# INFO ENTRY

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
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* Notes
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## Topic Info

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| info\_id | mod\_smr |
| question | Headers:  \*\*<font size="4"><span style="color:#2F5496">How does this relate to study design?</font></span>\*\*  \*\*<font size="4"><span style="color:#2F5496">How does that work?</font></span>\*\*  \*\*<font size="4"><span style="color:#2F5496">Why do we care?</font></span>\*\*  > \*\*Select “Unknown” if you’re not sure.\*\*  :::{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)  :::  \[in Clarke et al. 2023\]  {bdg-link-primary-line}`Spatial count<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_14\_mod\_sc.html>`  *2.1.1 Capture-Recapture* --> {bdg-link-primary-line}`Capture-recapture (CR) / Capture-mark-recapture (CMR)<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_10\_mod\_cr\_cmr.html>`  *2.1.2 Spatial Capture-Recapture* --> {bdg-link-primary-line}`Spatial capture-recapture (SCR) / Spatially explicit capture recapture (SECR)<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_11\_mod\_scr\_secr.html>` |

## Assumptions, Pros, Cons – if modelling approach

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| Assumptions | Pros | Cons |
| - {{ mod\_smr\_assump\_01 }}  - {{ mod\_smr\_assump\_02 }}  - {{ mod\_smr\_assump\_03 }}  - {{ mod\_smr\_assump\_04 }}  - {{ mod\_smr\_assump\_05 }}  - {{ mod\_smr\_assump\_06 }}  - {{ mod\_smr\_assump\_07 }}  - {{ mod\_smr\_assump\_08 }}  - {{ mod\_smr\_assump\_09 }}  - {{ mod\_smr\_assump\_10 }}  - {{ mod\_smr\_assump\_11 }}  - {{ mod\_smr\_assump\_12 }}  - {{ mod\_smr\_assump\_13 }}  - {{ mod\_smr\_assump\_14 }}  - {{ mod\_smr\_assump\_15 }}  - {{ mod\_smr\_assump\_16 }}  - {{ mod\_smr\_assump\_17 }} | - {{ mod\_smr\_pro\_01 }}  - {{ mod\_smr\_pro\_02 }}  - {{ mod\_smr\_pro\_03 }}  - {{ mod\_smr\_pro\_04 }} | - {{ mod\_smr\_con\_01 }}  - {{ mod\_smr\_con\_02 }}  - {{ mod\_smr\_con\_03 }}  - {{ mod\_smr\_con\_04 }}  - {{ mod\_smr\_con\_05 }}  - {{ mod\_smr\_con\_06 }} |

## Overview

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

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## 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)

:::

We have already discussed spatially-explicit density models for completely marked populations (spatial capture-recapture, SCR; see {bdg-link-primary-line}`Spatial capture-recapture (SCR) / Spatially explicit capture recapture (SECR)<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_11\_mod\_scr\_secr.html>`) and completely unmarked populations (spatial count, SC; see {bdg-link-primary-line}`Spatial count<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_14\_mod\_sc.html>`) – but what about the “intermediate” situation, in which only a fraction of a population carries marks? Spatial mark-resight (SMR) models were developed for such scenarios.

First, let’s familiarize ourselves with non-spatial mark-resight models (or simply markresight models). Mark-resight models are similar to capture-recapture (CR; see {bdg-link-primary-line}`Capture-recapture (CR) / Capture-mark-recapture (CMR)<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_10\_mod\_cr\_cmr.html>`) models, but relax CR’s stipulation that all animals in a study population are individually identifiable – that is, that all animals carry unique natural marks, or that all animals are trapped and tagged ({{ ref\_intext\_royle\_et\_al\_2014 }}; {{ ref\_intext\_sollmann\_et\_al\_2013a }}). Instead, mark-resight models need only a subset of the population to be marked (either naturally or from a single trapping-and-tagging event; {{ ref\_intext\_sollmann\_et\_al\_2013a }}). The entire population is then resighted using a “non-invasive” survey technique (i.e., a method that does not require the handling of animals, like an aerial or camera trap survey; {{ ref\_intext\_royle\_et\_al\_2014 }}, {{ ref\_intext\_sollmann\_et\_al\_2013a }}) and population size is calculated using the equation:

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where \*𝑚\* is the number of marked animals, \*𝑢\* is the number of unmarked animals and \*𝑝\* is detection probability – the latter of which is determined using data from marked individuals only ({{ ref\_intext\_chandler\_royle\_2013 }}). Dividing \*𝑁\* by the area of the sampling frame \*𝐴\* produces an estimate of total population density.

SMR models integrate spatial information into the mark-resight framework. The result is a hybrid model that combines data from the detection histories of marked individuals, as per SCR, with site-specific counts of unmarked individuals, as per SC ({{ ref\_intext\_royle\_et\_al\_2014 }}). For the remainder of this section, we will discuss camera trap SMR, for which animals are resighted using camera trap arrays.

The first SMR model, developed by Chandler and Royle (2013) and Sollmann et al. (2013a) and now coined “conventional SMR,” models the resighting process only (i.e., ignores the marking process; {{ ref\_intext\_whittington\_et\_al\_2018 }}). In doing so, conventional SMR makes the implicit assumption that marked animals are a random subset of the study population, and thus that 1) marked and unmarked animals are distributed similarly across the landscape, and 2) marked and unmarked animals have equal detection probabilities ({{ ref\_intext\_royle\_et\_al\_2014 }}; {{ ref\_intext\_whittington\_et\_al\_2018 }}). Such assumptions can hold – for example, when a random subset of the population carries natural marks, or when a closed population of animals is trapped and tagged at random locations ({{ ref\_intext\_sollmann\_et\_al\_2013a }}; {{ ref\_intext\_rich\_et\_al\_2014 }}; {{ ref\_intext\_whittington\_et\_al\_2018 }}). These assumptions are violated, however, when animals are trapped and tagged non-randomly (e.g., owing to inaccessibility, rough terrain) before resighting, since the distribution of marked animals will be clustered around trapping-and-tagging sites, and marked animals will have a higher chance of being detected at camera traps near where they were tagged ({{ ref\_intext\_whittington\_et\_al\_2018 }}).

To ease the assumptions and address the limitations of conventional SMR, Whittington et al. (2018) developed generalized SMR, which models the marking and resighting processes separately. The marking sub-model describes where animals were trapped and tagged on the study landscape – that is, how marked individuals are distributed in space ({{ ref\_intext\_jimenez\_et\_al\_2021 }}). Explicitly modelling the marking process allows practitioners to trap and tag animals non-randomly (e.g., using linear or grid trap layouts) without biasing density estimates ({{ ref\_intext\_whittington\_et\_al\_2018 }}). The resighting submodel combines marked individuals’ detection histories, camera trap-specific counts of unmarked individuals and estimates of detection probability to determine population density ({{ ref\_intext\_whittington\_et\_al\_2018 }}).

Practitioners should note that the number of marked animals in a population can influence the precision of SMR studies. The general trend in precision, based on previous SMR studies (both conventional and generalized), is: the more marked animals, the more precise the density estimation (see {{ ref\_intext\_whittington\_et\_al\_2018 }}). Of the four studies compared, only those with 22 or more marked individuals achieved coefficients of variation (CVs) below the accepted threshold for wildlife management (i.e., CV ≤ 0.2; {{ ref\_intext\_sollmann\_et\_al\_2013a }}; {{ ref\_intext\_whittington\_et\_al\_2018 }}; {{ ref\_intext\_williams\_et\_al\_2002 }}).

## Figures

|  |  |  |  |
| --- | --- | --- | --- |
| Image | file\_name | Caption (if applicable) | ref\_id |
|  | whittington\_et\_al\_2018\_fig1\_clipped.png | \*\*Whittington et al. (2018) - Fig. 1\*\* Differences in the distributions of marked and unmarked animals lead to bias in conventional SMR models but not generalized SMR models. (a) Animals (blue triangles) in the state-space are subject to trapping (+) and marking. (b) The expected distributions of marked and unmarked animals are assumed to be identical for conventional SMR models but depend on trap distribution for generalized SMR. (c) Marked and unmarked animals are observed during resight surveys. (d) The expected distribution of marked animals not resighted is incorrectly assumed to be highest near the edge of the state-space for conventional SMR, whereas generalized SMR models correctly assume it is highest closest to traps. | whittington\_et\_al\_2018 |
| A screenshot of a map  Description automatically generated | SECR\_creemmural.org\_secr.png | figure2\_caption | figure2\_ref\_id |
|  | clarke\_et\_al\_2023\_eqn\_smr1.png | figure3\_caption | clarke\_et\_al\_2023 |
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## Video

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## Shiny

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## Analytical tools & resources

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## References / Glossary

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| {{ ref\_bib\_chandler\_royle\_2013 }}  {{ ref\_bib\_clarke\_et\_al\_2023 }}  {{ ref\_bib\_jimenez\_et\_al\_2021 }}  {{ ref\_bib\_sollmann\_et\_al\_2013a }}  {{ ref\_bib\_rich\_et\_al\_2014 }}  {{ ref\_bib\_royle\_et\_al\_2014 }}  {{ ref\_bib\_whittington\_et\_al\_2018 }}  {{ ref\_bib\_williams\_et\_al\_2002 }} |  |

## Notes

# Markdown

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

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

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name: python3

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

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

- {{ mod\_rai\_assump\_01 }}

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- {{ mod\_rai\_pro\_01 }}

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

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

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\*\*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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In ecology, relative abundance (RA) is any count of animals or animal sign (e.g., number of deer sighted, number of bird vocalizations per unit time, number of moose tracks per kilometer of transect) that is assumed to correlate with absolute abundance ({{ ref\_intext\_obrien\_2011 }}). RA is a controversial index for two reasons: 1) there is often no documented relationship between the number of animals or signs observed and population size (i.e., index validation), and 2) detection probability is assumed to be constant between the areas, times or species being compared ({{ ref\_intext\_obrien\_2011 }}; {{ ref\_intext\_thompson\_et\_al\_1998 }}).

To the first point: the relationship between the number of animals or signs and abundance is rarely established ({{ ref\_intext\_burton\_et\_al\_2015 }}). Researchers often assume that counts and population size scale linearly – but many other kinds of relationships are possible. When the assumed relationship between counts and abundance diverges from the actual relationship, inferences from RA are not very meaningful ({{ ref\_intext\_thompson\_et\_al\_1998 }}). Validating a count-abundance relationship requires comparison with a robust, accurate estimate of absolute density (e.g., {{ ref\_intext\_krebs\_et\_al\_1987}}; {{ ref\_intext\_rovero\_marshall\_2009 }}; {{ ref\_intext\_villette\_et\_al\_2016 }}).

To the second point: consider the canonical equation,

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where \*𝑁\* is population size, \*𝐶\* is the count of animals or signs and \*𝑝\* is detection probability ({{ ref\_intext\_anderson\_2001 }}; {{ ref\_intext\_brennan\_2019 }}). This equation underlies many estimators of abundance, including capture-recapture (CR; see {bdg-link-primary-line}`Capture-recapture (CR) / Capture-mark-recapture (CMR)<https://ab-rcsc.github.io/rc-decision-support-tool\_concept-library/02\_dialog-boxes/03\_10\_mod\_cr\_cmr.html>`) and distance sampling (DS; 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>`) methods ({{ ref\_intext\_obrien\_2011 }}). RA comparisons assume that detection probability \*𝑝\* is constant across space, time or species, and can therefore be ignored ({{ ref\_intext\_anderson\_2011 }}; {{ ref\_intext\_obrien\_2011 }}; {{ ref\_intext\_sollmann\_et\_al\_2013b }}), such that:

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so count essentially becomes a surrogate for population size.

Assuming constant detection probability \*𝑝\* is problematic, since the likelihood an animal or sign is counted during a survey will vary with observational, environmental, and habitat- and species-specific factors, which in turn can vary with time ({{ ref\_intext\_anderson\_2001 }}). For example: at site A, animals may be difficult to spot in dense vegetation, while at site B, animals may be easy to spot in open grassland; and the effects of vegetation on observability may differ seasonally. If the effects of vegetation on detectability are not accounted for, how can we be sure that differences in animal counts at site A and B are due to true differences in abundance, and not simply artefacts of detection bias ({{ ref\_intext\_sollmann\_et\_al\_2013b }})?

In a camera trapping context, RA is the comparison of detection rates across space, time or species – where detection rates are typically reported as the number of images per 100 trap days, but can also be reported in terms of the total number of detections, other units of effort (e.g., camera trap hours), proportion of stations with detections, etc. ({{ ref\_intext\_burton\_et\_al\_2015 }}). As with other kinds of RA surveys, comparisons of camera trap detection rates can confound abundance with animal behaviour and observability ({{ ref\_intext\_anderson\_2001 }}; {{ ref\_intext\_burton\_et\_al\_2015 }}).

RA has been criticized as an abundance estimator. Anderson (2001) condemned the index as “unprofessional,” while O’Brien (2011) called it a “metric of last resort.” Sollmann et al. (2013b) used simulations to determine that camera trap RA analyses did not detect changes in big cat density, and called use of the index for wildlife management “alarming.” Nevertheless, some researchers have had success with the method and/or have argued for its conceptual and practical advantages (e.g., {{ ref\_intext\_rovero\_carbone\_et\_al\_2001, {{ ref\_intext\_johnson\_2008 }}; {{ ref\_intext\_palmer\_et\_al\_2018 }}; {{ ref\_intext\_rovero\_marshall\_2009 }}). Broadley et al. (2019) used simulations to show that RA could be sensitive to density-dependent movement, but generally tracked abundance well. Banks-Leite (2014) emphasized the importance of careful sampling design and protocols to control for variation in detectability, arguing that researchers should not solely rely on statistical corrections.

Ultimately, there is no “silver bullet” and researchers must carefully consider their inferential objectives and potential sources of sampling and estimation bias when choosing response variables and modelling frameworks for camera trap data.

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

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Modified from Gilbert et al. (2022) - Figure 3.

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\*\*Dénes et al. (2015) - Fig. 1.\*\* Mechanisms that cause different types of zero observations in count surveys and how species rarity, detectability and sampling effort affect them.

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(a) False zeroes are due to either imperfect detection or temporary absence. True zeroes can occur when the sample unit is unoccupied by the species, due to demographic stochasticity or due to ecological mechanisms such as unsuitable habitat or interspecific competition. (b) For common and detectable species (lower right), the majority of zeroes can be expected to result from ecological processes. As species detectability decreases, new false zeroes arise due to detection error (lower left). Species rarity results in fewer detections (dark green bars), additional true zeroes arise from unoccupied sample units (white bars) and increased demographic stochasticity (beige bars). (c) When the area sampled and/or the time of visit are small/ short relative to the species home range or movements, individuals may not be available for detection during the survey, resulting in additional false zeroes and fewer non-zero observations.

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::::{grid-item-card} {{ ref\_intext\_blasco\_moreno\_et\_al\_2019 }}

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\*\*Blasco-Moreno et al. (2019) - Fig 1.\*\* Different sources of zeros that could emerge in count data.

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The example shows the presence (>0) or absence (0) of herbivores on a plant species. Zeros due to the lack of experience of the observer (a–b) or resulting from a poor experimental design (c–h) are called False Zeros and should be minimized when performing the experiment. Structural Zeros, that is, zeros related to the ecological system under study (i–k), and Random Zeros emerging from the sampling variability (l) are known as True Zeros. Classifying a zero as a design error or structural zero depends on whether the event is part of the hypotheses tested. Only when the study includes the possibility of a zero value as part of the hypotheses (e.g. the study aims to test whether the interaction is occurring) the resulting zeros would be structural and should be included in the statistical analysis. The following text explains different scenarios that would result in a zero value, and, in brackets, how errors due to false zeros can be minimized: (a) the insects or the damage exerted are so small that the observer cannot detect them [sample when the insects are expected to be well developed]; (b) the observer does not see the herbivore (e.g. it is mistaken for a seed) or the damage is associated to other causes not related to herbivory (e.g. mechanical damage during sampling, pathogens, etc.) [the observer should be trained properly]; (c) the distributional areas of herbivores and plants are not coincident [know the species distribution before sampling]; (d) a herbivore is not present in a certain location within its distributional area, for example due to the microclimatic conditions [sample in habitats with adequate environmental conditions for a herbivore, or perform replicate surveys in different areas]; (e) a single survey is conducted, and is not coincident with the herbivore phenology [know the herbivore life cycle or perform long‐term surveys]; (f) a long‐term survey is conducted, but the low sampling frequency does not enable capture of the presence of the herbivore [sample on a more frequent basis]; (g) herbivores are not found because they are absent at the time of sampling [record plant damage instead of the presence of insects]; (h) herbivores are so infrequent that the design cannot capture their presence [perform extensive sampling with a high number of replicates]; (i) phenology of plants and herbivores are not completely coincident at a temporal level; (j) herbivores do not recognize a plant as a potential host; (k) herbivores recognize a plant as a host but prefer to feed on another species and (l) the herbivore population is not large enough to saturate the available plant resources.

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\*\* Denes et al. (2015) - Fig. 2\*\* Summary of the main modelling approaches for estimating abundance of unmarked animal populations described in the text.

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Red boxes represent important model assumptions (in bold) and sampling design requirements (in italic), green boxes represent the types of input data used by each model, lilac and orange ellipses represent established and emerging methods, respectively, and blue diamonds represent additional parameters estimated. w indicates models that estimate potential occupancy probability, / indicates models that estimate probability of temporary emigration from the sample unit, and q indicates models that account for correlation in detection of individuals. p is site-level detection probability, c and x are arrival rate and survival probability parameters, respectively, r is the spatial correlation in counts, and Ω is the probability that a species is present in the supercommunity.

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https://www.mdpi.com/2673-4591/39/1/38

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::::{grid-item-card} {{ ref\_intext\_denes\_et\_al\_2015 }}

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figure8\_caption

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::::{grid-item-card} {{ ref\_intext\_figure9\_ref\_id }}

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figure9\_caption

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figure10\_caption

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figure11\_caption

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

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Using Hurdle Models to Analyze Zero-Inflated Count Data

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::::{grid-item-card} {{ ref\_intext\_cao\_2021 }}

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Hurdle models

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::::{grid-item-card} {{ ref\_intext\_tilestats\_2021 }}

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Zero-inflated Poisson (ZIP) regression

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Poisson Regression Review

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Poisson Regression: Zero Inflation (Excessive Zeros)

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::::{grid-item-card} {{ ref\_intext\_russel\_2020 }}

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</div>

Fitting Poisson and zero-inflated Poisson models.

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

Check back in the future!

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

:::::{card} Microbiome Analysis: Relative Abundance Boxplots

A Shiny app allows you to visualize data by using R scripts without having to interact with the R script itself. This Shiny app will allow you to plot your **Relative Abundance** microbiome data in an easy-to-view format. If this is your first time utilizing this Shiny app, follow the step below to start visualising your data now!

<iframe

width="100%"

height="900"

src="https://guthub.org/shiny/sample-apps/absboxplot/ "

frameborder="0"

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

allowfullscreen>

</iframe>

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::::{dropdown} **Error! Reference source not found.**

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allowfullscreen>

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

| Type | Name | Note | URL |Reference |

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

| R resource | abmi.camera.extras: Animal Density from Camera Data > Probabilistic gaps | | Main resource page: <https://mabecker89.github.io/abmi.camera.extras/index.html>;<br>[Probabilistic gaps]<https://mabecker89.github.io/abmi.camera.extras/articles/gaps.html> | {{ ref\_bib\_becker\_et\_al\_2020 }} |

| App/Program | Introduction to Camera Trap Data Management and Analysis in R > Chapter 12 Activity | | <https://bookdown.org/c\_w\_beirne/wildCo-Data-Analysis/activity.html> | {{ ref\_bib\_wildco\_lab\_2021d }} |

| App/Program | R package “activity” | Provides functions to express clock time data relative to anchor points (typically solar); fit kernel density functions to animal activity time data; plot activity distributions; quantify overall levels of activity; statistically compare activity metrics through bootstrapping; evaluate variation in linear variables with time (or other circular variables). | <https://cran.r-project.org/web/packages/activity/index.html> | {{ ref\_bib\_rowcliffe\_2023 }} |

| R package | R package “overlap” | Estimates of Coefficient of Overlapping for Animal Activity Patterns | <https://cran.r-project.org/web/packages/overlap/index.html> | {{ ref\_bib\_campbell\_2024 }} |

| Tutorial | Chapter 6 Modeling Relative Abundance | | <https://cornelllabofornithology.github.io/ebird-best-practices/abundance.html> | {{ ref\_bib\_strimasmackey\_et\_al\_2023 }} |

| R package | glmmTMB: Generalized Linear Mixed Models using Template Model Builder | resource6\_note | <https://cran.r-project.org/web/packages/glmmTMB/index.html> | {{ ref\_bib\_resource6\_ref\_id }} |

| R package | R package “zicounts” | Counts data models: zero-inflation as well as interval icensored | <https://github.com/cran/zicounts> | {{ ref\_bib\_resource7\_ref\_id }} |

| R package | R package “DHARMa” | Can be used to assess goodness-of-fit of a mixed effect model via quantile–quantile (Q–Q) plots of standardized residuals | <https://CRAN.R-project.org/package=DHARMa>| {{ ref\_bib\_hartig\_2019}} |

| R package | R package “Pscl” | resource9\_note | < https://cran.r-project.org/web/packages/pscl/index.html> | {{ ref\_bib\_jackman\_2024 }} |

| R package | R package “countreg” | Can be used to assess goodness-of-fit of a mixed effect hurdle model via rootograms ({{ ref\_intext\_kleiber\_zeileis\_2016 }}) | <https://rdrr.io/rforge/countreg/><br>

https://rdrr.io/rforge/countreg/f/inst/doc/countreg.pdf><br><https://www.zeileis.org/papers/Kleiber+Zeileis-2016.pdf> | {{ ref\_bib\_zeileis\_et\_al\_2008 }} |

| resource11\_type | A guide to modeling outcomes that have lots of zeros with Bayesian hurdle lognormal and hurdle Gaussian regression models | resource11\_note | <https://www.andrewheiss.com/blog/2022/05/09/hurdle-lognormal-gaussian-brms> | {{ ref\_bib\_resource11\_ref\_id }} |

| resource12\_type | resource12\_name | resource12\_note | resource12\_url | {{ ref\_bib\_resource12\_ref\_id }} |

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{{ ref\_bib\_anderson\_2001 }}

{{ ref\_bib\_banksleite\_2014 }}

{{ ref\_bib\_blasco\_moreno\_et\_al\_2019 }}

{{ ref\_bib\_brennan\_2019 }}

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

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

{{ ref\_bib\_carbone\_et\_al\_2001 }}

{{ ref\_bib\_cao\_2021 }}

{{ ref\_bib\_clark\_et\_al\_2003 }}

{{ ref\_bib\_dectre\_accel\_2016 }}

{{ ref\_bib\_hartig\_2019 }}

{{ ref\_bib\_heilbron\_1994 }}

{{ ref\_bib\_kleiber\_zeileis\_2016 }}

{{ ref\_bib\_krebs\_et\_al\_1987 }}

{{ ref\_bib\_johnson\_2008 }}

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{{ ref\_bib\_marinstats\_2020b }}

{{ ref\_bib\_markle\_et\_al\_2020 }}

{{ ref\_bib\_martin\_et\_al\_2005 }}

{{ ref\_bib\_mullahy\_1986 }}

{{ ref\_bib\_obrien\_2011 }}

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

{{ ref\_bib\_rovero\_marshall\_2009 }}

{{ ref\_bib\_russel\_2020 }}

{{ ref\_bib\_sollmann\_et\_al\_2013b }}

{{ ref\_bib\_thompson\_et\_al\_1998 }}

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{{ ref\_bib\_villette\_et\_al\_2016 }}

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

{{ ref\_bib\_zeileis\_et\_al\_2008 }}

+check others

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