### (#i\_mod\_occupancy)=

### Occupancy models

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| **Occupancy model (MacKenzie et al., 2002):** A modelling approach used to account for imperfect detection by first evaluating the detection probability of a species via detection histories (i.e., present or absent) to determine the probability of the true presence or absence of a species at a site (MacKenzie et al., 2002). | | | | | |
| Overview - How the Model Works | | | | | |
| Advanced - How the Model Works (Clarke et al., 2023)  Occupancy models describe spatial patterns of animal occurrence (Sollmann 2018) and have been proposed as a proxy for abundance (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 (MacKenzie et al. 2017)? The basic equation for occupancy is:  A mathematical equation with symbols  Description automatically generated with medium confidence  ```{figure} ./images/Mccomb-et-al\_2010\_Fig10.1.png  :align: center  ```  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 (MacKenzie et al. 2017). Unlike simple measures of presence-absence, occupancy models account for imperfect detection (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 (Gaston et al. 2000, Royle and 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 (Noon et al. 2012, Sollmann 2018). * Occupancy-abundance relationships appear to be robust to territoriality, grouptravelling behaviour and other biological traits (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 (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 (Efford and 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 (Neilson et al. 2018, 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 (Neilson et al 2018, Stewart et al. 2018). | | | | | |
| Assumptions (RCSC et al., 2023) | | Pros (RCSC et al., 2023) | | | Cons (RCSC et al., 2023) |
| * Occupancy is constant (MacKenzie et al., 2002) (abundance is constant) (MacKenzie et al., 2006) * Camera locations are independent (MacKenzie et al., 2006) * Detections are independent (MacKenzie et al., 2006) * The probability of occupancy and detection are constant across all camera locations within a stratum or can be modelled using covariates (MacKenzie et al., 2006) * Species are not misidentified (MacKenzie et al., 2006) | | * Does not require individual identification (MacKenzie et al., 2006) * Only requires detection/non-detection data for each site (Wearn & Glover-Kapfer, 2017) * Relatively easy-to-use software exists for fitting models (PRESENCE, MARK, and the “unmarked” R package) (Wearn & Glover-Kapfer, 2017) * “Open” models exist that allow for the estimation of site colonization and extinction (MacKenzie et al., 2006; Wearn & Glover-Kapfer, 2017) * Multi-species occupancy models (MacKenzie et al., 2002) allow the inclusion of interactions among species while controlling for imperfect detection (Wearn & Glover-Kapfer, 2017) | | | * Occupancy (MacKenzie et al., 2002) only measures distribution; it may be a misleading indicator of changes in abundance (Wearn & Glover-Kapfer, 2017) * Interpretation/communication of results may not be straightforward (if the scale of movement is much larger than the camera spacing the results should be interpreted as “probability of use” rather than occupancy) (Wearn & Glover-Kapfer, 2017) |
| Figures & Videos | | | | | |
| A diagram of a scientific experiment  Description automatically generated with medium confidence  ```{figure} ./images/Murray\_et-al\_2021.jpg  :align: center  ``` | | | A diagram of a method of disintegrating  Description automatically generated  ```{figure} ./images/Southwell-et-al\_2019.png  :align: center  ``` | | |
| **Video:** [Occupancy Modeling Video 1 -- Sampling Techniques for Mammals](https://www.youtube.com/watch?v=n21Ugw0lYcY)  https://www.youtube.com/watch?v=n21Ugw0lYcY | | | **Video:** [Occupancy Modeling Video 2 -- Introductory Statistical Review](https://www.youtube.com/watch?v=u--F8_oRpVU)  https://www.youtube.com/watch?v=u--F8\_oRpVU | | |
| **Video:** [Occupancy Modeling Video 3 -- What are Occupancy Models and What are the Applications?](https://www.youtube.com/watch?v=-F-txltI_iA)  https://www.youtube.com/watch?v=-F-txltI\_iA | | | **Video:** [Occupancy Modeling Video 4 -- How to Run and Interpret the Models in PRESENCE](https://www.youtube.com/watch?v=DVo4KVMPnWg)  https://www.youtube.com/watch?v=DVo4KVMPnWg | | |
| **Video:** [Occupancy modelling - more than species presence/absence! (Darryl MacKenzie)](https://www.youtube.com/watch?v=Sp4kb4_TiBA)  https://www.youtube.com/watch?v=Sp4kb4\_TiBA | | |  | | |
| Analytical tools & resources | | | | | |
| Name | Link | | Reference | Additional\_info | |
| JAGS/R code - “mfidino/multi-state-occupancy-models | https://github.com/mfidino/multi-state-occupancy-models | |  | [Mason Fidino's GitHub](https://github.com/mfidino) | |
| JAGS/R code - “mfidino/integrated-occupancy-model” | https://github.com/mfidino/integrated-occupancy-model | |  | [Mason Fidino's GitHub](https://github.com/mfidino) | |
| JAGS code - “mfidino/auto-logistic-occupancy” | https://github.com/mfidino/auto-logistic-occupancy | |  | [Mason Fidino's GitHub](https://github.com/mfidino) | |
| R package - “autoOcc” | https://github.com/mfidino/autoOcc | |  | [Mason Fidino's GitHub](https://github.com/mfidino); An R package for fitting autologistic occupancy models | |
| R code - “mfidino/periodicity” | https://github.com/mfidino/periodicity | |  | Using Fourier series to predict periodic patterns in dynamic occupancy models | |
| R Shiny - “Simulated Occupancy Model Shiny App” | https://drive.google.com/drive/folders/1B-h1yGYgfxz5ki-O4Q8R\_-1Ts\_\_SnpIM | |  | could incorporate mammal data fairly easily to provide information on occupancy and detection probability | |
| 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 | |  |  | |
| Program - “Presence” | www.mbr-pwrc.usgs.gov/ software/presence.html  www.phidot.org (for help forum) | |  | "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) | |
| R package - “RPresence” | https://www.mbr-pwrc.usgs.gov/software/presence.shtml | |  | "The R counterpart to Presence. Cross-platform (Windows, Mac and Linux)." (Wearn & Glover-Kapfer, 2017) | |
| R package "unmarked” | https://cran.r-project.org/web/packages/unmarked/index.html  https://groups.google.com/g/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) | |
| R code/Tutorial - “Multi-season Occupancy Models” | https://darinjmcneil.weebly.com/multi-season-occupancy.html | |  |  | |
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| References  Alberta Remote Camera Steering Committee (RCSC), Stevenson, C., Hubbs, A., & Wildlife Cameras for Adaptive Management (WildCAM). 2023. Remote Camera Survey Guidelines: Guidelines for Western Canada. Edmonton, Alberta. <https://ab-rcsc.github.io/RCSC-WildCAM_Remote-Camera-Survey-Guidelines-and-Metadata-Standards/1_survey-guidelines/1_0.1_Citation-and-Info.html>  Clarke, J., Bohm, H., Burton, C., & Constantinou, A. (2023). *Using Camera Traps to Estimate Medium and Large Mammal Density: Comparison of Methods and Recommendations for Wildlife Managers*. <https://doi.org/10.13140/RG.2.2.18364.72320>  MacKenzie, D. I., Nichols, J. D., Hines, J. E., Knutson, M. G., & Franklin, A. B. (2003). Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology*, *84*(8), 2200–2207. <https://doi.org/10.1890/02-3090>  MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. L., & Hines, J. E. (2006). *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*. Academic Press, USA.  Murray, M. H., Fidino, M., Lehrer, E. W., Simonis, J. L., & Magle, S. B. (2021). A multi-state occupancy model to non-invasively monitor visible signs of wildlife health with camera traps that accounts for image quality. J Anim Ecol, 90(8), 1973–1984. Medline. https://doi.org/10.1111/1365-2656.13515  Southwell, D. M. *et al.* Spatially explicit power analysis for detecting occupancy trends for multiple species. *Ecol Appl* **29**, e01950 (2019).  Wearn, O. R., & Glover-Kapfer, P. (2017). *Camera-trapping for conservation: A guide to best-practices* (Vol. 1). <http://dx.doi.org/10.13140/RG.2.2.23409.17767> | | | | | |

notes

### (#i\_app\_occupancy)=

### Occpancy app

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| Overview - How the app works | | | |
| Advanced - How the app works | | | |
| Figures & Videos (if needed/not already in approach) | | | |
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| Analytical tools & resources (if needed/not already in approach) | | | |
| Name | Link | Reference | Additional\_info |
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| References | | | |

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