# 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)
  + [WILL BE HERE, BUT INSERTED DIRECTLY FROM CSV FILE (THUS NO INPUT NEEDED)]
* 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
  + (future ref / not included in markdown conversion)

## Topic Info

|  |  |
| --- | --- |
| info\_id | mod\_rest |
| question | NULL  *2.2.2* *Distance Sampling*--> {bdg-link-primary-line}`Distance sampling<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_20\_mod\_ds.html>`  *2.2.6 Time-toEvent Model*--> {bdg-link-primary-line}`Time-to-event<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_20\_mod\_tte.html>` |

## Assumptions, Pros, Cons

|  |  |  |
| --- | --- | --- |
| Assumptions | Pros | Cons |
| - {{ mod\_rest\_assump\_01 }}  - {{ mod\_rest\_assump\_02 }}  - {{ mod\_rest\_assump\_03 }}  - {{ mod\_rest\_assump\_04 }}  - {{ mod\_rest\_assump\_05 }}  - {{ mod\_rest\_assump\_06 }}  - {{ mod\_rest\_assump\_07 }}  - {{ mod\_rest\_assump\_08 }} | - {{ mod\_rest\_pro\_01 }} | - {{ mod\_rest\_con\_01 }}  - {{ mod\_rest\_con\_02 }}  - {{ mod\_rest\_con\_03 }} |

## Overview

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

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“The REST model describes the relationship among population density, mean number of detections by a camera trap during a survey period, and staying time of individual animals in a predetermined detection zone in which individuals are certain to be detected by the camera trap.” ({{ ref\_intext\_nakashima\_et\_al\_2017 }}).

## 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 and staying time (REST) model is an extension of the random encounter model (REM; ({{ ref\_intext\_gilbert\_et\_al\_2020 }}). Like the REM, the REST treats animals like ideal gas particles (i.e., like randomly and independently moving entities); unlike the REM, the REST does not require measures of animal movement speed. Instead, the model uses the time animals spend in the camera viewshed (i.e., their “staying time”) as a proxy for animal movement speed, since the two measures are inversely proportional ({{ ref\_intext\_nakashima\_et\_al\_2017 }}).

The REST equation is a modified version of the REM equation which substitutes staying time for movement speed, and a detection area of set size for detection zone radius and angle, such that:

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where \*𝑌\*is the number of detections, \*𝑇\* is the staying time, \*𝑠\* is the area within which all individuals are certain to be detected (hereafter, focal area), and \*𝐻\* is the total research period (i.e., the total sampling time; {{ ref\_intext\_nakashima\_et\_al\_2017 }}). This equation produces an estimate of density \*𝐷\* at a single camera; to determine population density for the study area, density estimates must be averaged across camera stations.

To implement the REST model, practitioners must first establish the focal area \*𝑠\*. Methods at practitioners’ disposal include testing focal areas of different sizes under controlled conditions (e.g., using domestic animals) and determining detection probabilities ({{ ref\_intext\_nakashima\_et\_al\_2017 }}; {{ ref\_intext\_rowcliffe\_et\_al\_2014 }}), or using distance sampling (DS) functions to delineate the zone of certain detection (as described in Hofmeester et al. [2017] and implemented in Palencia et al. [2021]). Although it can be any shape, a triangular focal area maximizes the number of usable detections (fewer captures fall outside of the focal area; {{ ref\_intext\_nakashima\_et\_al\_2017 }}).

Once established, the focal area is staked out in front of every camera in the field (e.g., using ropes and pegs), a reference image is taken, and any staking equipment is removed before the camera is left to collect images or videos ({{ ref\_intext\_nakashima\_et\_al\_2017 }}; {{ ref\_intext\_palencia\_et\_al\_2021 }}; {{ ref\_intext\_nakajima\_2021a }}). During image processing, captures of animals are overlaid on reference images (Figure 8A; {{ ref\_intext\_nakajima\_2021a }}). Alternatively, the focal area can be superimposed on captures of animals as in Figure 8B. Markers (e.g., stones) placed at known distances from the camera are used as a guide for placing the focal area ({{ ref\_intext\_palencia\_et\_al\_2021 }}). Staying time \*𝑇\* is the time an animal spends in the focal area; it is measured from the moment an animal’s hind leg enters the focal area until it exits (i.e.,\* 𝑇<sub>𝑒𝑥𝑖𝑡</sub> − 𝑇<sub>𝑒𝑛𝑡𝑒𝑟</sub>\*).

Importantly, estimates of density \*𝐷\* must be corrected for activity level – that is, the proportion of time animals are active – such that:

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where \*𝐷̂\* is the corrected density estimate and \*𝑎\* is the activity level ({{ ref\_intext\_palencia\_et\_al\_2021 }}, ({{ ref\_intext\_rowcliffe\_et\_al\_2014 }}). Activity level is determined as per Rowcliffe et al. (2014).

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\*\*Clarke et al. 2023 - Fig. 8.\*\* A) Still from 中島啓裕’s (2021a) video series. Example of overlaying a video recording of an animal on a Reference image of the focal area (faint triangle) to determine staying time \*𝑇\*. B) Still from Appendix S2 from Palencia et al. (2021). Example of superimposing the focal area on an image capture.

## Simulations and Field Experiments

Nakashima et al. (2017) ran random walk simulations to test the REST’s performance. In its simplest form, a random walk models the series of steps an animal (the “walker”) takes – each in a completely arbitrary direction, or in a pattern informed by behaviour, ecology and environment ({{ ref\_intext\_codling\_et\_al\_2008 }}). Nakashima et al.’s (2017) simulations showed that the REST model was robust to grouping behaviour and variation in animal movement speed. More specifically, the REST produced accurate estimates of density when animals travelled in pairs, and when animals covered different distances during the sampling period ({{ ref\_intext\_nakashima\_et\_al\_2017 }}). The model produced biased results, however, when captures of animals resting in the focal area were included in staying times ({{ ref\_intext\_nakashima\_et\_al\_2017 }}). To minimize bias: 1) any detections with exceedingly long staying times (i.e., right outliers) should be discarded; and 2) density estimates should be corrected for activity level \*𝑎\* using the method outlined in Rowcliffe et al. (2014; {{ ref\_intext\_nakashima\_et\_al\_2017 }}).

Garland et al. (2020) ran a “real life” simulation of the REST using human volunteers. The researchers found that the model produced accurate density estimates, even when home range size, population size and movement patterns varied – but that scenarios in which people moved at a constant rate yielded more precise estimates than those in which people rested periodically ({{ ref\_intext\_garland\_et\_al\_2020 }}). Larger populations were also associated with lower-precision estimates (i.e., the bigger the population, the less precise the density estimate) – as population size increases, so too does the variation in staying times, reducing the overall precision of REST estimates ({{ ref\_intext\_garland\_et\_al\_2020 }}). Note than humans were fully agnostic to detectors – an assumption often violated by animals ({{ ref\_intext\_caravaggi\_et\_al\_2020 }}).

Both Garland et al. (2020) and Nakashima et al. (2018) tested the effect of sampling effort on the REST; both concluded that the model can yield accurate results, even when effort is relatively small (1% of study area sampled or 10 cameras deployed for 10 days, respectively). Note, however, that these results pertain to very high-density populations – animal density was 125 to 750 individuals per km<sup>2</sup> in Garland et al. (2020) and 10 individuals per km<sup>2</sup> in Nakashima et al. (2018) – and likely do not apply to average-to-low density populations. Low sampling effort was also linked to imprecision – the fewer cameras deployed, the less precise the density estimate ({{ ref\_intext\_garland\_et\_al\_2020 }}; {{ ref\_intext\_nakashima\_et\_al\_2017 }}). Thus, although little sampling effort is needed to produce accurate density estimates for very dense populations, considerable sampling effort will be necessary for most populations, and to produce precise estimates.

### In the field

- The REST was initially validated by Nakashima et al. (2018), who compared density estimates of forest-dwelling antelopes from the camera data-based model and line-transect surveys (see {bdg-link-primary-line}`Distance sampling<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_20\_mod\_ds.html>`). In this system, both methods produced similar estimates of antelope density, with similar precision ({{ ref\_intext\_nakashima\_et\_al\_2017 }}). A follow-up study in the same area further demonstrated that the model can produce unbiased estimates of density ({{ ref\_intext\_nakashima\_et\_al\_2020 }}).

- The model produced estimates of snowshoe hare density comparable to livetrapping SCR in the boreal forest of the northwestern United States ({{ ref\_intext\_jensen\_et\_al\_2022 }}). REST- and REM-based estimates were also consistent with each other, and both models outperformed the time-to-event model (TTE; see {bdg-link-primary-line}`Time-to-event<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_20\_mod\_tte.html>`; {{ ref\_intext\_jensen\_et\_al\_2022 }}).

- Palencia et al. (2021) found that REST-derived density estimates were consistent with line-transect surveys of deer, but not with drive-count surveys of boar; the REST underestimated density compared to the latter. The model was, however, highly consistent with the REM and camera trap distance sampling (DS; {{ ref\_intext\_palencia\_et\_al\_2021 }}). Furthermore, the REST was more precise than the other two camera models – although not significantly ({{ ref\_intext\_palencia\_et\_al\_2021 }}).

Practitioners should be aware that population densities were quite high in the studies listed above (about 1 to 160 animals per km<sup>2</sup>; {{ ref\_intext\_jensen\_et\_al\_2022 }}; {{ ref\_intext\_nakashima\_et\_al\_2017 }}). Thus, while the REST model applies well to very dense populations, it may not be appropriate for average-to-low density populations (e.g., wildlife populations in BC, with densities often <1 animal/km<sup>2</sup>); further investigation is needed ({{ ref\_intext\_morin\_et\_al\_2022 }}). The precision of the REST is also inversely related to population size – the smaller the population, the less precise the density estimate ({{ ref\_intext\_morin\_et\_al\_2022 }}).

## Figures

|  |  |  |  |
| --- | --- | --- | --- |
| Image | file\_name | Caption (if applicable) | ref\_id |
| A black and white math equation  Description automatically generated with medium confidence | clarke\_et\_al\_2023\_eqn\_rest1.png |  | clarke\_et\_al\_2023 |
| A black and white image of a mathematical equation  Description automatically generated | clarke\_et\_al\_2023\_eqn\_rest2.png |  | clarke\_et\_al\_2023 |
| A fox in the woods  Description automatically generated | clarke\_et\_al\_2023\_fig8\_clipped.png | \*\*Clarke et al. (2023) - Fig. 8 \*\* A) Still from 中島啓裕’s (2021) video series. Example of overlaying a video recording of an animal on a Reference image of the focal area (faint triangle) to determine staying time \*𝑇\*. B) Still from Appendix S2 from Palencia et al. (2021). Example of superimposing the focal area on an image capture. | clarke\_et\_al\_2023 |
|  | nakashima\_et\_al\_2017\_fig1\_clipped.png | \*\*Nakashima et al. (2017) - Fig. 1\*\* The view-angle and total area in which camera traps (Bushnell Trophy Cam 2010) can successfully detect passing animals and capture video images of them (grey triangle). Only video data capturing animals that passed within the larger (white; 2.67 m2) or smaller focal area (black; 0.67 m2) were used for density estimations. See text for the details. | nakashima\_et\_al\_2017 |
|  | figure5\_filename.png | figure5\_caption | figure5\_ref\_id |
|  | figure6\_filename.png | figure6\_caption | figure6\_ref\_id |
|  | figure7\_filename.png | figure7\_caption | figure7\_ref\_id |
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|  | figure10\_filename.png | figure10\_caption | figure10\_ref\_id |
|  | figure11\_filename.png | figure11\_caption | figure11\_ref\_id |
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## Video

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| caption | URL (no < / > before/after URL | ref\_id |
| Density Estimation with the REST Model > REST\_01\_Set\_Focal\_Area | https://www.youtube.com/embed/pUa9rgxSGVA?si=pOIqFPL6AxNuUYJtl | nakajima\_2021b |
| Density Estimation with the REST Model > REST\_02\_Set\_Up\_Emv | https://www.youtube.com/embed/wqEF\_up7EGs?si=IL2\_moYR0XpdR-Fk | nakajima\_2021c |
| Density Estimation with the REST Model > REST\_03\_MeasureStayingTime | https://www.youtube.com/embed/s-d81K72yWs?si=PqWOR\_dvvkCfoLY7 | nakajima\_2021d |
| vid4\_caption | vid4\_url | vid4\_ref\_id |
| vid5\_caption | vid5\_url | vid5\_ref\_id |
| vid6\_caption | vid6\_url | vid6\_ref\_id |

## Shiny

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## Analytical tools & resources

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## References / Glossary

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| {{ ref\_bib\_caravaggi\_et\_al\_2020 }}  {{ ref\_bib\_clarke\_et\_al\_2023 }}  {{ ref\_bib\_codling\_et\_al\_2008 }}  {{ ref\_bib\_garland\_et\_al\_2020 }}  {{ ref\_bib\_gilbert\_et\_al\_2020 }})  {{ ref\_bib\_hofmeester\_et\_al\_2017 }})  {{ ref\_bib\_jensen\_et\_al\_2022 }}  {{ ref\_bib\_morin\_et\_al\_2022 }}  {{ ref\_bib\_nakashima\_et\_al\_2017 }}  {{ ref\_bib\_nakashima\_et\_al\_2020 }}  {{ ref\_bib\_palencia\_et\_al\_2021 }}  {{ ref\_bib\_rowcliffe\_et\_al\_2014 }}  {{ ref\_bib\_nakajima\_2021a }}  {{ ref\_bib\_nakajima\_2021b }}  {{ ref\_bib\_nakajima\_2021c }}  {{ ref\_bib\_nakajima\_2021d }} | keys\_here |

## Notes

* UBC\_CAMERA\_Report1\_Density\_31Jan2023.pdf
* Garland\_et\_al\_(2020) advise that the REST model should not be used for species that exhibit heterogeneous patterns of moving and resting.

# Markdown

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

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

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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 }}

- {{ mod\_occupancy\_assump\_05 }}

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

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

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

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- {{ mod\_occupancy\_pro\_04 }}

- {{ mod\_occupancy\_pro\_05 }}

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

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

- {{ mod\_occupancy\_con\_02 }}

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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.

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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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:::

figure10\_caption

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::::{grid-item-card} {{ ref\_intext\_figure11\_ref\_id }}

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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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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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allow="accelerometer; autoplay; clipboard-write; encrypted-media; gyroscope; picture-in-picture"

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 }}

{{ ref\_bib\_gimenez\_2023 }}

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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 }}

{{ ref\_bib\_proteus\_2018 }}

{{ 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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