# Assumptions, Pros, Cons

## changes here will reflect in books above

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| **Objective** | **Approach** | **Assumptions** | **Pros** | **Cons** |
| [Species inventory](#mods_inventory) | [Species inventory](#mods_inventory) | No formal [assumption](#mods_modelling_assumption)s {{Wearn & Glover-Kapfer, 2017}} | Maximum flexibility for [study](#survey) design (e.g., [camera days per camera location](#camera_days_per_camera_location) or use of [lure](#baitlure_lure) {{Rovero et al., 2013}}){{Wearn & Glover-Kapfer, 2017}} | Not reliable estimates for inference ("considered as unfinished, working drafts"){{Wearn & Glover-Kapfer, 2017}} |
| Species richness | Species richness | [Camera location](#camera_location)s are [randomly placed](#sampledesign_random){{Wearn & Glover-Kapfer, 2017}}  [Camera location](#camera_location)s are independent{{Wearn & Glover-Kapfer, 2017}}  [Detection probability](#detection_probability) of different species remains the same1 ("true" species richness estimation involves attempting to correct for "[imperfect detection](#imperfect_detection)"{{Wearn & Glover-Kapfer, 2017}})  Sampling effort is comparable between [camera location](#camera_location)s {{Royle & Nichols, 2003}} | Fundamental to ecological theory and often a key metric used in management{{Wearn & Glover-Kapfer, 2017}}  Simple to analyze, interpret and communicate{{Wearn & Glover-Kapfer, 2017}}  Models exist to estimate asymptotic species richness, including unseen species (simple versions of these models - "EstimateS" and the "vegan" R-packages){{Wearn & Glover-Kapfer, 2017}} | Dependent on the scale (as captured in the species-area relationship){{Wearn & Glover-Kapfer, 2017}}  All species have equal weight in calculations, and community evenness is disregarded{{Wearn & Glover-Kapfer, 2017}}  Insensitive to changes in abundance, community structure and community composition{{Wearn & Glover-Kapfer, 2017}} |
| Species diversity | Species diversity | [Camera location](#camera_location)s are [randomly placed](#sampledesign_random){{Wearn & Glover-Kapfer, 2017}})  [Camera location](#camera_location)s are independent {{Wearn & Glover-Kapfer, 2017}})  [Detection probability](#detection_probability) of different species remains the same{{Wearn & Glover-Kapfer, 2017}}) | Captures evenness and richness (although some indices only reflect evenness) {{Wearn & Glover-Kapfer, 2017}}  Most indices are easy to calculate and widely implemented in software packages (e.g., "EstimateS" and "vegan" in R){{Wearn & Glover-Kapfer, 2017}} | Many indices exist, and it can be difficult to choose the most appropriate {{Wearn & Glover-Kapfer, 2017}}  Comparing measures across space, time and studies can be very difficult {{Wearn & Glover-Kapfer, 2017}}  Insensitive to changes in community composition {{Wearn & Glover-Kapfer, 2017}} (however, this may be conditional on study design) |
| Species diversity | β-diversity | [Camera location](#camera_location)s are [randomly placed](#sampledesign_random) {{Wearn & Glover-Kapfer, 2017}}  Randomness and independence{{Wearn & Glover-Kapfer, 2017}}  Samples are assumed to have been taken at random from the broader population of sites{{Wearn & Glover-Kapfer, 2017}} | * Can be used to track changes in community composition {{Wearn & Glover-Kapfer, 2017}} * Plays a critical role in effective conservation prioritization (e.g., designing reserve networks) {{Wearn & Glover-Kapfer, 2017}} * Important for detecting changes in the fundamental processes{{Wearn & Glover-Kapfer, 2017}} | No single best measure for all purposes {{Wearn & Glover-Kapfer, 2017}}  Interpretation/communication not always straightforward {{Wearn & Glover-Kapfer, 2017}}  Scale-dependent (i.e., influenced by the size of the communities that are being included) {{Wearn & Glover-Kapfer, 2017}} |
| [Occupancy](#occupancy) | [Occupancy models](#mods_occupancy){{MacKenzie et al., 2002}} | [Occupancy](#occupancy) is constant {{MacKenzie et al., 2002}} (abundance is constant) {{MacKenzie et al., 2006}}  [Camera location](#camera_location)s are independent{{MacKenzie et al., 2006}}  Detections are [independent](#independent_detections) {{MacKenzie et al., 2006}}  The probability of [occupancy](#occupancy) and detection are constant across all [camera location](#camera_location)s within a stratum or can be modelled using covariates {{MacKenzie et al., 2006}}  Species are not misidentified{{MacKenzie et al., 2006}} | Does not require individual identification {{MacKenzie et al., 2006}}  Only requires detection/non-detection data for each site {{Wearn & Glover-Kapfer, 2017}}  Relatively easy-to-use software exists for fitting models (PRESENCE, MARK, and the "unmarked" R package){{Wearn & Glover-Kapfer, 2017}}  "Open" models exist that allow for the estimation of site colonization and extinction rates{{MacKenzie et al., 2006; Wearn & Glover-Kapfer, 2017}}  Multi-species [occupancy models](#mods_occupancy) {{MacKenzie et al., 2002}} allow the inclusion of interactions among species while controlling for [imperfect detection](#imperfect_detection){{Wearn & Glover-Kapfer, 2017}} | [Occupancy](#occupancy) {{MacKenzie et al., 2002}} only measures distribution; it may be a misleading indicator of changes in abundance{{Wearn & Glover-Kapfer, 2017}}  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)){{Wearn & Glover-Kapfer, 2017}} |
| [Relative abundance indices](#mods_relative_abundance) | [Poisson](#mods_poisson) | Many [assumption](#mods_modelling_assumption)s exist(since used for many approaches){{Wearn & Glover-Kapfer, 2017}} | Simple to calculate and technically possible (even with small sample sizes when robust methods might fail){{Wearn & Glover-Kapfer, 2017}}  [Relative abundance indices](#mods_relative_abundance) often do correlate with abundance{{Wearn & Glover-Kapfer, 2017}}  Calibration with independent [density](#density) estimates is possible{{Wearn & Glover-Kapfer, 2017}} | Difficult to draw inferences (a large number of [assumptions](#mods_modelling_assumption)); comparisons across space, time, species, and studies are difficult{{Wearn & Glover-Kapfer, 2017}}  Requires stringent [study design](#survey) (e.g., random sampling, standardized methods){{Wearn & Glover-Kapfer, 2017}}  Detection rates from remote cameras cannot be used as an index to compare relative abundance across species {{Rowcliffe & Carbone, 2008}} |
|  | [Zero-inflated Poisson (ZIP)](#Mods_zip) {{Lambert, 1992}} |  |  |  |
|  | [Negative binomial (NB)](#mods_negative_binomial){{Mullahy, 1986}} |  |  |  |
|  | [Zero-inflated negative binomial (ZINB)](#mods_zinb){{McCullagh & Nelder, 1989}} |  |  |  |
|  | [Hurdle models](#mods_hurdle) {{Mullahy, 1986; Heilbron 1994}} |  |  |  |
|  | Other |  |  |  |
|  |  |  |  |  |
| Population size / Absolute abundance / vital rates / [Density](#density); [Marked population](#typeid_marked) | [Capture-recapture (CR) / capture-mark-recapture (CMR)](#mods\_cr\_cmr) {{Karanth, 1995; Karanth & Nichols, 1998}} | * Demographic closure (i.e., no births or deaths) {{Wearn & Glover-Kapfer, 2017}} * Geographic closure (i.e., no immigration or emigration) {{Wearn & Glover-Kapfer, 2017}} * All individuals have at least some probability of being detected {{Rovero et al., 2013}} * Sampled area encompasses the full extent of individuals’ movements {{Karanth & Nichols, 1998; Rovero et al., 2013}} * Activity centres are randomly dispersed {{Clarke et al., 2023}} * Activity centres are stationary {{Clarke et al., 2023}} | * May be used as a [relative abundance index](#mods_relative_abundance) that controls for [imperfect detection](#imperfect_detection) {{Wearn & Glover-Kapfer, 2017}} * 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_mr)) {{Wearn & Glover-Kapfer, 2017}} * Can use the robust design with "open" models to obtain recruitment and survival rate estimates {{Wearn & Glover-Kapfer, 2017}} | * Requires that individuals are distinguishable {{Wearn & Glover-Kapfer, 2017}}. However, CR {{Karanth, 1995; Karanth & Nichols, 1998}} has also been used to estimate abundance of species that lack natural markers but that have phenotypic and/or environment-induced characteristics {{Noss et al., 2003; Kelly et al., 2008; Rovero et al., 2013}} * When the sample size is large enough to reliably estimate [density](#density) with CR, {{Karanth, 1995; Karanth & Nichols, 1998}} individuals are unlikely to have a unique marker {{Noss et al., 2003; Kelly et al., 2008; Rovero et al., 2013}} * Dependent on the surveyed area, which is difficult to track and calculate {{Wearn & Glover-Kapfer, 2017}} * Requires a minimum number of captures and recaptures {{Wearn & Glover-Kapfer, 2017}} * Relatively stringent requirements for [study design](#survey) (e.g., no "holes" in the trapping grid) {{Wearn & Glover-Kapfer, 2017}} * Geographic closure at the plot level, which is often unrealistic {{Wearn & Glover-Kapfer, 2017}} * Assumes a specific relationship between abundance and detection {{Wearn & Glover-Kapfer, 2017}}  * [Density](#density) cannot be explicitly estimated because the true area animals occupy is never measured (only approximated) {{Chandler & Royle, 2013}} |
| [Density](#density) / population size; [Marked population](#typeid_marked) | [Spatially explicit capture recapture (SECR)](#mods_scr_secr) {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}} (also referred to as [Spatial capture-recapture [SCR])](#mods_scr_secr) | Demographic closure (i.e., no births or deaths) {{Wearn & Glover-Kapfer, 2017}}  [Detection probability](#detection_probability) of different individuals is equal {{Wearn & Glover-Kapfer, 2017}}  {{bullet2}} or, for SECR, individuals have equal [detection probability](#detection_probability) at a given distance from the centre of their home range {{Wearn & Glover-Kapfer, 2017}}  Detections of different individuals are [independent](#independent_detections) {{Wearn & Glover-Kapfer, 2017}}  Behaviour is unaffected by cameras and marking {{Wearn & Glover-Kapfer, 2017}}  Individuals do not lose marks {{Wearn & Glover-Kapfer, 2017}}  Individuals are not misidentified {{Wearn & Glover-Kapfer, 2017}}  Surveys are independent {{Wearn & Glover-Kapfer, 2017}}  For conventional models, geographic closure (i.e., no immigration or emigration) {{Wearn & Glover-Kapfer, 2017}}  Spatially explicit models have further [assumption](#mods_modelling_assumption)s about animal movement {{Wearn & Glover-Kapfer, 2017; Rowcliffe et al., 2008; Royle et al., 2009; O’Brien et al., 2011}}; these include:  {{bullet2}} Home ranges are stable {{Wearn & Glover-Kapfer, 2017}}  {{bullet2}} Movement is unaffected by cameras {{Wearn & Glover-Kapfer, 2017}}  {{bullet2}} [Camera location](#camera_location)s are [randomly placed](#sampledesign_random) with respect to the distribution and orientation of home ranges {{Wearn & Glover-Kapfer, 2017}}  {{bullet2}} Distribution of home range centres follows a defined distribution ([Poisson](#mods_poisson), or other, e.g.,negative binomial) {{Wearn & Glover-Kapfer, 2017}} | Produces direct estimates of [density](#density) or population size for explicit spatial regions {{Chandler & Royle, 2013}}  Allows researchers to mark a subset of the population/to take advantage of natural markings {{Wearn & Glover-Kapfer, 2017}}  Estimates are fully comparable across space, time, species and studies {{Wearn & Glover-Kapfer, 2017}}  [Density](#density) estimates obtained in a single model, fully incorporate spatial information of locations and individuals {{Wearn & Glover-Kapfer, 2017}}  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) {{Wearn & Glover-Kapfer, 2017}}  Flexibility in [study](#survey) design (e.g., "holes" in the trapping grid) {{Wearn & Glover-Kapfer, 2017}}  "Open" [SECR](#mods_scr_secr) {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}} models exist that allow for estimation of recruitment and survival rates {{Wearn & Glover-Kapfer, 2017}}  "Avoid ad-hoc definitions of [study area](#study_area) and edge effects" {{Doran-Myers, 2018}}  [SECR](#mods_scr_secr) {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}} accounts for variation in individual [detection probability](#detection_probability); can produce spatial variation in [density](#density); [SECR](#mods_scr_secr) {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}} more sensitive "to detect moderate-to-major populations changes" (+/-20-80%) {{Morin et al., 2022; Clarke et al., 2023}} | Requires that individuals are identifiable {{Wearn & Glover-Kapfer, 2017}}  Requires that a minimum number of individuals are trapped (each recaptured multiple times ideally) {{Wearn & Glover-Kapfer, 2017}}  Requires that each individual is captured at a number of [camera locations](#camera_location) {{Wearn & Glover-Kapfer, 2017}}  Multiple cameras per station may be required to identify individuals; difficult to implement at large spatial scales as it requires a high density of cameras {{Morin et al., 2022; Clarke et al., 2023}}  May not be precise enough for long-term monitoring {{Green et al., 2020}}  Cameras must be close enough that animals are detected at multiple [camera location](#camera_location)s {{Wearn & Glover-Kapfer, 2017}} (may be challenging to implement at large scales as many cameras are needed)" {{Chandler & Royle, 2013}}  ½ MMDM (Mean Maximum Distance Moved) will usually lead to an underestimation of home range size and thus overestimation of [density](#density) {{Parmenter et al., 2003; Noss et al., 2012; Wearn & Glover-Kapfer, 2017}} |
| [Density](#density); [Marked population](#typeid_marked) | [Spatial mark-resight (SMR)](#mods_smr) (type of SCR model) {{Chandler & Royle, 2013; Sollmann et al., 2013a; Sollmann et al., 2013b}} | Demographic closure (i.e., no births or deaths) {{Chandler & Royle, 2013; Clarke et al., 2023}}  Geographic closure (i.e., no immigration or emigration) {{Chandler & Royle, 2013; Clarke et al., 2023}}  Individuals do not lose marks {{Wearn & Glover-Kapfer, 2017}} (for maximum precision), but [SMR](#mods_smr) {{Chandler & Royle, 2013; Sollmann et al., 2013a; Sollmann et al., 2013b}} does allow for inclusion of [marked](#typeid_marked) but unidentified resighting detections {{Sollmann et al., 2013b; Rich et al., 2014}}  Individuals are not misidentified {{Wearn & Glover-Kapfer, 2017}}  Failure to identify marked individuals is random {{Whittington et al., 2018; Clarke et al., 2023}}  [Marked animals](#typeid_marked) are a random sample of the population with home ranges located inside the state space {{Sollmann et al., 2013a; Rich et al., 2014}}  Detections are [independent](#independent_detections) {{Chandler & Royle, 2013; Clarke et al., 2023}}  Individuals have equal [detection probability](#detection_probability) at a given distance from the centre of their home range {{Wearn & Glover-Kapfer, 2017}}  Detections of different individuals are [independent](#independent_detections) {{Wearn & Glover-Kapfer, 2017}}  Movement is unaffected by cameras {{Wearn & Glover-Kapfer, 2017}}  Behaviour is unaffected by cameras and marking {{Wearn & Glover-Kapfer, 2017}}  [Camera location](#camera_location)s are [randomly placed](#sampledesign_random) relative to the distribution and orientation of home ranges {{Wearn & Glover-Kapfer, 2017}}  [Camera location](#camera_location)s are close enough together that animals are detected at multiple cameras {{Chandler & Royle, 2013; Clarke et al., 2023}}  Surveys are independent {{Wearn & Glover-Kapfer, 2017}}  Home ranges are stable {{Wearn & Glover-Kapfer, 2017}}  Distribution of home range centres follows a defined distribution ([Poisson](#mods_poisson), or other, e.g.,negative binomial) {{Wearn & Glover-Kapfer, 2017}}  Animals’ activity centres are randomly dispersed {{Chandler & Royle, 2013; Clarke et al., 2023}}  Animals’ activity centres are stationary {{Chandler & Royle, 2013; Clarke et al., 2023}}  All animals have stable activity centres within home ranges where detection probability is greatest {{Royle & Nichols, 2003; Sollmann et al., 2013a; Whittington et al., 2018}} | Estimates are fully comparable to [SECR](#mods_scr_secr) {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}} of [marked](#typeid_marked) species {{Wearn & Glover-Kapfer, 2017}}  Can be applied to a broader range of species than [SECR](#mods_scr_secr) {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}} {{Wearn & Glover-Kapfer, 2017}}  Allows researcher to take advantage of natural markings {{Wearn & Glover-Kapfer, 2017}}  Allows researcher to mark a subset of the population (note - precision is dependent on number of [marked](#typeid_marked) individuals in a population) {{Wearn & Glover-Kapfer, 2017}} | Animals may have to be physically captured and [marked](#typeid_marked) if natural marks do not exist on enough individuals {{Wearn & Glover-Kapfer, 2017}}  All individuals must be identifiable {{Wearn & Glover-Kapfer, 2017}}  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 value {{Wearn & Glover-Kapfer, 2017}}  Remains poorly tested with camera data, although it offers promise {{Wearn & Glover-Kapfer, 2017}}  [Density](#density) estimates are likely less precise than with [SECR](#mods_scr_secr) {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}} or [REM](#mods_rem), unless a large proportion of the population have marks {{Wearn & Glover-Kapfer, 2017}}  Requires sampling points to be close enough that individuals encounter multiple cameras {{Wearn & Glover-Kapfer, 2017}} |
| [Density](#density); [Unmarked population](#typeid_unmarked) | [Spatial count (SC)](#mods_sc) / Unmarked spatial capture-recapture (type of SCR model) {{Chandler & Royle, 2013; Royle et al., 2014}} | [Camera location](#camera_location)s are close enough together that animals are detected at multiple cameras {{Chandler & Royle, 2013; Clarke et al., 2023}}  Demographic closure (i.e., no births or deaths) {{Chandler & Royle, 2013; Clarke et al., 2023}}  Geographic closure (i.e., no immigration or emigration) {{Chandler & Royle, 2013; Clarke et al., 2023}}  Detections are [independent](#independent_detections) {{Chandler & Royle, 2013; Clarke et al., 2023}}  Animals’ activity centres are randomly dispersed {{Chandler & Royle, 2013; Clarke et al., 2023}}  Animals’ activity centres are stationary {{Chandler & Royle, 2013; Clarke et al., 2023}} | Does not require individual identification {{Clarke et al., 2023}} | Produces imprecise estimates even under ideal circumstances unless supplemented with auxiliary data (e.g., telemetry) {{Doran-Myers, 2018; Chandler & Royle, 2013; Sollmann et al., 2013a; Sollmann et al., 2013b}}  Precision decreases with an increasing number of individuals detected at a camera" {{Morin et al., 2022}} (as overlap of individuals’ home ranges increases) {{Augustine et al., 2019; Clarke et al., 2023}}  Not appropriate for low [density](#density) or elusive species when recaptures too few to confidently infer the number and location of activity centres" {{Clarke et al., 2023; Burgar et al., 2018}}  Not appropriate for high-[density](#density) populations with evenly spaced activity centres (camera[-specific] counts will be too similar and impair activity centre inference)" {{Clarke et al., 2023}}  Ill-suited to populations that exhibit group-travelling behaviour" {{Sun et al., 2022; Clarke et al., 2023}}  Study design (camera arrangement) can dramatically affect the accuracy and precision of [density](#density) estimates" {{Clarke et al., 2023; Sollmann, 2018}}  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)" {{Chandler & Royle, 2013; Clarke et al., 2023}} |
| [Density](#density) / population size; [Partially Marked population](#typeid_partially_marked) | [Spatial Partial Identity Model (Categorical SPIM; catSPIM)](#mods_catspim) {{Augustine et al., 2019; Sun et al., 2022}}  (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) {{Augustine et al., 2019; Sun et al., 2022; Clarke et al., 2023}}  {{bullet2}} Camera must be close enough together that animals are detected at multiple cameras {{Chandler & Royle, 2013; Clarke et al., 2023}}  {{bullet2}} Demographic closure (i.e., no births or deaths) {{Chandler & Royle, 2013; Clarke et al., 2023}}  {{bullet2}} Geographic closure (i.e., no immigration or emigration) {{Chandler & Royle, 2013; Clarke et al., 2023}}  {{bullet2}} Detections are independent {{Chandler & Royle, 2013; Clarke et al., 2023}}  Activity centres are randomly dispersed {{Chandler & Royle, 2013; Clarke et al., 2023}}  Activity centres are stationary {{Chandler & Royle, 2013; Clarke et al., 2023}}  Each categorical identifier (e.g., male/female, collared/not collared, etc) has fixed number of possibilities {{Sun et al., 2022}}  All possible values of categorical identifiers occur in the population with probabilities that can be estimated {{Augustine et al., 2019; Sun et al., 2022; Clarke et al., 2023}}  Every individual is assigned "full categorical identity" (i.e., "set of traits given all categorical identifiers and possibilities") {{Augustine et al., 2019; Clarke et al., 2023}}  Individuals' identifying traits do not change during the survey (e.g., antlers present/absent) {{Augustine et al., 2019}} | May produce more precise and less biased [density](#density) estimates than [SC](#mods_sc) with less information {{Sun et al., 2022; Clarke et al., 2023}} | Sensitive to non-independent movement (e.g., group-travel; can cause over-dispersion and bias estimates {{Sun et al., 2022; Clarke et al., 2023}}); may limit application to solitary species only {{Sun et al., 2022; Clarke et al., 2023}}  May produce be less reliable/accurate estimates for high-[density](#density) populations {{Sun et al., 2022; Clarke et al., 2023}}  Too few categorical identifiers/ possibilities can result in mis-assignments and overestimating [density](#density) {{Augustine et al., 2019; Parmenter et al., 2003; Clarke et al., 2023}} |
| [Density](#density) / population size; [Partially Marked population](#typeid_partially_marked) | [Spatial Partial Identity Model (2-flank SPIM](#mods_2flankspim)[)](#mods_2flankspim) {{Augustine et al., 2018}} (extension of [SCR](#mods_scr_secr) model augmented with data from partially-identifying images) | Same as [SCR](#mods_scr_secr) {{Augustine et al., 2018; Clarke et al., 2023}}  Capture processes for left-side, right-side and both-side images are independent {{Augustine et al., 2018; Clarke et al., 2023}} | Same as [SCR](#mods_scr_secr) {{Augustine et al., 2018; Clarke et al., 2023}}  Improved precision of [density](#density) estimates relative to [SCR](#mods_scr_secr) {{Augustine et al., 2018; Davis et al., 2021; Clarke et al., 2023}}  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)s {{Augustine et al., 2018; Davis et al., 2021; Clarke et al., 2023}}  Can be used with single-camera and hybrid sampling designs, and therefore requires fewer cameras (or sample more area) than [SCR](#mods_scr_secr) {{Augustine et al., 2018; Clarke et al., 2023}}  May be more robust to non-independence than [SC](#mods_sc) {{Augustine et al., 2018; Clarke et al., 2023}} | Computationally intensive {{Augustine et al., 2018; Clarke et al., 2023}}  Increased precision is less pronounced in high-[density](#density) populations {{Augustine et al., 2018; Clarke et al., 2023}} |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Random encounter models (REM)](#mods_rem) {{Rowcliffe et al., 2008; Rowcliffe et al., 2013}}> | Demographic closure {{Rowcliffe et al., 2008; Doran-Myers, 2018}}(i.e., no births or deaths)  Geographic closure {{Rowcliffe et al., 2008; Doran-Myers, 2018}}(i.e., no immigration or emigration)  [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed relative to animal movement {{Wearn & Glover-Kapfer, 2017; Rowcliffe et al., 2008}}  Animal movement is unaffected by the cameras {{Wearn & Glover-Kapfer, 2017; Rowcliffe et al., 2008}}  Accurate counts of independent "contacts" [camera location](#camera_location)s {{Wearn & Glover-Kapfer, 2017; Rowcliffe et al., 2008}}  Unbiased estimates of animal activity levels and speed {{Rowcliffe et al., 2014; Rowcliffe et al., 2016; Wearn & Glover-Kapfer, 2017}}  Camera’s [detection zone](#detection_zone) can be approximated well using a 2D cone shape, defined by the radius and angle parameters {{Rowcliffe et al., 2011}}  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 activity {{Rowcliffe et al., 2014}}  Animals moving quickly past a camera are not missed {{Rowcliffe et al., 2016}} | Flexible study design (e.g., "holes" in grids allowed, [camera spacing](#camera_spacing) less important) {{Wearn & Glover-Kapfer, 2017}}  Can be applied to [unmarked](#typeid_unmarked) species {{Wearn & Glover-Kapfer, 2017}}  Allows community-wide [density](#density) estimation {{Wearn & Glover-Kapfer, 2017}}  Outputs also include informative parameter estimates (i.e., animal speed and activity levels, and [detection zone](#detection_zone) parameters) {{Wearn & Glover-Kapfer, 2017}}  Comparable estimates to [SECR](#mods_scr_secr)[ {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}}] {{Wearn & Glover-Kapfer, 2017}}  Does not require [marked animals](#typeid_marked) or identification of individuals {{Rowcliffe et al., 2008; Doran-Myers, 2018}}  Can use [camera spacing](#camera_spacing) without regard to population home range size {{Rowcliffe et al., 2008; Doran-Myers, 2018}}  Direct estimation of [density](#density); avoids ad-hoc definitions of [study area](#study_area) {{Rowcliffe et al., 2008}} | Requires relatively stringent study design, particularly (e.g., random sampling and use of [bait](#baitlure_bait) or [lure](#baitlure_lure)) {{Wearn & Glover-Kapfer, 2017}}  Requires independent estimates of animal speed or measurement of animal speed within videos {{Wearn & Glover-Kapfer, 2017}}  No dedicated, simple software {{Wearn & Glover-Kapfer, 2017}}  Random relative to animal movement, grid preferred, avoid multiple captures of same individual, area coverage important for abundance estimation {{Rovero et al., 2013}}  Possible sources of error include inaccurate measurement of [detection zone](#detection_zone) and movement rate {{Rowcliffe et al., 2013; Cusack et al., 2015}} |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Random encounter and staying time (REST)](#mods_rest) {{Nakashima et al., 2018}} | 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)) {{Rowcliffe et al., 2008}}  Detection is perfect {{Wearn & Glover-Kapfer, 2017}} ([detection probability](#detection_probability) "p" = 1) unless otherwise modelled {{Nakashima et al., 2018}}  [Camera location](#camera_location)s are representative of the available habitat {{Nakashima et al., 2018}}  [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed relative to the spatial distribution of animals {{Nakashima et al., 2018}}  Animal movement and behaviour are not affected by cameras {{Nakashima et al., 2018}}  Detections are [independent](#independent_detections) {{Nakashima et al., 2018}}  The observed distribution of staying time in the focal area fits the distribution of movement {{Nakashima et al., 2018}}  The observed staying time must follow a given parametric distribution {{Nakashima et al., 2018}} | Provides unbiased estimates of animal [density](#density), even when animal movement speed varies, and animals travel in pairs {{Nakashima et al., 2018}} | Attraction or aversion to cameras is exhibited in some species {{Meek et al., 2016}} and could affect the time within the [detection zone](#detection_zone) and subsequently affect estimates of [density](#density) {{Doran-Myers, 2018}}  Requires accurate measurements of the area of the camera [detection zone](#detection_zone), which has been a challenge in previous studies {{Rowcliffe et al., 2011; Cusack et al., 2015; Anile & Devillard, 2016; Doran-Myers, 2018; Nakashima et al., 2018}}  Mathematically challenging {{Cusack et al., 2015}} |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Time in front of the camera (TIFC)](#mods_tifc) {{Huggard, 2018; Warbington & Boyce, 2020; Becker et al., 2022}} | [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed or representative relative to animal movement {{Becker et al., 2022}}  Movement is unaffected by the cameras {{Becker et al., 2022}}  Reliable detection of animals in part of the camera’s [FOV](#field_of_view) (at least) {{Becker et al., 2022}} | Does not require individual identification {{Warbington & Boyce, 2020}}  Makes no [assumption](#mods_modelling_assumption) about home range {{Warbington & Boyce, 2020}}  Comparable to estimates from [SECR](#mods_scr_secr) {{Efford, 2004; Borchers & Efford, 2008; Royle & Young, 2008; Royle et al., 2009}} {{Warbington & Boyce, 2020}} | Requires careful calculation of the effective area of detection {{Warbington & Boyce, 2020}}  A high level of measurement error {{Becker et al., 2022}} |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Distance sampling (DS)](#mods_distance_sampling) {{Borchers & Marques, 2017; Howe et al., 2017}} | [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) {{Howe et al., 2017}}  [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed relative to animal movement {{Palencia et al., 2021}}  Detection is perfect ([detection probability](#detection_probability) "p" = 1) at focal area / distance 0 {{Palencia et al., 2021}}  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)) {{Palencia et al., 2021}}  Animal movement and behaviour are unaffected by the cameras {{Palencia et al., 2021}}  Animals are detected at initial locations (e.g., they do not change course in response to the camera prior to detection) {{Palencia et al., 2021}}  Distances are measured exactly (however if the data from different distances will be grouped ("binned") for analysis later, an accuracy of +/- 1m may suffice) {{Palencia et al., 2021}}  Detections are [independent](#independent_detections) {{Palencia et al., 2021}}  Snapshot moments selected independently of animal locations {{Palencia et al., 2021}} | 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 species {{Wearn & Glover-Kapfer, 2017}}  [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)" {{Howe et al., 2017; Clarke et al., 2023}}  Can be applied to low-[density](#density) populations {{Howe et al., 2017; Clarke et al., 2023}}  Does not require individual identification {{Howe et al., 2017}} | May require discarding a portion of the dataset (when the best fitting model truncates the dataset) {{Wearn & Glover-Kapfer, 2017}}  Biased by movement speed {{Palencia et al., 2021}}  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" {{Howe et al., 2017; Clarke et al., 2023}}  Does not permit inference about spatial variation in abundance (unless using hierarchical distance which can model spatial variation as a function of covariates) {{Gilbert et al., 2021; Clarke et al., 2023}}  "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)" {{Clarke et al., 2023}}  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)" {{Howe et al., 2017; Palencia et al., 2021; Clarke et al., 2023}}  Tends to underestimate [density](#density) {{Howe et al., 2017; Twining et al., 2022; Clarke et al., 2023}}  Low population [density](#density) and reactivity to cameras may be major sources of bias" {{Bessone et al., 2020; Clarke et al., 2023}} |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Time-to-event (TTE) model](#mods_tte) {{Moeller et al., 2018}} | Demographic closure (i.e., no births or deaths) {{Moeller et al., 2018; Loonam et al., 2021}}  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) {{Moeller et al., 2018; Loonam et al., 2021}}  Animal movement and behaviour are unaffected by the cameras {{Palencia et al., 2021}}  [Camera location](#camera_location)s placement is [random](#sampledesign_random), [systematic](#sampledesign_systematic), or [systematic random](#sampledesign_systematic_random) {{Moeller et al., 2018}}  Detections are [independent](#independent_detections) {{Moeller et al., 2018}}  Spatial counts of animals (or counts in equal subsets of the landscape) are Poisson-distributed {{Loonam et al., 2021}}  Accurate estimate of movement speed {{Loonam et al., 2021}}  Detection is perfect ([detection probability](#detection_probability) "*\*p\**" = 1) {{Moeller et al., 2018}} | Can be efficient for estimating abundance of common species (with a lot of images) {{Moeller et al., 2018}} | Requires independent estimates of movement rate (difficult to obtain without telemetry data) {{Moeller et al., 2018}}  Assumes that [detection probability](#detection_probability) is 1 (or apply extension to account for [imperfect detection](#imperfect_detection)) {{Moeller et al., 2018}} |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Space-to-event (STE)](C:\\Users\\cassi\\Documents\\GitHub_AB-RCSC\\rc-tool_concept-library\\testing123\\02_dialog-boxes\\mods_ste) models {{Moeller et al., 2018}} | Demographic closure (i.e., no births or deaths) {{Moeller et al., 2018}}  Geographic closure (i.e., no immigration or emigration) {{Moeller et al., 2018}}  [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed {{Moeller et al., 2018}}  Detections are [independent](#independent_detections) {{Moeller et al., 2018}}  Spatial counts of animals in a small area (or counts in equal subsets of the landscape) are Poisson-distributed {{Loonam et al., 2021}}  Detection is perfect ([detection probability](#detection_probability) "*\*p\**" = 1) {{Moeller et al., 2018}} | Can be efficient for estimating abundance of common species (with a lot of images) {{Moeller et al., 2018}}  Does not require estimate of movement rate {{Moeller et al., 2018}} | Assumes that [detection probability](#detection_probability) is 1 {{Moeller et al., 2018}} |
| [Density](#density); [Unmarked](#typeid_unmarked) | [Instantaneous sampling (IS)](#mods_instantaneous_sampling) {{Moeller et al., 2018}} | Demographic closure (i.e., no births or deaths) {{Moeller et al., 2018}}  Geographic closure (i.e., no immigration or emigration) {{Moeller et al., 2018}}  [Camera location](#camera_location)s are [random](#sampledesign_random)ly placed {{Moeller et al., 2018}}  Detections are [independent](#independent_detections) {{Moeller et al., 2018}}  Detection is perfect ([detection probability](#detection_probability) "*\*p\**" = 1) {{Moeller et al., 2018}} | Can be efficient for estimating abundance of common species (with a lot of images) {{Moeller et al., 2018}}  Flexible [assumption](#mods_modelling_assumption) of animals’ distribution {{Moeller et al., 2018}} | Requires accurate counts of animals {{Moeller et al., 2018}}  Assumes that perfect ([detection probability](#detection_probability) "*\*p\**" = 1) {{Moeller et al., 2018}}  Reduced precision {{Moeller et al., 2018}} |
| Behaviour | Behaviour | [Assumption](#mods_modelling_assumption)s vary depending on the behavioural metric {{Wearn & Glover-Kapfer, 2017}}  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 cycle {{Royle et al., 2014; Rovero & Zimmerman, 2016}} | Can detect difficult to observe behaviours (i.e., boldness, or mating) {{Bridges & Noss, 2011}}  Long-term data on behavioural changes that would be difficult to obtain otherwise (i.e., time-limited human observers, or costly GPS collars) {{Bridges & Noss, 2011}}  Can monitor behaviour in response to specific locations (i.e., compost sites, which might be more difficult using GPS collars for example) {{Rovero & Zimmerman, 2016}}  Can evaluate interactions between species {{Rovero & Zimmerman, 2016}} | Behavioural metrics may not reflect the behavioural state (inferred) {{Rovero & Zimmerman, 2016}}  Biases associated with equipment (i.e., presence of the camera itself may change behaviour studied) {{Rovero & Zimmerman, 2016}}  Difficult to consider individual variation {{Rovero & Zimmerman, 2016}} |