## 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

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| **question** | NULL |

## Assumptions, Pros, Cons

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| **Assumptions** | **Pros** | **Cons** |
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## Overview

Add some info here

## Advanced

<!—refs checked; need fix sollman 2018 -->

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:

<br>

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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. <br>

<br>

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. <br>

<br>

Advantages of occupancy as an index of abundance include: <br>

<br>

- 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, grouptravelling 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 }}). <br>

<br>

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. <br>

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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 }}).

## Figures

|  |  |  |  |
| --- | --- | --- | --- |
| **Image** | **file\_name** | **Caption (if applicable)** | **ref\_id** |
| A diagram of a scientific experiment  Description automatically generated with medium confidence | murray\_et\_al\_2021.jpg | figure1\_caption | murray\_et\_al\_2021 |
| A diagram of a method of disintegrating  Description automatically generated | southwell\_et\_al\_2019\_fig1.png | NULL | southwell\_et\_al\_2019 |
|  | clarke\_et\_al\_2023\_eqn\_occupancy1.png | figure4\_caption | clarke\_et\_al\_2023 |
|  | chatterhee\_et\_al\_2021\_table2.png | figure4\_caption | chatterhee\_et\_al\_2021 |
|  | c……..h | figure5\_caption | figure5\_ref\_id |
|  | figure6\_filename.png | figure6\_caption | figure6\_ref\_id |

## Video

|  |  |  |
| --- | --- | --- |
| **caption** | **URL (no < / > before/after URL** | **ref\_id** |
| Occupancy Modeling Video 1 -- Sampling Techniques for Mammals | https://www.youtube.com/embed/n21Ugw0lYcY?si=RUCD7WjcLPJdHR00 | vid1\_ref\_id |
| Occupancy Modeling Video 2 -- Introductory Statistical Review | https://www.youtube.com/embed/u--F8\_oRpVU?si=XzL4GMaQmvlL-noj | vid2\_ref\_id |
| Occupancy Modeling Video 3 -- What are Occupancy Models and What are the Applications? | https://www.youtube.com/embed/-F-txltI\_iA?si=C8R-MQ3pKcskOcQt | vid3\_ref\_id |
| Occupancy Modeling Video 4 -- How to Run and Interpret the Models in PRESENCE | https://www.youtube.com/embed/DVo4KVMPnWg?si=m\_umrFr9FjNb9KlK | vid4\_ref\_id |
| Occupancy modelling - more than species presence/absence! (Darryl MacKenzie) | https://www.youtube.com/embed/Sp4kb4\_TiBA?si=HfYJ3DgqOJfiJ4Z4l | vid5\_ref\_id |
| Occupancy modelling - the difference between probability and proportion of units occupied | https://www.youtube.com/embed/zKQFY8W4ceU?si=ibziVu2KyWro5IUx | proteus\_2019a |
| Occupancy models - how many covariates can I include? | https://www.youtube.com/embed/tCh7rTu6fvQ?si=xHlbwdQa69Kma-Ma | proteus\_2019b |
|  |  |  |
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## Shiny

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## Analytical tools & resources

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type** | **Name** | **Note** | **URL** | **ref\_id** |
| rJAGS/R code | mfidino/multi-state-occupancy-models | [Mason Fidino's GitHub](https://github.com/mfidino) | <https://github.com/mfidino/multi-state-occupancy-models> | resource1\_ref\_id |
| JAGS/R code | mfidino/integrated-occupancy-model” | [Mason Fidino's GitHub](https://github.com/mfidino) | <https://github.com/mfidino/integrated-occupancy-models>l | resource2\_ref\_id |
| JAGS code | mfidino/auto-logistic-occupancy | [Mason Fidino's GitHub](https://github.com/mfidino) | <https://github.com/mfidino/auto-logistic-occupancy> | resource3\_ref\_id |
| R package | R package - “autoOcc” | An R package for fitting autologistic occupancy models | <https://github.com/mfidino/autoOcc> | resource4\_ref\_id |
| R code | mfidino/periodicity | Using Fourier series to predict periodic patterns in dynamic occupancy models | <https://github.com/mfidino/periodicity> | resource5\_ref\_id |
| R shiny | Simulated Occupancy Model Shiny App | could incorporate mammal data fairly easily to provide information on occupancy and detection probability | <https://drive.google.com/drive/folders/1B-h1yGYgfxz5ki-O4Q8R\_-1Ts\_\_SnpIM> | 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> | resource7\_ref\_id |
| 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>  - \*\*Help forum\*\*: <www.phidot.org> | resource8\_ref\_id |
| R package | R 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> | resource9\_ref\_id |
| 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>  <https://groups.google.com/g/unmarked> | resource10\_ref\_id |
| R code/Tutorial | “Multi-season Occupancy Models” | [Mason Fidino's GitHub](https://github.com/mfidino) | <https://darinjmcneil.weebly.com/multi-season-occupancy.html> | resource11\_ref\_id |
| R package |  | R package for analyzing wildlife data with detection error |  | resource12\_ref\_id |
|  |  |  |  | resource13\_ref\_id |
|  |  |  |  | resource14\_ref\_id |

:::note

See also home range size

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## References / Glossary

|  |  |
| --- | --- |
| **ref\_id** | **glossary\_keys** |
| {{ ref\_bib\_burton\_2015 }}  {{ ref\_bib\_efford & dawson\_2012 }}  {{ ref\_bib\_gaston\_et\_al\_2000 }}  {{ ref\_bib\_mackenzie\_et\_al\_2017 }}  {{ ref\_bib\_murray\_et\_al\_2021 }}  {{ ref\_bib\_neilson\_et\_al\_2018 }}  {{ ref\_bib\_noon\_et\_al\_2012 }}  {{ ref\_bib\_royle\_dorazio\_2008 }}  {{ ref\_bib\_sollmann\_2018 }}  {{ ref\_bib\_southwell\_et\_al\_2019 }}  {{ ref\_bib\_steenweg\_et\_al\_2018 }}  {{ ref\_bib\_stewart\_et\_al\_2018 }} | keys\_here |

## Notes

# POPULATE MARKDOWN

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(i\_mod\_divers\_rich)=

# {{ name\_mod\_divers\_rich }}

### :::::::::{div} full-width

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

:::::{grid}

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

- {{ mod\_behaviour\_assump\_01 }}

- {{ mod\_behaviour\_assump\_02 }}

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

- {{ mod\_behaviour\_pro\_01 }}

- {{ mod\_behaviour\_pro\_02 }}

- {{ mod\_behaviour\_pro\_03 }}

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

- {{ mod\_behaviour\_con\_01 }}

- {{ mod\_behaviour\_con\_02 }}

- {{ mod\_behaviour\_con\_03 }}

- {{ mod\_behaviour\_con\_04 }}

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### :::::::{tab-set}

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

\*\*{{ term\_mod\_divers\_rich }}\*\*: {{ term\_def\_mod\_divers\_rich }}

<br>

“Species richness is simply the number of species in an area ({{ ref\_intext\_wearn\_gloverkapfer\_2017 }})

Species diversity is more complex, and includes a measure of the number of species in a community, and a measure of the abundance of each species. Species diversity is usually described by an index, such as Shannon's Index H'.” {{ ref\_intext\_pyron\_2010 }}

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#### ::::::

#### ::::::{tab-item} Advanced

Parameters**:**

- \*\*α-richness (alpha richness)\*\*: species richness at the level of an individual camera location {{ ref\_intext\_wearn\_gloverkapfer\_2019 }}

- \*\*γ-richness (gamma richness)\*\*: species richness across a whole study area {{ ref\_intext\_wearn\_gloverkapfer\_2019 }}

- \*\*β-diversity (betadiversity)\*\*: the differences between the communities or, more formally, the variance among the communities {{ ref\_intext\_wearn\_gloverkapfer\_2019 }}

<br>

\*\*Observed \*vs\* estimated species richness\*\* (from {{ ref\_intext\_wearn\_gloverkapfer\_2019 }}):

- \*\*Observed species richness\*\*: the sum of the number of species seen (e.g. {{ ref\_intext\_kitamura\_et\_al\_2010 }}; {{ ref\_intext\_pettorelli\_et\_al\_2010 }}; {{ ref\_intext\_ahumada\_et\_al\_2011 }}; {{ ref\_intext\_samejima\_et\_al\_2012 }})

- Observed species richness will not, in general, be a reliable index of actual species richness because, even if sampling effort is strictly controlled, the detectability of species will vary across samples

- \*\*Estimated species richness\*\*: when the “sum of the number of species seen” is adjusted based on corrections for “imperfect detection” (i.e. the fact that some species in a given sample may have been missed)

- (e.g. {{ ref\_intext\_tobler\_et\_al\_2008 }}; {{ ref\_intext\_kinnaird-&-obrien-2012 }}; {{ ref\_intext\_brodie\_et\_al\_2015 }}; {{ ref\_intext\_yue\_et\_al\_2015 }}; {{ ref\_intext\_wearn\_et\_al\_2016 }})

- The \*\*two principal ways of estimating species richness from remote camera data \*\* are (from {{ ref\_intext\_wearn\_gloverkapfer\_2019 }}):<br>

- non-parametric estimators ({{ ref\_intext\_gotelli\_chao\_2013 }}), which use information about the rarest species in the sample to provide a minimum estimate of the number of true species (e.g. {{ ref\_intext\_tobler\_et\_al\_2008 }}),

- or 2) occupancy models ({{ ref\_intext\_mackenzie\_et\_al\_2006 }})

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

##### :::::{grid} 3

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###### ::::{grid-item-card} {{ ref\_intext\_pyron\_2010 }}

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\*\*Pyron (2010) - Figure 1\*\*: Species evenness and species richness for animalcule communities

<!-- Both communities contain five species of animalcules. Species richness is the same. The community on the left is dominated by one of the species. The community on the right has equal proportions of each species. Evenness is higher when species are present in similar proportions. Thus the community on the left has higher species diversity, because evenness is higher. -->

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\*\*Vandooren (2016) – Figure 1\*\*: Species accumulation curves. Species richness is the asymptote of a species accumulation curve, which expresses the dependence on sampling effort of the number of species sampled from an assemblage….

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\*\*Loreau et al. (2010) – Figure 4.\*\* Species accumulation and rarefaction curves. Species accumulation curves show the number of species obtained by successively censusing either individual organisms (individual-based accumulation curves) or samples (sample-based accumulation curves). Smoothed species rarefaction curves represent the statistical expectation of the corresponding accumulation curves. Credit: Rob Colwell, after Gotelli and Colwell (2001)

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###### ::::{grid-item-card} {{ ref\_intext\_loreau\_2010 }}

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\*\*Loreau et al. (2010) – Figure 3.\*\* The various levels of organisation and components that define the multiple facets

of biodiversity

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Abundance, species richness, and diversity

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Species accumulation and rarefaction curves

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Using vegan to calculate alpha diversity metrics within the tidyverse in R (CC196)

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Species abundance tools in Genstat

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Species Diversity and Species Richness

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Field Ecology - Diversity Metrics in R

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

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\*\* iNEXTOnline \*\*

shiny\_caption

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#### ::::::

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

| Type | Name | Note | URL |Reference |

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

| R package | Chapter 9 Community composition | \- | <https://bookdown.org/c\_w\_beirne/wildCo-Data-Analysis/composition.html#estimated-richnes> | {{ ref\_bib\_wildco\_lab\_2021b }} |

| R package | R package “vegan | \- | <https://cran.r-project.org/web/packages/vegan/index.html> | {{ ref\_bib\_oksanen\_et\_al\_2024 }} |

| Program | EstimateS | Dedicated software for estimating diversity, using asymptotic or rarefaction methods. Mac version available | <https://www.robertkcolwell.org/pages/1407> | {{ ref\_bib\_colwell\_2022 }} |

| R package | Package ‘iNEXT’ - Interpolation and Extrapolation for Species Diversity | The iNext package (INterpolation and EXTrapolation of species richness) - is both easy to use and rapid to compute. It also comes with a wealth of plotting functions - see the iNext Quick Introduction for a great walk through tutorial. Its core functionality is based on: Chao, Anne, et al. “Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies.” Ecological monographs 84.1 (2014): 45-67. | <https://cran.r-project.org/web/packages/iNEXT/iNEXT.pdf> | {{ ref\_bib\_hsieh\_et\_al\_2015 }} |

| Exercise/Tutorial | 2.2: Measuring Species Diversity | Easy to interpet explanation of species richness vs evenness, species area curves, rarefaction, and how to calculate diversity | <https://bio.libretexts.org/Courses/University\_of\_California\_Davis/BIS\_2B%3A\_Introduction\_to\_Biology\_-\_Ecology\_and\_Evolution/02%3A\_Biodiversity/2.02%3A\_Measuring\_Species\_Diversity> | {{ ref\_bib\_gerhartbarley\_nd }} |

| R package / Tutorial | Species Accumulation Curves with vegan, BiodiversityR and ggplot2 | Software for interpolation and extrapolation of species diversityRarefied Species Accumulation Curves (the simple way) | <https://rpubs.com/Roeland-KINDT/694021> | {{ ref\_bib\_resource6\_ref\_id }} |

| resource7\_type | resource7\_name | resource7\_note | resource7\_note | {{ ref\_bib\_resource7\_ref\_id }} |

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#### ::::::{tab-item} References

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{{ ref\_bib\_ahumada\_et\_al\_2011 }}

{{ ref\_bib\_baylor\_tutoring\_center\_2021 }}

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

{{ chao\_et\_al\_2016 }}

{{ chao\_et\_al\_2014 }}

{{ ref\_bib\_colwell\_2022 }}

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