# INFO ENTRY - QUESTION INFO

ENTRY NOTES:

* green = does not need to be editted
* yellow = info for the inputter
* ref\_id = “refs\_glossary\_2024-08-09.xls > “references” tab
  + if the reference not present, either add it (if you’re confident that you can follow the format), or add a comment in this doc with the info and I will adjust
* **images – file name in** “refs\_glossary\_2024-08-09.xls > “references” tab
* Ignore everything in the “POPULATE MARKDOWN” section
* Size of columns in tables and text format do not matter; see note on bold and italize below
* Any content with “glue}`` prefix or surrounded by “{{ “ / “ }}” indicates where text will be inserted from the keys
* You may see “<br>” throughout, you can ignore these
* additional formatting notes (optional)
  + \*\***bold**\*\*
  + \*italics\*
* Topic Info
  + If the topic is NOT related to a question, you can leave “question” as NULL
  + “question” here is more for your reference
* Assumptions, Pros, Cons
  + Only for modelling approaches; can ignore otherwise (leave table here)
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* Advanced
  + If the topic doesn’t warrant inclusion, you can leave as NULL
* Figures
  + Placeholders here as “filename” can leave in if not <5 images
* Video
  + no “<” before the URL text and a “>” after URL in this case
  + ref\_id in this example is not correct, just for illustrative purposes
* Analytical tools & resources
  + The ref\_id should be included in the reference column (and the full text reference in the master reference file). If you aren’t sure if the reference is in the master doc, add the full text ref as a comment.
  + Please add a “<” before the URL text and a “>” after (e.g., <http://www.somesitelink.com>)
  + Type can be something similar to: Article, App/Program, R package
* References / Glossary
  + items in-text above (IGNORE FOR NOW)
* Notes
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## Topic Info

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| question | NULL |

## Assumptions, Pros, Cons – if modelling approach

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| Assumptions | Pros | Cons |
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## Overview

This section will be available soon! In the meantime, check out the information in the other tabs!

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## Advanced

:::{note}

\*\*This content was adapted from\*\*: The Density Handbook, "[Using Camera Traps to Estimate Medium and Large Mammal Density: Comparison of Methods and Recommendations for Wildlife Managers](https://www.researchgate.net/publication/368601884\_Using\_Camera\_Traps\_to\_Estimate\_Medium\_and\_Large\_Mammal\_Density\_Comparison\_of\_Methods\_and\_Recommendations\_for\_Wildlife\_Managers)" (Clarke et al.. 2024)

:::

The random encounter model (REM) treats animals like ideal gas particles – that is, like randomly moving entities which are neither attracted to nor repelled by one another or landscape features ({{ ref\_intext\_gilbert\_et\_al\_2021 }}; {{ ref\_intext\_rowcliffe\_et\_al\_2008 }}

). If animals behave like ideal gas particles, the rate at which they “bump into” and trigger camera traps is a function of animal movement, population density and the area within which cameras detect animals ({{ ref\_intext\_nakashima\_et\_al\_2017 }}). So, the more animals move, the more animals in a population, or the larger the viewshed – the more images will be captured ({{ ref\_intext\_palencia\_et\_al\_2022 }}). This relationship can be used to estimate density, such that:

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where \*𝑌\* is the number of detection events, \*𝑇\* is the total sampling time and 𝑣 is animal movement speed (or the distance travelled by an individual in a day); and \*𝑟\* and \*𝜃\*, the mean radius and angle of the detection zone (i.e., the area within which animals are detected with certainty) are used to calculate the area of the detection zone ({{ ref\_intext\_nakashima\_et\_al\_2017 }}; {{ ref\_intext\_pettigrew\_et\_al\_2021 }}; {{ ref\_intext\_rowcliffe\_et\_al\_2008 }}).

Independent estimates of \*𝑣\* can be sourced from telemetric studies, estimated from intensive observation or calculated using camera trap data ({{ ref\_intext\_nakashima\_et\_al\_2017 }}, {{ ref\_intext\_rowcliffe\_et\_al\_2008 }}, {{ ref\_intext\_rowcliffe\_et\_al\_2016 }}). To calculate 𝑣 using camera traps: for each observation, practitioners should determine how long it took the animal to pass through the viewshed (i.e., time between first and last image in a sequence), then measure the distance the animal travelled by either a) retracing their path in the field using photos as a guide or b) estimating their movement image-to-image during photo processing using markers ({{ ref\_intext\_pfeffer\_et\_al\_2018 }}, {{ ref\_intext\_rowcliffe\_et\_al\_2016 }}).

\*𝑟\* and \*𝜃\* can be measured in a few different ways. The first is by field trial: the detection zone is delineated by approaching the camera trap from different angles and at different speeds, recording where the sensor is triggered (Figure 7; {{ ref\_intext\_rowcliffe\_et\_al\_2008 }}). The second is using a distance sampling method described in Rowcliffe et al. (2011). The third is by setting a focal area of standard size and shape (i.e., of known 𝑟 and 𝜃), within which detection is assumed to be perfect; only animals captured within the focal area are considered for analyses ({{ ref\_intext\_nakashima\_et\_al\_2017 }}). \*𝜃\* may also be specified by the manufacturer ({{ ref\_intext\_pettigrew\_et\_al\_2021 }}).

When the species of interest travels in packs or herds, density as calculated per the equation above represents group density (i.e., the number of groups per unit area; {{ ref\_intext\_rowcliffe\_et\_al\_2008 }}). To convert group density to individual density, \*𝐷\* must be multiplied by an independent estimate of average group size ({{ ref\_intext\_rowcliffe\_et\_al\_2008 }}).

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\*\*Clarke et al. (2023) - Fig. 7\*\* Measuring \*𝑟\* and \*𝜃\* by field trial. The perimeter of the detection zone is determined by approaching the camera from different angles and at different speeds, and noting where the camera’s sensor (red flash) detects motion (red dots).

## Simulations and Field Experiments

Of all the unmarked density models, the REM has undergone the most empirical testing ({{ ref\_intext\_palencia\_et\_al\_2021 }}). Rowcliffe et al. (2008) piloted the model in an enclosed animal park housing populations of known sizes, and found that the REM produced accurate density estimates for three out of four target species (two cervids and a marsupial). The model underestimated the density of the fourth species (a large rodent) because cameras were deployed in habitats it did not frequent – a violation of assumption 3 ({{ ref\_intext\_rowcliffe\_et\_al\_2008 }}).

The REM has proven robust in many study systems. Examples include:

- Palencia et al. (2021) found that the REM yielded similar density estimates as two non-camera methods, line-transect sampling and drive counts, for red deer and wild boar, respectively. The researchers also compared the REM to two other camera methods (random encounter and staying time (REST) and distance sampling (DS) models) – of the three, the REM was the most consistent ({{ ref\_intext\_palencia\_et\_al\_2021 }}). In this study, animal movement speed \*𝑣\* was determined using camera trap data.

- REM-derived density estimates of a mountain ungulate were highly consistent with visual count survey results ({{ ref\_intext\_kavcic\_et\_al\_2021 }}). Animal movement speed was measured using camera trap data ({{ ref\_intext\_kavcic\_et\_al\_2021 }}).

- A study on black bears in Québec found that the REM produced comparable results to DNA mark-recapture using hair samples, but that REM estimates were less precise ({{ ref\_intext\_pettigrew\_et\_al\_2021 }}). The researchers estimated animal movement speed by averaging 19 years of telemetry data from four neighbouring black bear populations ({{ ref\_intext\_pettigrew\_et\_al\_2021 }}).

- In the boreal forest of Washington state, REM and live-trapping spatial capturerecapture (SCR) produced similar density estimates for snowshoe hare ({{ ref\_intext\_jensen\_et\_al\_2022 }}). The REM and the REST performed identically in this system; both models outperformed the time-to-event (TTE) model ({{ ref\_intext\_jensen\_et\_al\_2022 }}). Measures of animal movement speed \*𝑣\* were pulled from camera data and combined with telemetry data from a study in the Yukon.

- The REM yielded similar density estimates as, and was more precise than, livetrapping SCR at almost 90% of sampling sites in a study of hedgehogs ({{ ref\_intext\_schaus\_et\_al\_2020 }}). Moreover, the REM was powerful enough to detect a 25% population change in this system ({{ ref\_intext\_schaus\_et\_al\_2020 }}). Animal movement speed was estimated from camera trap images.

The REM has also significantly over and underestimated the densities of natural populations. In Africa, for example, estimates of lioness density using the REM were significantly higher than from pride censuses ({{ ref\_intext\_cusack\_et\_al\_2015 }}). REM-derived densities skewed high because cameras were placed under shady trees, which attracted lions in the daytime (a violation of assumption 3), inflating the number of detection events \*𝑌\* ({{ ref\_intext\_cusack\_et\_al\_2015 }}). When only nighttime detections were considered, however, REM-derived densities did not differ significantly from censusderived densities ({{ ref\_intext\_cusack\_et\_al\_2015 }}). \*𝑣\*, animal movement speed, was determined via intensive observation. A study comparing the REM with fecal DNA mark-recapture found that the REM underestimated marten density by 60% or more ({{ ref\_intext\_balestrieri\_et\_al\_2016 }}). Animal movement speed 𝑣 may have biased density low; the researchers estimated 𝑣 from studies of pine marten occupying a different kind of habitat, where individuals may have moved more ({{ ref\_intext\_balestrieri\_et\_al\_2016 }}).

Simulations suggest that, to achieve adequate precision using the REM, a minimum of 20 to 40 camera stations should be deployed for as long as needed to collect at least 10 to 20 image sets ({{ ref\_intext\_rowcliffe\_et\_al\_2008 }}). For populations with variable detection: about 100 cameras are needed to obtain a level of precision appropriate for wildlife management (coefficient of variation (CV) of 0.20 or less; {{ ref\_intext\_palencia\_et\_al\_2021 }}, {{ ref\_intext\_williams\_et\_al\_2002 }}). To collect 10 to 20 image sets takes approximately 100 to 1,000 camera trap days for most mammal species; for rare species, cameras may need to be deployed for 1,000 camera trap days or more ({{ ref\_intext\_rowcliffe\_et\_al\_2008 }}).

## Figures

|  |  |  |  |
| --- | --- | --- | --- |
| Image | file\_name | Caption (if applicable) | ref\_id |
| A math equation with black text  Description automatically generated | clarke\_et\_al\_2023\_eqn\_rem1.png |  | clarke\_et\_al\_2023 |
| A diagram of a cone with a person walking  Description automatically generated | clarke\_et\_al\_2023\_fig7\_clipped.png | \*\*Clarke et al. (2023) - Fig. 7\*\* Measuring \*𝑟\* and \*𝜃\* by field trial. The perimeter of the detection zone is determined by approaching the camera from different angles and at different speeds, and noting where the camera’s sensor (red flash) detects motion (red dots). | clarke\_et\_al\_2023 |
|  | henrich\_et\_al\_2022\_fig1\_clipped.png | \*\*Henrich et al. (2022) - Fig. 1\*\* Potential problems caused by animal behavior in the estimation of population densities of unmarked animal species using camera traps and our proposed solutions. | henrich\_et\_al\_2022 |
|  | rowcliffe\_et\_al\_2008\_fig1\_clipped.png | \*\*Rowcliffe et al. (2008) - Fig. 1\*\* Diagram illustrating the variation in profile presented to animals approaching from different angles by a segment-shaped camera trap detection zone.  :::{dropdown}  Approach directions are indicated by arrows, the detection zone is the shaded segment, defined by radial distance r and angle θ, and the profiles presented are indicated by heavy lines. Six limiting cases are shown for π approach angles, with five resulting transitions. The angles opposite the profiles, γ, are indicated for transitions 1, 2, 4 and 5 (the profile for transition 3 is constant so no such angle is required). The widths of profiles and ranges of γ for each transition are given by: transitions 1 and 5, 2r sin(θ/2) sin(γ), (π – θ)/ 2 ≤ γ ≤ π/2; transitions 2 and 4, r sin(γ), θ ≤ γ ≤ π/2; transition 3, r for θ approach angles.  ::: | rowcliffe\_et\_al\_2008 |
|  | rowcliffe\_et\_al\_2008\_fig4\_clipped.png | \*\*Rowcliffe et al. (2008) - Fig. 4\*\* The precision of estimated density from simulated data in relation to variation in sampling effort, assuming high or low variance in camera trapping rate (upper and lower curves, respectively, in each graph).  :::{dropdown}  Effort is varied as either (a) the number of cameras while holding time per camera constant; (b) the time per camera (indexed by the total number of photographs taken) while holding the number of cameras constant; and (c) the number of camera placements while holding the total amount of camera time constant.  ::: | rowcliffe\_et\_al\_2008 |
|  | rowcliffe\_et\_al\_2008\_fig5\_clipped.png | \*\*Rowcliffe et al. (2008) - Fig. 5\*\* Expected trapping effort (camera days, indicated by contours) required to achieve 10 photographs given varying density and day range, assuming a group size of 1.  :::{dropdown}  Typical combinations of day range and density are indicated for carnivores (C), ungulates (U) and rodents (R), calculated using allometric equations for day range and density at carrying capacity (see text) and illustrating densities between 10% and 100% of carrying capacity.  ::: | rowcliffe\_et\_al\_2008 |
|  | figure7\_filename.png | figure7\_caption | figure7\_ref\_id |
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## Video

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| Camera Trap Methods for Density Estimation | https://www.youtube.com/embed/NUW4oLGeQwk?si=isAJ3uO31eANSkDv | palencia\_enetwild\_2022 |
| vid2\_caption | vid2\_url | vid2\_ref\_id |
| vid3\_caption | vid3\_url | vid3\_ref\_id |
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| vid6\_caption | vid6\_url | vid6\_ref\_id |

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## Analytical tools & resources

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## References / Glossary

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## Notes

* Palencia\_et\_al\_2023 - Accordingly, to obtain a CV lower than 0.20, required for effective wildlife management Palencia (Williams\_et\_al\_2002), the effort with REM will be around 100 camera traps.
* Accordingly, to obtain a CV lower than 0.20, required for effective wildlife management (Williams\_et\_al\_2002), the effort with REM will be around 100 camera traps. Regarding CT-DS, Bessone\_et\_al\_(2020) obtained an average CV of 0.37 in spite of sampling 750 locations.
* In this respect, Capelle\_et\_al\_(2021) concluded that a wide variety of survey designs can be applied to achieve CV between 0.10 and 0.20 with CT-DS, for instance, with at least 100 sampling days at as few 50 camera trap placements.

# Markdown

## File from = 00\_00\_template-master\_2024-09-29.docx

**POPULATE MARKDOWN \_2024-09-28** - MODS

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(i\_mod\_occupancy)=

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:::::{admonition}

\*\*{{ term\_mod\_occupancy }}\*\*: {{ term\_def\_mod\_occupancy }}

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::::::{dropdown} Assumptions, Pros, Cons

:::::{grid}

::::{grid-item-card} Assumptions

- {{ mod\_occupancy\_assump\_01 }}

- {{ mod\_occupancy\_assump\_02 }}

- {{ mod\_occupancy\_assump\_03 }}

- {{ mod\_occupancy\_assump\_04 }}

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::::{grid-item-card} Pros

- {{ mod\_occupancy\_pro\_01 }}

- {{ mod\_occupancy\_pro\_02 }}

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::::{grid-item-card} Cons

- {{ mod\_occupancy\_con\_01 }}

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::::::{tab-item} Overview

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::::::{tab-item} In-depth

:::{note}

\*\*This content was adapted from\*\*: The Density Handbook, "[Using Camera Traps to Estimate Medium and Large Mammal Density: Comparison of Methods and Recommendations for Wildlife Managers](https://www.researchgate.net/publication/368601884\_Using\_Camera\_Traps\_to\_Estimate\_Medium\_and\_Large\_Mammal\_Density\_Comparison\_of\_Methods\_and\_Recommendations\_for\_Wildlife\_Managers)" (Clarke et al.. 2024)

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Occupancy models describe spatial patterns of animal occurrence ({{ ref\_intext\_sollmann\_2018 }}) and have been proposed as a proxy for abundance ({{ ref\_intext\_noon\_et\_al\_2012 }}). They ask: what proportion of a study area is inhabited by a population – that is, at how many camera sites do one or more individuals of a species occur ({{ ref\_intext\_mackenzie\_et\_al\_2017 }})? The basic equation for occupancy is:

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where \*𝜓\* is the probability a site is occupied, \*𝑥̂\* is the estimated number of occupied sites (i.e., the count of sites where animals were detected, corrected for detection probability) and 𝑠 is the total number of sites surveyed ({{ ref\_intext\_mackenzie\_et\_al\_2017 }}). Unlike simple measures of presence-absence, occupancy models account for imperfect detection ({{ ref\_intext\_sollmann\_2018 }}). They attempt to differentiate between absence – animals truly not present – and nondetection – animals present but not detected – by repeatedly sampling sites over time. The central assumption of basic occupancy models is that repeated samples occur during a period in which the site is closed to changes in occupancy (i.e., occupancy status – present or absent – does not change during the sampling period). Thus if a species is detected during one of three sampling occasions, it is assumed that it was present during all three occasions but undetected during two.

In theory, occupancy and abundance share a predictable relationship. As population size increases, the number of sites occupied by members of that population should also increase (until all sites are occupied); likewise, a decrease in population size should lead to a decrease in the number of sites used ({{ ref\_intext\_gaston\_et\_al\_2000 }}; {{ ref\_intext\_royle\_dorazio\_2008 }}). This is called an occupancy-abundance relationship, and – because of it – occupancy can be used as an index of abundance.

Advantages of occupancy as an index of abundance include:

- Occupancy studies may be easier to implement than some abundance or density estimators ({{ ref\_intext\_noon\_et\_al\_2012 }}; {{ ref\_intext\_sollmann\_2018 }}).

- Occupancy-abundance relationships appear to be robust to territoriality, group travelling behaviour and other biological traits (

{{ ref\_intext\_steenweg\_et\_al\_2018 }}).

- Occupancy can be modelled as a function of site- and sampling-specific covariates to better understand which factors predict animal occurrence ({{ ref\_intext\_sollmann\_2018 }}).

However, many researchers have cautioned against the use occupancy as an index. As with relative abundance (RA; see above), there is no consistent, long-term relationship between occupancy and abundance ({{ ref\_intext\_efford\_dawson\_2012 }}). Occupancy can change with abundance, but also with survey duration, species home range size, animal movement, etc., muddling occupancy-abundance relationships and thus inferences about population size ({{ ref\_intext\_neilson\_et\_al\_2018 }}; {{ ref\_intext\_steenweg\_et\_al\_2018 }}). While occupancy is a powerful stand-alone metric, Sollmann (2018) says it should not be “misinterpreted” as an index of abundance.

Despite its widespread use, occupancy may be particularly problematic for camera trap studies due to the violation of the closure assumption. Burton et al. (2015) highlighted that many camera trap studies using occupancy do not explicitly define the “site,” although is often implicitly given as some larger area around a camera trap. Since camera trap studies typically target mammal species with relatively large home ranges, the site closure assumption is almost certainly violated in most cases. Many camera trappers therefore assume that “occupancy” is in fact “use” of a site (i.e., the site is not closed), and that detection probability also includes availability for detection. Mackenzie et al. (2017) suggested that estimates should be unbiased if movements in and out of a site are random, but this assumption is rarely tested. And where occupancy estimates have been tested using realistic mammal movements, they have generally performed poorly ({{ ref\_intext\_neilson\_et\_al\_2018 }}; {{ ref\_intext\_stewart\_et\_al\_2018 }}).

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::::::{tab-item} Visual resources

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\*\*Murray et al. (2021) - Fig. 1\*\* Schematic of our multi- state occupancy model to estimate the occurrence of coyotes and mange.

:::{dropdown}

We used images of coyotes collected along transects following an urban gradient in the Chicago metro area in a standard single-species multi-season model with a stacked design. Following the coyote occupancy model, our mange model estimates the distribution of coyote with sarcoptic mange conditional on the distribution of coyote, mangy or otherwise, using by-image variation in the presence of mange signs and the quality of the image.

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\*\*Southwell et al. (2019) - Fig. 1.\*\* Structure of the spatially explicit power analysis framework for multiple species in dynamic landscapes.

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\*\*Chatterjee et al. (2021) - Table 2.\*\* Broad classifications of mammals based on occupancy and detection probabilities.

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figure11\_caption

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figure12\_caption

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::::{grid-item-card} {{ ref\_intext\_cove\_2020a }}

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Occupancy Modeling Video 1 -- Sampling Techniques for Mammals

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::::{grid-item-card} {{ ref\_intext\_cove\_2020b }}

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Occupancy Modeling Video 2 -- Introductory Statistical Review

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::::{grid-item-card} {{ ref\_intext\_cove\_2020c }}

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Occupancy Modeling Video 3 -- What are Occupancy Models and What are the Applications?

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Occupancy Modeling Video 4 -- How to Run and Interpret the Models in PRESENCE

::::

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</div>

</div>

Occupancy modelling - more than species presence/absence! (Darryl MacKenzie)

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::::{grid-item-card} {{ ref\_intext\_proteus\_2019a }}

<div>

<div style="position:relative;padding-top:56.25%;">

<iframe src="https://www.youtube.com/embed/zKQFY8W4ceU?si=ibziVu2KyWro5IUx" frameborder="0" allowfullscreen

style="position:absolute;top:0;left:0;width:100%;height:100%;"></iframe>

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Occupancy modelling - the difference between probability and proportion of units occupied

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::::::{tab-item} Shiny apps/Widgets

Check back in the future!

<!--::::{dropdown}-->

:::::{card} shiny\_name

shiny\_caption

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frameborder="0"

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allowfullscreen>

</iframe>

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:::::

::::{dropdown} Bias in single-season occupancy models

Compute the relative bias (in %) in the maximum-likelihood estimator of the occupancy probability ψ in a single-season (aka static) occupancy model with constant parameters fitted with the package 'unmarked'.

{{ ref\_bib\_gimenez\_2020a }}

<iframe https://ecologicalstatistics.shinyapps.io/bias\_occupancy/

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allowfullscreen>

</iframe>

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::::::{tab-item} Analytical tools & resources

| Type | Name | Note | URL |Reference |

|:----------------|:-------------------------------|:----------------------------------------------------------------|:----------------------|:----------------------------------------|

| rJAGS/R code | mfidino/multi-state-occupancy-models | | <https://github.com/mfidino/multi-state-occupancy-models> | {{ ref\_bib\_fidino\_2021a }} |

| JAGS/R code | A gentle **introduction to an integrated occupancy model that combines presence-only and detection/non-detection data, and how to fit it in**JAGS**; <br>**integrated-occupancy-model” | | <https://masonfidino.com/bayesian\_integrated\_model/>;<br><https://github.com/mfidino/integrated-occupancy-model> | {{ ref\_bib\_fidino\_2021b }}; {{ ref\_bib\_fidino\_2021c }} |

| JAGS code/Tutorial | So, **you don't have enough data to fit a dynamic occupancy model? An introduction to auto-logistic occupancy models; <br>**auto-logistic-occupancy |

| <https://masonfidino.com/autologistic\_occupancy\_model/>;<br><https://github.com/mfidino/auto-logistic-occupancy> | {{ ref\_bib\_fidino\_2021d }}; {{ ref\_bib\_fidino\_2021e }} |

| R package | Package “autoOcc” | An R package for fitting autologistic occupancy models | <https://github.com/mfidino/autoOcc> | {{ ref\_bib\_fidino\_2023 }} |

| R code | mfidino/periodicity | Using Fourier series to predict periodic patterns in dynamic occupancy models | <https://github.com/mfidino/periodicity> | {{ ref\_bib\_fidino\_magle\_2017 }} |

| resource13\_type | Bias in **occupancy estimate for a static model** |

| < > | {{ ref\_bib\_resource6\_ref\_id }} |

| R code/Tutorial | “An Introduction to Camera Trap Data Management and Analysis in R > Chapter 11 Occupancy” | | <https://bookdown.org/c\_w\_beirne/wildCo-Data-Analysis/occupancy.html> | {{ ref\_bib\_wildco\_lab\_2021c }} |

| Program | Program “PRESENCE” | "Relatively simple, but comprehensive, software dedicated to occupancy estimation. Linux version available. Can also be used for occupancy-based species richness estimation." (Wearn & Glover-Kapfer, 2017) | \*\*Software\*\*: <www.mbr-pwrc.usgs.gov/ software/presence.html>;<br>\*\*Help forum\*\*: <www.phidot.org>| {{ ref\_bib\_hines\_2006}} |

| R package | Package “RPresence” | “The R counterpart to Presence. Cross-platform (Windows, Mac and Linux)." (Wearn & Glover-Kapfer, 2017) | <https://www.mbr-pwrc.usgs.gov/software/presence.shtml> | {{ ref\_bib\_hines\_2006 }} |

| R package | R package "unmarked” | "Implements a wide variety of occupancy and count-based abundance models (the latter are mostly not appropriate for camera-trapping). Actively being developed and supported by a community of users. Cross-platform (Windows, Mac and Linux)." (Wearn & Glover-Kapfer, 2017) | <https://cran.r-project.org/web/packages/unmarked/index.html>;<br><https://groups.google.com/d/forum/unmarked,>;<br>https://hmecology.github.io/unmarked> | {{ ref\_bib\_kellner\_et\_al\_2023 }}; {{ ref\_bib\_fiske\_chandler\_2011 }} |

| R code/Tutorial | Multi-season Occupancy Models | | <https://darinjmcneil.weebly.com/multi-season-occupancy.html> | {{ ref\_bib\_mcneil\_nd }} |

| R package | Package “detect” | R package for analyzing wildlife data with detection error | <https://github.com/psolymos/detect> | {{ ref\_bib\_solymos\_2023 }} |

| Spreadsheet | OccPower.xlsx | Spreadsheet to compute power to detect difference in 2 independent occupancy estimates using asymptotic approximations described in Guillera-Arroita et. al. (2012). | [Download the XLS](../09\_downloads/OccPower.xlsx) | {{ ref\_bib\_guillera\_arroita\_et\_al\_2012 }} |

| Tutorial | occupancyTuts: Occupancy modelling tutorials with RPresence | Occupancy modelling tutorials with RPresence | <https://doi.org/10.1111/2041-210X.14285> | {{ ref\_bib\_donovan\_et\_al\_2024 }} |

| R code/Tutorial | Implicit dynamics occupancy models in R | Implicit dynamics occupancy models with the R package RPresence. These models estimate occupancy probability when it changes through time without estimating colonization and extinction parameters.<br>

The code and sample data from this tutorial are available on GitHub; < https://github.com/jamesepaterson/occupancyworkshop>. | <https://jamesepaterson.github.io/jamespatersonblog/2024-06-02\_implicitdynamicsoccupancy.html> | {{ ref\_bib\_paterson\_2024 }} |

| resource16\_type | Using the mgcvmgcv package **to create a generalized additive occupancy model in**R | resource16\_note | <https:**//masonfidino.com/generalized\_additive\_occupancy\_model>** | {{ ref\_bib\_resource16\_ref\_id }} |

| resource17\_type | Bias in single-season occupancy models | "Compute the relative bias (in %) in the maximum-likelihood estimator of the occupancy probability ψ in a single-season (aka static) occupancy model with constant parameters fitted with the package 'unmarked'." | \*\*Repo\*\*: <https://github.com/oliviergimenez/bias\_occupancy\_flexdashboard><br>\*\*App\*\*: <https://ecologicalstatistics.shinyapps.io/bias\_occupancy> | {{ ref\_bib\_gimenez\_2020a }} |

| R code | Bias in occupancy estimate for a static model | "R code to calculate bias in occupancy estimate as a function of the detection probability given various levels of occupancy probability, various number of sites and surveys." | <https://github.com/oliviergimenez/bias\_occupancy>| {{ ref\_bib\_gimenez\_2020b}} |

| resource19\_type | resource19\_name | resource19\_note | resource19\_url | {{ ref\_bib\_resource19\_ref\_id }} |

| resource20\_type | resource20\_name | resource20\_note | resource20\_url | {{ ref\_bib\_resource20\_ref\_id }} |

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{{ ref\_bib\_burton\_et\_al\_2015 }}

{{ ref\_bib\_cove\_2020a }}

{{ ref\_bib\_cove\_2020b }}

{{ ref\_bib\_cove\_2020c }}

{{ ref\_bib\_cove\_2020d }}

{{ ref\_bib\_donovan\_et\_al\_2024 }}

{{ ref\_bib\_efford\_dawson\_2012 }}

{{ ref\_bib\_fidino\_2021d }}

{{ ref\_bib\_fidino\_2021a }}

{{ ref\_bib\_fidino\_2021b }}

{{ ref\_bib\_fidino\_2021c }}

{{ ref\_bib\_fidino\_2021e }}

{{ ref\_bib\_fidino\_2023 }}

{{ ref\_bib\_fidino\_magle\_2017 }}

{{ ref\_bib\_fiske\_chandler\_2011 }}

{{ ref\_bib\_gaston\_et\_al\_2000 }}

{{ ref\_bib\_gimenez\_2020a }}

{{ ref\_bib\_gimenez\_2020b }}

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{{ ref\_bib\_hines\_2006 }}

{{ ref\_bib\_kellner\_et\_al\_2023 }}

{{ ref\_bib\_mackenzie\_et\_al\_2017 }}

{{ ref\_bib\_mcneil\_nd }}

{{ ref\_bib\_murray\_et\_al\_2021 }}

{{ ref\_bib\_neilson\_et\_al\_2018 }}

{{ ref\_bib\_noon\_et\_al\_2012 }}

{{ ref\_bib\_paterson\_2024 }}

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{{ ref\_bib\_proteus\_2019a }}

{{ ref\_bib\_proteus\_2019b }}

{{ ref\_bib\_royle\_dorazio\_2008 }}

{{ ref\_bib\_sollmann\_2018 }}

{{ ref\_bib\_solymos\_2023 }}

{{ ref\_bib\_southwell\_et\_al\_2019 }}

{{ ref\_bib\_steenweg\_et\_al\_2018 }}

{{ ref\_bib\_stewart\_et\_al\_2018 }}

{{ ref\_bib\_weecology\_2020 }}

{{ ref\_bib\_wildco\_lab\_2021c }}

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