Attachment:** record the method/tools used to attach the camera. If “Other,” describe in Camera Location Comments.

**\*Camera Direction (degrees):** record the cardinal direction that a camera faces. Ideally, cameras should face north (N, i.e. “0” degrees), or south (S; i.e. “180” degrees) if north is not possible. The Camera Direction should be chosen to ensure the field of view (FOV) is of the original FOV Target Feature.

**Camera Height (m):** record the height from the ground (below snow) to the bottom of the lens (metres; to the nearest 0.05 m).

**Camera ID:** recorda unique alphanumeric ID for the camera that distinguishes it from other cameras of the same make or model.

**\*Camera Location Characteristics:** record any significant features around the camera at the time of the visit. Camera Location Characteristics differ from FOV Target Features in that Camera Location Characteristics could include those not in the camera’s FOV. If “Other,” describe in the Camera Location Comments.

**\*Camera Location Comments:** comments describing additional details about a camera location.

**Camera Location Name**: record a unique alphanumeric identifier for the location where a single camera was placed (e.g., “bh1”).

**Camera Make:** record the make (i.e., the manufacturer) of the camera deployed (e.g., “Reconyx” or “Bushnell”).

**Camera Model:** record the model number of the camera deployed (e.g., “PC900” or “Trophy Cam HD”).

**Coordinates:** coordinates for the camera location should be taken from the GPS with five decimal places and in decimal degrees if using latitude/longitude or including UTM zone if using easting/northing.

**Deployment Crew:** record the first and last names of the individuals who collected data during the deployment visit.

**\*Deployment Area Photos Taken / Deployment Area Photo Numbers:** images of the area where the camera was deployed. Record the image numbers from a camera or phone. Leave blank if not applicable.

**\*Deployment Comments:** comments describing additional details about the deployment.

**Deployment Start Date Time (DD-MMM-YYYY HH:MM:SS):** the date and time that a camera was placed for a specific deployment.

**FOV Target Feature:** record the specific man-made or natural feature at which the camera is aimed to maximize the detection of wildlife species or to measure the use of that feature. If “Other,” describe in the Camera Location Comments.

**\*FOV Target Feature Distance (m):** record the distance from the camera to the FOV Target Feature (metres; to the nearest 0.05 m). Leave blank if not applicable.

**GPS Unit Accuracy (m):** record the margin of error of the GPS unit used to record spatial information (in metres; e.g., if the margin of error is +/- 3.5 m, record 3.5 m).

**\*Key ID:** record the unique ID for the key or set of keys used to lock/secure the camera to the post, tree, etc.

**3\*Meal [Bait/lure Type]:** including carcass placed by the crew.

**Motion Image Interval (seconds):** record the time (in seconds) between events (triggers) that occur due to motion, heat, or triggering of external trigger devices. If a Motion Image Interval was not set, enter “0” seconds (i.e., instantaneous).

**Photos Per Trigger:** record the number of photos taken each time the camera was triggered.

**Project Name:** record the unique alphanumeric identifier for the project (e.g., "uofa\_oilsands\_2018").

**Quiet Period (seconds):** record the time (in seconds) between shutter “triggers”; that is, if the camera was programmed to pause between firing initially and firing a second time. If a Quiet Period was not set, enter “0.”

**1Road crossing [FOV Target Feature]:** e.g., overpass, underpass, or bridge.

**Sample Station Name:** record the sequential alphanumeric identifier given to each camera location within a grouping of two more non-independent camera locations when cameras are deployed in clusters, pairs or arrays (e.g., "ss1" in "ss1\_bh1," "ss1\_bh2," "ss1\_bh3," and "ss1\_bh4"). Leave blank if not applicable. “Hierarchical (multiple)\*,”

**\*SD card information / Battery %:** record the ID label on the SD card (e.g., “cmu\_100”). Note the card status (% FULL) and remaining battery power. Toggle through options to find STATUS to record the # of photos (differs for different Camera Models).

**\*Security:** record the equipment used to secure the camera.

**\*Stake Distance (m):** record the distance from the camera to the stake (metres; to the nearest 0.05 m). Leave blank if not applicable.

**\*Test Image Taken:** record whether a test image (i.e., an image taken from a camera after it has been set up to provide a permanent record of the visit metadata) was taken. Arm the camera and walk towards the camera from ~5 m in front while holding the Test Image Sheet (see next page).

**Trigger Mode(s):** record the camera settings that determine how the camera will trigger: by motion ("Motion Image"), at set intervals ("Time-lapse image"), and/or by video ("Video"; possible with newer camera models, such as Reconyx HP2X).

**Trigger Sensitivity:** record how sensitive a camera is to activation (“triggering”) via the infrared and/or heat sensors (if applicable). If the Trigger Mode is set to Time-lapse or if the camera does not have a sensitivity setting, circle “Unknown.”

**\*Video Length (seconds):** if recording video, note the video length selected in seconds. Leave blank if not applicable.

**\*Walktest Complete:** indicate whether a walktest was performed to ensure the Camera Height, tilt, etc., adequately captures the desired detection zone. Put the camera in “walktest” mode and move your hand along detection bands at ~5 m from the camera. Motion is detected when the red walktest light flashes.

**\*Walktest Distance (m):** record the horizontal distance at which the crew performs the walktest (metres; to the nearest 0.05 m). Leave blank if not applicable.

**\*Walktest Height (m):** record the vertical distance at which the crew performs the walktest (metres; to the nearest 0.05 m. Leave blank if not applicable.

##### Test Image Sheet

Sample Station Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Camera Location Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Crew: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Deployment Start Date Time: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

##### Camera Service/Retrieval Field Datasheet

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Visit metadata** | | | | | | | | | | | | | | | |
| **Project Name** | | |  | | | | | | | **Service/Retrieval Crew / Deployment Crew**||(list full names) | | | |  | |
| **Sample Station Name** | | |  | | | | | | |
| **Camera Location Name** | | |  | | | | | | | **Deployment End Date Time** /  **Deployment Start Date Time**|| | | | | DD-MMM-YYYY HH:MM:SS | |
| **Purpose of Visit** (circle one) | | | | Service / Retrieval | | | | | |
| **Retrieval - Equipment information** | | | | | | | | | | | | **Service - Placement**|| | | | |
| **\*Camera Active on Arrival** (circle one) | | | | | | | | Y / N | | | | **Bait/lure Type**  (circle one) | Scent / Meal**1**  / Bait Tree / Visual / Acoustic / Other‡ / None / Unknown | | |
| **\*Camera Damaged**  (circle one) | | | Physical‡ / Mechanical‡ / None | | | | | | | | |
| **\*SD Card ID** |  | | **\*SD Card Status (% full)** | | | | | | | |  | **Service - Equipment checks**|| | | | |
| **\*# Of Images** |  | | **\*RemainingBattery (%)** | | | | | | | |  | **\*Test Image Taken**  (circle one; see Test Image Sheet) | | | Y / N |
| **Service - Equipment information**|| | | | | | | | | | | | |
| **New Camera ID**# | |  | | | | | **New SD Card ID**# | | | |  | **\*Walktest Complete** | | | Y / N |
| **New Camera Make**# | | |  | | | | | | **Batteries Replaced**  (circle one) | | Y / N | **\*Walktest Distance (m)** (nearest 0.05 m) | | |  |
| **New Camera Model**# | | |  | | | | | | **\*Walktest Height (m)** (nearest 0.05 m) | | |  |
| **New Camera Serial Number**# | | | | | |  | | | | | | **\*Camera Active on Departure** | | | Y / N |
|  | | | | | | | | | | | | | | | |
| **\*Camera Location Comments** | | | | |  | | | | | | | | | | |
| **\*Service/Retrieval Comments** | | | | |  | | | | | | | | | | |
|  | | | | | | | | | | | | | | | |
| **Visit metadata** | | | | | | | | | | | | | | | |
| **Project Name** | | |  | | | | | | | **Service/Retrieval Crew / Deployment Crew**||(list full names) | | | |  | |
| **Sample Station Name** | | |  | | | | | | |
| **Camera Location Name** | | |  | | | | | | | **Deployment End Date Time** /  **Deployment Start Date Time**|| | | | | DD-MMM-YYYY HH:MM:SS | |
| **Purpose of Visit** (circle one) | | | | Service / Retrieval | | | | | |
| **Retrieval - Equipment information** | | | | | | | | | | | | **Service - Placement**|| | | | |
| **\*Camera Active on Arrival** (circle one) | | | | | | | | Y / N | | | | **Bait/lure Type**  (circle one) | Scent / Meal**1**  / Bait Tree / Visual / Acoustic / Other‡ / None / Unknown | | |
| **\*Camera Damaged**  (circle one) | | | Physical‡ / Mechanical‡ / None | | | | | | | | |
| **\*SD Card ID** |  | | **\*SD Card Status (% full)** | | | | | | | |  | **Service - Equipment checks**|| | | | |
| **\*# Of Images** |  | | **\*RemainingBattery (%)** | | | | | | | |  | **\*Test Image Taken**  (circle one; see Test Image Sheet) | | | Y / N |
| **Service - Equipment information**|| | | | | | | | | | | | |
| **New Camera ID**# | |  | | | | | **New SD Card ID**# | | | |  | **\*Walktest Complete** | | | Y / N |
| **New Camera Make**# | | |  | | | | | | **Batteries Replaced**  (circle one) | | Y / N | **\*Walktest Distance (m)** (nearest 0.05 m) | | |  |
| **New Camera Model**# | | |  | | | | | | **\*Walktest Height (m)** (nearest 0.05 m) | | |  |
| **New Camera Serial Number**# | | | | | |  | | | | | | **\*Camera Active on Departure** | | | Y / N |
|  | | | | | | | | | | | | | | | |
| **\*Camera Location Comments** | | | | |  | | | | | | | | | | |
| **\*Service/Retrieval Comments** | | | | |  | | | | | | | | | | |
|  | | | | | | | | | | | | | | | |

**\*** Optional and not required by the Remote Camera Metadata: Standards fStandards or Alberta (RCSC, 2022)

**†** The option should be described in the Camera Location Comments

**‡** The option should be described in the Service/Retrieval Comments.

**#** If the camera or SD card is replaced.

**||** If the Purpose of Visit is “Service,” such that the current deployment ends after the visit, and a new deployment begins.

**Notes:** Abbreviations: Y = yes; N = no.

**Bait/lure Type:** record the type of bait or lure used at the camera location. Record “None” if a Bait/Lure Type was not used and "Unknown" if not known. If “Other,” describe in the Deployment Comments.

**\*Camera Active On Arrival:** record whether the camera was functional upon arrival.

**\*Camera Damaged:** record whether there is any damage to the camera (physical or mechanical). If damage is present, describe the damage in the Service/Retrieval Comments.

**Camera ID:** record the unique alphanumeric ID for the camera that distinguishes it from other cameras of the same make or model.

**\*Camera Location Comments:** comments describing additional details about a camera location.

**Camera Location Name**: record the unique alphanumeric identifier for the location where a single camera was placed (e.g., “bh1”).

**Camera Make:** record the make (i.e., the manufacturer) of the camera deployed (e.g., “Reconyx” or “Bushnell”).

**Camera Model:** record the model number of the camera deployed (e.g., “PC900” or “Trophy Cam HD”).

**\*Deployment Area Photos Taken / Deployment Area Photo Numbers:** images of the area where the camera was deployed. Record the image numbers from a camera or phone. Leave blank if not applicable.

**Deployment Start Date Time (DD-MMM-YYYY HH:MM:SS):** the date and time that a camera was placed for a specific deployment.

**1\*Meal [Bait/lure Type]:** including carcass placed by the crew.

**Project Name:** record the unique alphanumeric identifier for the project (e.g., "uofa\_oilsands\_2018").

**Purpose Of Visit:** record the reason for visiting the camera location (i.e. to retrieve the camera ['retrieve'] or to change batteries/SD card or replace the camera ['service']).

**Sample Station Name:** record the sequential alphanumeric identifier given to each camera location within a grouping of two more non-independent camera locations when cameras are deployed in clusters, pairs or arrays (e.g., "ss1" in "ss1\_bh1," "ss1\_bh2," "ss1\_bh3," and "ss1\_bh4"). Leave blank if not applicable.

**\*SD card information / Battery %:** record the ID label on the SD card (e.g., “cmu\_100”). Note the card status (% FULL) and remaining battery power. Toggle through options to find STATUS to record the # of photos (differs for different Camera Models).

**\*Service:** record whether the SD card has been swapped and the batteries replaced.

**\*Service/Retrieval Comments:** comments describing additional details about the service/retrieval.

**Service/Retrieval / Deployment Crew:** record the first and last names of the individuals who collected data during the service/retrieval visit.

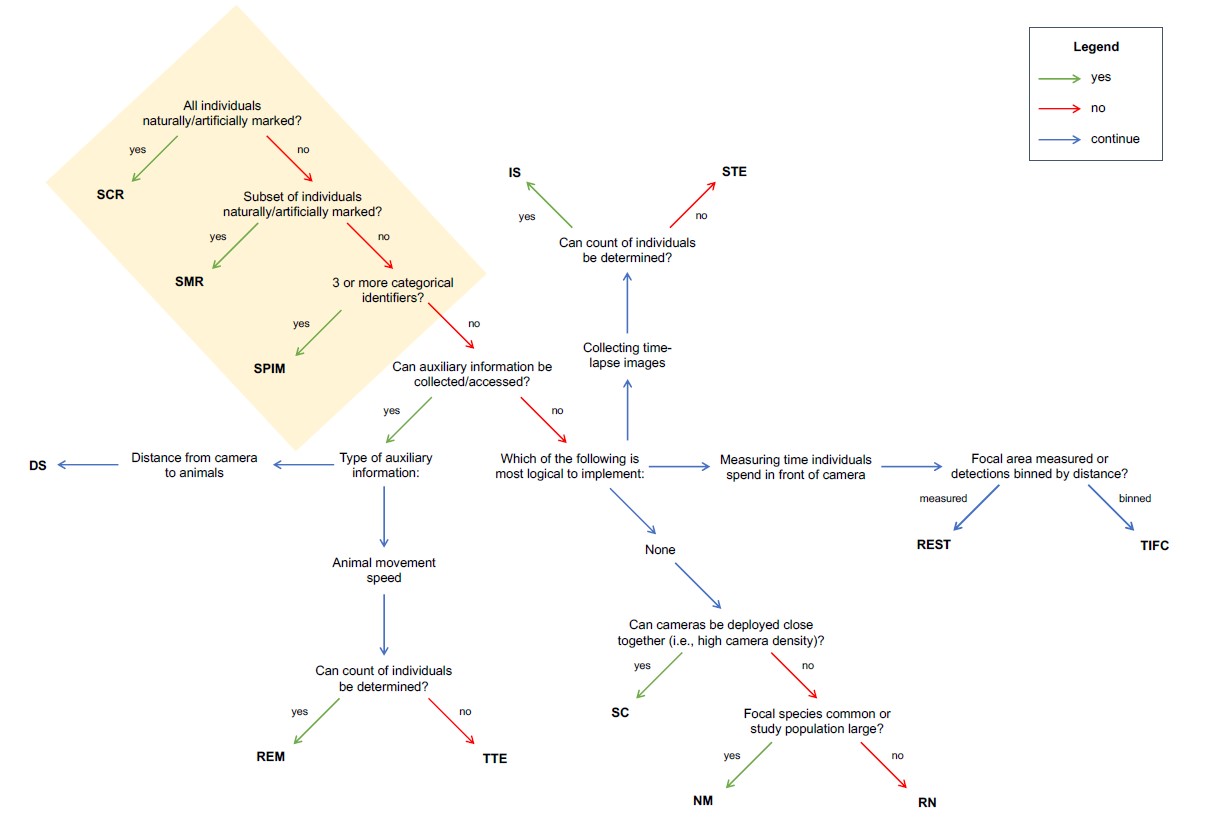
**\*Test Image Taken:** record whether a test image (i.e., an image taken from a camera after it has been set up to provide a permanent record of the visit metadata) was taken. Arm the camera and walk towards the camera from ~5 m in front while holding the Test Image Sheet (see next page).

**\*Walktest Complete:** indicate whether a walktest was performed to ensure the Camera Height, tilt, etc., adequately captures the desired detection zone. Put the camera in “walktest” mode and move your hand along detection bands at ~5 m from the camera. Motion is detected when the red walktest light flashes.

**\*Walktest Distance (m):** record the horizontal distance at which the crew performs the walktest (metres; to the nearest 0.05 m). Leave blank if not applicable.

**\*Walktest Height (m):** record the vertical distance at which the crew performs the walktest (metres; to the nearest 0.05 m. Leave blank if not applicable.

# Appendix B

****

**Appendix B - Figure B1.** “Adapted from Gilbert et al. (2021) and Sun (unpublished). Decision tree for selecting camera trap [density](#density) models. The models in the yellow rectangle are for [marked](#typeid_marked) and [partially-marked populations](#typeid_partially_marked); the remaining models are for [unmarked populations](#typeid_unmarked). Note, the models in this decision tree are not necessarily ordered from strongest to weakest, but rather are organized by key features” (Clarke et al., 2022).