## 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** | sp\_det\_prob\_cat |
| **question** | How detectable is Target Species?  Are all of the Target Species similarly detectable? (e.g., ) If all are similar, which best describes the Target Species detectability?  Describe detectability; define "detectability" options; incorporate interaction with lure? + ways to address + considerations.  [insert info on how this relates to study design recommendations; ideally, modelled using project data] |

## Overview

\*\*Detection probability categories are defined as follows:\*\*

- \*\*Low\*\*:

- < 0.1 ({{ ref\_intext\_tobler\_powell\_2013 }})

- < 0.05 ({{ ref\_intext\_shannon\_et\_al\_2014 }})

- 0–0.37 ({{ ref\_intext\_chatterjee\_et\_al\_2021 }})

- \*\*Medium\*\*:

- 0.37–0.67 ({{ ref\_intext\_chatterjee\_et\_al\_2021 }})

- \*\*High\*\*:

- 0.67–1 ({{ ref\_intext\_chatterjee\_et\_al\_2021 }})

- \> 0.5 ({{ ref\_intext\_mackenzie\_royle\_2005 }})

- \*\*Unknown\*\*: select this option if you’re not sure of the detection probability of your [Target Species](/09\_gloss\_ref/09\_glossary.md#target\_species) (single or multiple species)

- \*\*Multiple\*\*: select this option if your study include multiple [Target Species](/09\_gloss\_ref/09\_glossary.md#target\_species).

\

\*\*<font size="4"><span style="color:#2F5496">How this relates to study design</font></span>\*\*

\*\*{{ term\_detection\_probability }}\*\*: {{ term\_def\_detection\_probability }}

We use this information to adjust the recommended [camera days per camera location](/09\_gloss\_ref/09\_glossary.md#camera\_days\_per\_camera\_location) and [total number of camera days](/09\_gloss\_ref/09\_glossary.md#total\_number\_of\_camera\_days). For example, if the species is hard to detect, you may have to deploy cameras for longer to ensure you’ve sampled long enough to say that the species truly was not there (\*vs.\* it was there, but you did not detect it; “missed detections”, e.g., high cover of shrubs impeding your ability to see the species).

When you fail to detect an individual/species that was, in fact, present, this is called a “false absence”, which may lead to incorrect conclusions from the data. Understanding and correcting for sources of this type of error is often thought of in terms of probabilities (i.e., "detection probability" aka detectability).

\*\*Note! It’s not an exact science\*\* - Since detectability is affected by many other processes, it's best incorporated in models (using your data) since this will result in the best suited information to inform your design.

\

\*\*<font size="4"><span style="color:#2F5496">How does that work?</font></span>\*\*

:::::{grid} 2

::::{grid-item}

:columns: 8

Individuals and/or species are not always detected when they are present (i.e., detected "imperfectly”; ({{ ref\_intext\_mackenzie\_et\_al\_2004 }}). Missed detections occur or many reasons, including due characteristics of the environment (e.g., due to cover of vegetation), the time period (e.g., seasons), characteristics of the species (e.g., cryptic nature or small size), etc. \*\*The question here is asking about detection probability as it relates to the characteristics of the species (not the species in a particular habitat type or during a specific season).\*\*

You may need to consult previous studies to get a sense of which category is the most appropriate for your study and Target Species.

> \*\*Select “Unknown” if you’re not sure.\*\*

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::::{grid-item}

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:::{image} ../03\_images/03\_image\_files/det.gif

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:::::

:::::{seealso} Analysis aside

:class: dropdown

Many sources of detection error can be accounted for in analysis; this is done by assessing the relationships between the characteristics of the environment that we might expect to affect detection (e.g., cover of shrubs in front of the camera), and information on where (and when) the species was and was not detected. For example, there were consistently fewer detections on cameras placed in high shrub cover.

By assessing the relationships at locations repeatedly sampled over time, we begin to unravel the relationship between the environmental characteristics and missed detections on your cameras. We can then use this information to determine if we have sampled long enough (i.e., do we have enough information to differentiate between missed detections and true absences) and/or correct for this error in analysis by incorporating these effects in our models.

:::::

## Advanced

09\_gloss\_ref

Before study design choices are made, there is one critical concept to understand in remote camera research, which may impact study design choices at all levels of the data hierarchy. Reliable use of remote cameras to detect wildlife species hinges on the [assumption](/09\_gloss\_ref/09\_glossary.md#mods\_modelling\_assumption) that what is captured on the cameras accurately reflects what is present on the landscape. However, species are often detected "imperfectly," meaning that they are not always detected when they are present (i.e., [imperfect detection](/09\_gloss\_ref/09\_glossary.md#imperfect\_detection); e.g., due to cover of vegetation, cryptic nature or small size) ({{ ref\_intext\_mackenzie\_et\_al\_2004 }}). [Imperfect detection](/09\_gloss\_ref/09\_glossary.md#imperfect\_detection) can occur because the camera failed to capture an individual present at the site or because the animal was simply not present during the [survey](/09\_gloss\_ref/09\_glossary.md#survey) period ({{ ref\_intext\_martin\_et\_al\_2005 }}).

[Imperfect detection](/09\_gloss\_ref/09\_glossary.md#imperfect\_detection) results in “false absences” and may lead to incorrect conclusions from the data. Understanding and correcting for sources of “false absences” is often thought of in terms of probabilities. [Detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) is the probability (likelihood) that an individual from the population of interest is included in the count at time or location \*i\* ({{ ref\_intext\_mackenzie\_kendall\_2002 }}). [Detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) can be influenced through multiple processes and at multiple scales. Understanding the sources of “false absences” and factors that affect [detection probabilities](/09\_gloss\_ref/09\_glossary.md#detection\_probability) is an essential step when designing a study, deploying cameras and analyzing camera data.

The [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) of an animal by a camera depends on three \*\*conditional probabilities (Pr) of detection\*\* that may operate alone or potentially in combination ([Figure 1](#TOC\_surv\_guidelines\_fig\_1)).

(TOC\_surv\_guidelines\_fig\_1)=

```{figure} ../03\_images/03\_image\_files/rcsc\_et\_al\_2024\_detection\_probability\_2023\_05\_04\_clipped.jpg

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::::{grid} 3

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<span style="color:white">...</font>

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:columns: 10

\*\*RCSC et al. (2024) - Fig. 1.\*\* Three conditional probabilities (Pr) of detection that may impact the [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) of an animal (or species) by a camera (adapted from Moeller et al. \[2023\], Hofmeester et al. \[2019\], and Findlay et al. \[2020\]).

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<span style="color:white">...</font>

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[Detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) can be affected by species-specific characteristics, [Camera Model](/09\_gloss\_ref/09\_glossary.md#camera\_model) specifications and set-up, and environmental variables ({{ ref\_intext\_hofmeester\_et\_al\_2019 }}). For example, \*\*species-specific characteristics\*\* (individuals or populations), such as body size (e.g., {{ ref\_intext\_obrien\_et\_al\_2011 }}), behaviour (e.g., {{ ref\_intext\_caravaggi\_et\_al\_2020 }}; {{ ref\_intext\_rowcliffe\_et\_al\_2011 }}), and rarity can influence [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability), with larger, bolder and more common species generally having higher [detection rates](/09\_gloss\_ref/09\_glossary.md#detection\_rate). [\*\*Camera Model\*\*](/09\_gloss\_ref/09\_glossary.md#camera\_model) \*\*specifications and set-up\*\*, such as the [Trigger Sensitivity](/09\_gloss\_ref/09\_glossary.md#settings\_trigger\_sensitivity), [Camera Height](/09\_gloss\_ref/09\_glossary.md#camera\_height), or [angle](/09\_gloss\_ref/09\_glossary.md#camera\_angle) may affect [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) in that smaller species might not be detected or identifiable if the [Trigger Sensitivity](/09\_gloss\_ref/09\_glossary.md#settings\_trigger\_sensitivity) is low, or the [Camera Height](/09\_gloss\_ref/09\_glossary.md#camera\_height) or [angle](/09\_gloss\_ref/09\_glossary.md#camera\_angle) is too high. The [Camera Direction](/09\_gloss\_ref/09\_glossary.md#camera\_direction) could impact the probability of an animal triggering a camera if it is directed towards an object that impedes the [Field of View (FOV)](/09\_gloss\_ref/09\_glossary.md#field\_of\_view) or image quality (e.g. due to sun glare). \*\*Environmental factors\*\* (e.g., vegetation cover, snow depth) may affect [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) and occurrence (e.g., {{ ref\_intext\_becker\_et\_al\_2022 }}; {{ ref\_intext\_hofmeester\_et\_al\_2019 }}; {{ ref\_intext\_iknayan\_et\_al\_2014 }}; {{ ref\_intext\_steenweg\_et\_al\_2019 }}). For example, a low number of detections in a densely vegetated site might be because of poor camera visibility or avoidance of this habitat by the species of interest.

Hofmeester et al. (2019) suggested there are \*\*six scales (orders) that may impact\*\* [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) and that should be considered within an explicit time period (adapted from Hofmeester et al. \[2019\]; [Figure 2](#TOC\_surv\_guidelines\_fig\_2)):

1) \*\*Distribution range\*\* (1st order; i.e., the physical or geographical range of a species)

2) \*\*Landscape\*\* (2nd order; i.e., the location of an individual’s home range within the geographic range)

3) \*\*Habitat patch\*\* (3rd order; i.e., usage of habitat components within an individual’s home range)

4) \*\*Microsite\*\* (4th order; usage of microhabitats such as food items/feeding patches/nest sites/movement trails, etc. within a habitat)

5) \*\*Camera specification / set-up\*\* (5th order; i.e., factors that affect the probability that an animal [triggers](/09\_gloss\_ref/09\_glossary.md#trigger\_event) the camera if present)

6) \*\*Image\*\* (6th order; i.e., factors that affect correct identification of animals or individuals)

(TOC\_surv\_guidelines\_fig\_2)=

```{figure} ../03\_images/03\_image\_files/rcsc\_et\_al\_2024\_detectionprob\_hofmeester\_et\_al\_2019\_fig1\_clipped.png

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\*\*Figure 2.\*\* Spatial scales (1-6) and processes that determine the [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) ({{ ref\_intext\_hofmeester\_et\_al\_2019 }}; abbreviated figure caption).

It is important to consider how all these factors and scales will impact study design. Unmeasured variation in [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) can result in the inability to differentiate the effects of [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) \*vs.\* habitat preference ({{ ref\_intext\_jennelle\_et\_al\_2002 }}) and, in turn, cause erroneous estimates of occurrence and abundance ({{ ref\_intext\_burton\_et\_al\_2015 }}; {{ ref\_intext\_denes\_et\_al\_2015 }}; {{ ref\_intext\_kays\_et\_al\_2021 }}).

Factors that influence [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) at the microsite and camera specification / set-up scales are likely to result in the largest biases and thus warrant the most consideration (see Hofmeester et al. [2019] for details). Therefore, it is particularly important to consider \*how\* to place cameras to avoid such biases. Deploying cameras in a consistent fashion (e.g., carefully ensuring that cameras are always set at the same [Camera Height](/09\_gloss\_ref/09\_glossary.md#camera\_height), orientation ([direction](/09\_gloss\_ref/09\_glossary.md#camera\_direction)), and [angle](/09\_gloss\_ref/09\_glossary.md#camera\_angle) is essential.

## Figures

|  |  |  |  |
| --- | --- | --- | --- |
| **Image** | **file\_name** | **Caption (if applicable)** | **ref\_id** |
| A screenshot of a computer  Description automatically generated | rcsc\_et\_al\_2024\_detection\_probability\_2023\_05\_04\_clipped.jpg | \*\*RCSC et al. (2024) - Fig. 1.\*\* Three conditional probabilities (Pr) of detection that may impact the detection probability of an animal (or species) by a camera (adapted from Moeller et al. [2023], Hofmeester et al. [2019], and Findlay et al. [2020]). | rcsc\_et\_al\_2024 |
|  | rcsc\_et\_al\_2024\_detectionprob\_hofmeester\_et\_al\_2019\_fig1\_clipped.png | \*\*RCSC et al. (2024) - Fig. 2.\*\* Spatial scales (1-6) and processes that determine the detection probability (Hofmeester et al., 2019; abbreviated figure caption). | rcsc\_et\_al\_2024 |
|  | tourani\_et\_al\_2020\_fig1\_clipped.png | \*\*Tourani et al., (2020) - Fig. 1\*\* Conceptual diagram showing different aspects of detectability during camera trap surveys and the modulating effect of biological characteristics. In addition to direct impacts on detectability, a longer visit and a closer image of focal species increase the chance of identifying the visitor, thereby increasing detectability. [Colour figure can be viewed at zslpublications.onlinelibrary.wiley.com]. | tourani\_et\_al\_2020 |
|  | iknayan\_et\_al\_2014\_fig2\_clipped.png | \*\*Iknayan et al., (2020) - Fig. 2\*\* - Categories of species at surveyed sites resulting from imperfect detection and how they change with different temporal and spatial sampling strategies.  :::{dropdown}  (A) The true (unknown) species pool of a metacommunity represented at a site comprises species that have been detected there (green bin), those that have not yet been detected at the site but have been detected at other surveyed sites (yellow bin), and those that have not yet been detected at this or any site but occur in the region (white bin). (B) As temporal and spatial replication (i.e., sampling effort) increases, knowledge of the species pool changes for both the site (green bins) and the metacommunity (green + yellow + white bins). When a site is surveyed few times, the relative size of each bin depends on the factors affecting detectability (Figure 1). If there are few sites and few surveys per site, a large portion of the metacommunity may not be detected (white bin of upper left rectangle), either at the site or at other sites. As the number of surveys per site increases (temporal replication) but not the number of sites surveyed (i.e., little spatial replication), the total number of species detected per site increases (green bin in upper right rectangle), mostly as a result of detecting species that are likely to occur at other sites (yellow bin). When the total number of sites surveyed increases (spatial replication) but not the number of surveys (i.e., little temporal replication), the number of species undetected in the region decreases (white bin in lower left rectangle), but the number of species detected per site remains the same (green bin). As both the number of surveys per site and the number of sites surveyed increase, a greater proportion of species in the metacommunity will be known (green + yellow bins in lower right rectangle), either from being directly detected at the site (green bin) or by being detected at other sites (yellow bin).  ::: | iknayan\_et\_al\_2014 |
|  | oconnell\_et\_al\_2011\_fig6\_1\_clipped.png | \*\*O’Connell et al. (2011) - Fig. 6.1\*\* The cumulative likelihood of capturing an individual with a Pr(detection) per sampling occasion = \*p\* over \*K\* = 1 ... 30 sampling occasions. As \*p\* and \*K\* increase, the likelihood of detection approaches 1. | oconnell\_et\_al\_2011 |
|  | findlay\_et\_al\_2020\_fig1\_clipped.png | \*\*Findlay et al. (2020) - Fig. 1\*\* The sequential processes required to detect an animal on a cameratrap given that it is present. Failure of any of these processes leads to a false-negative; therefore, detection success requires a positive outcome from all the component processes. Specific terminology we use in this study to quantify these processes is also shown. ‘Detection probability’ can thus be considered the product of a series of conditional probabilities representing each of these processes. | findlay\_et\_al\_2020 |
|  | findlay\_et\_al\_2020\_fig8\_clipped.png | \*\*Findlay et al. (2020) - Fig. 8\*\* Hypothesized mechanism showing how distance to camera-trap (CT) can interact with animal speed to influence registration probability. Registration probability is positively affected by distance due to the larger area within the field-of-view at greater distances. Conversely, faster moving animals can completely pass through the small width of the field-ofview close to the CT before the camera takes an image | findlay\_et\_al\_2020 |
|  | burton\_et\_al\_2015\_fig1.jpg | \*\*Burton et al. (2015) - Fig. 1.\*\* The detection of animals by camera traps is affected by ecological and observational processes occurring at both the local scale of the camera trap detection zone and the broader scale of the surrounding landscape. Explicitly accounting for these underlying processes is an important challenge for wildlife surveys with camera traps. (Image by Jeff Dixon). | burton\_et\_al\_2015 |
|  | figure9\_filename.png | figure9\_caption | figure9\_ref\_id |
|  | figure10\_filename.png | figure10\_caption | figure10\_ref\_id |
|  | figure11\_filename.png | figure11\_caption | figure11\_ref\_id |
|  | figure12\_filename.png | figure12\_caption | figure12\_ref\_id |

## Video

|  |  |  |
| --- | --- | --- |
| **caption** | **URL (no < / > before/after URL** | **ref\_id** |
| Probability of Detection: Eg 01 | https://www.youtube.com/embed/WBgWOQBlNoI?si=h16\_LVMHmwT0ntPd | turlapaty\_2014 |
| vid2\_caption | vid2\_url | vid2\_ref\_id |
| vid3\_caption | vid3\_url | vid3\_ref\_id |
| vid4\_caption | vid4\_url | vid4\_ref\_id |
| vid5\_caption | vid5\_url | vid5\_ref\_id |
| vid6\_caption | vid6\_url | vid6\_ref\_id |

## Shiny

Shiny name = Probabilistic detection calculator (online application)

Shiny caption = Online application used as an aid in sampling planning; calculates the probability of detecting disease (or other similar feature) with the given within-group prevalence and sample size for both finite and infinite group sizes. The detection means that at least one of the samples is detected positive. The sensitivity of the testing method can also be taken into account in the case of an imperfect test. <br>Additional information can be found here: <https://zenodo.org/records/13120206><br>

({{ ref\_intext\_mikkela\_2024 }})

Shiny URL = https://detcal-shiny.2.rahtiapp.fi/

Shiny name = smsPOMDP

Shiny caption = A Shiny r app to solve the problem of when to stop managing or surveying species under imperfect detection. <br>Additional information can be found here: <https://github.com/conservation-decisions/smsPOMDP> or <https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.13501><br>

({{ ref\_intext\_pascal\_et\_al\_2020 }})

Shiny URL = https://conservation-decisions.shinyapps.io/smsPOMDP/

## Analytical tools & resources

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type** | **Name** | **Note** | **URL** | **ref\_id** |
| R package | detect: analyzing wildlife data with detection error | The R package implements models to analyze site occupancy and count data models with detection error. The package development was supported by the Alberta Biodiversity Monitoring Institute and the Boreal Avian Modelling (BAM) Project. | <https://github.com/psolymos/detect>;<br><https://peter.solymos.org/detect> | solymos\_et\_al\_2024 |
| R Shiny app | Probabilistic detection calculator (online application) | Online application used as an aid in sampling planning; calculates the probability of detecting disease (or other similar feature) with the given within-group prevalence and sample size for both finite and infinite group sizes.<br><br> Additional information can be found here: <https://zenodo.org/records/13120206>. | Shiny app: <https://detcal-shiny.2.rahtiapp.fi/>;<br>  Related documents: <https://zenodo.org/records/13120206> | mikkela\_2024 |
| resource3\_type | resource3\_name | resource3\_note | resource3\_url | resource3\_ref\_id |
| resource4\_type | resource4\_name | resource4\_note | resource4\_url | resource4\_ref\_id |
| resource5\_type | resource5\_name | resource5\_note | resource5\_url | resource5\_ref\_id |
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| resource15\_type | resource15\_name | resource15\_note | resource15\_url | resource15\_ref\_id |

## References / Glossary

|  |  |
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| **ref\_id** |  |
| {{ ref\_bib\_rcsc\_et\_al\_2024 }}  {{ ref\_bib\_hofmeester\_et\_al\_2019 }}  {{ ref\_bib\_burton\_et\_al\_2015 }}  {{ ref\_bib\_caravaggi\_et\_al\_2020 }}  {{ ref\_bib\_chatterjee\_et\_al\_2021 }}  {{ ref\_bib\_denes\_et\_al\_2015 }}  {{ ref\_bib\_findlay\_et\_al\_2020 }}  {{ ref\_bib\_hofmeester\_et\_al\_2019 }}  {{ ref\_bib\_iknayan\_et\_al\_2014 }}  {{ ref\_bib\_jennelle\_et\_al\_2002 }}  {{ ref\_bib\_kays\_et\_al\_2021 }}  {{ ref\_bib\_mackenzie\_kendall\_2002 }}  {{ ref\_bib\_mackenzie\_royle\_2005 }}  {{ ref\_bib\_mackenzie\_et\_al\_2004 }}  {{ ref\_bib\_martin\_et\_al\_2005 }}  {{ ref\_bib\_mikkela\_2024 }}  {{ ref\_bib\_moeller\_et\_al\_2023 }}  {{ ref\_bib\_obrien\_et\_al\_2011 }}  {{ ref\_bib\_pascal\_et\_al\_2020 }}  {{ ref\_bib\_rowcliffe\_et\_al\_2011 }}  {{ ref\_bib\_shannon\_et\_al\_2014 }}  {{ ref\_bib\_solymos\_et\_al\_2024 }}  {{ ref\_bib\_tobler\_powell\_2013 }}  {{ ref\_bib\_tourani\_et\_al\_2020 }} |  |

## Notes

* It is important to understand and account for factors that affect detectability since unmeasured variation in detectability can result in the inability to differentiate the effects of detectability vs. preference (Jennelle et al., 2002).
* **MEEK -** The relationship between the target animals and the camera trap model or study design used is particularly important because design features of a camera, and the way in which it is deployed, may affect the ability to detect target species (Harmsen et al. 2009).
* Unmeasured variation in detectability can cause large errors in estimates of both occurrence and abundance (Burton et al. 2015; Dénes et al. 2015; Kays et al. 2021).
* Species with higher dispersal ability (i.e., able to travel further distances) are more likely to be absent during the survey

**- \*\*Low\*\*:**

\*For example:\*

- "Species living in groups have a higher chance of triggering the camera when they pass in front of the camera, and carnivores are known to cover a larger distance than species of other feeding guilds" (Garland, 1983)

- Species vary in emissions of infrared radiation, which can inflate relative detection rates of warmer, larger species (Wearn & Glover-Kapfer, 2017).

- [insert example "at multiple scales"]

[\*\*insert info on how this relates to study design recommendations; ideally, modelled using project data + caveat that its not going to be perfect\*\*]

[\*\*insert info on find these value; from lit or modelling\*\*]

* **A Shiny r app to solve the problem of when to stop managing or surveying species under imperfect detection <https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.13501>**

# POPULATE MARKDOWN

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text\_representation:

extension: .md

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jupytext\_version: 1.16.1

kernelspec:

display\_name: Python 3

language: python

name: python3

editor\_options:

markdown:

wrap: none

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(i\_sp\_det\_prob\_cat)=

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# {{ title\_i\_sp\_det\_prob\_cat }}

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

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

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

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

<br>\*\*Detection probability categories are defined as follows:\*\*

- \*\*Low\*\*:

- < 0.1 ({{ ref\_intext\_tobler\_powell\_2013 }})

- < 0.05 ({{ ref\_intext\_shannon\_et\_al\_2014 }})

- 0–0.37 ({{ ref\_intext\_chatterjee\_et\_al\_2021 }})

- \*\*Medium\*\*:

- 0.37–0.67 ({{ ref\_intext\_chatterjee\_et\_al\_2021 }})

- \*\*High\*\*:

- 0.67–1 ({{ ref\_intext\_chatterjee\_et\_al\_2021 }})

- \> 0.5 ({{ ref\_intext\_mackenzie\_royle\_2005 }})

- \*\*Unknown\*\*: select this option if you’re not sure of the detection probability of your [Target Species](./09\_gloss\_ref/09\_glossary.md##target\_species) (single or multiple species)

- \*\*Multiple\*\*: select this option if your study include multiple [Target Species](./09\_gloss\_ref/09\_glossary.md##target\_species).

\*\*How this relates to study design\*\*

{{ term\_detection\_probability }}\*\*: {{ term\_def\_detection\_probability }}

We use this information to adjust the recommended [camera days per camera location](./09\_gloss\_ref/09\_glossary.md#camera\_days\_per\_camera\_location) and [total number of camera days](./09\_gloss\_ref/09\_glossary.md#total\_number\_of\_camera\_days). For example, if the species is hard to detect, you may have to deploy cameras for longer to ensure you’ve sampled long enough to say that the species truly was not there (\*vs.\* it was there, but you did not detect it; “missed detections”, e.g., high cover of shrubs impeding your ability to see the species).

You may need to consult previous studies to get a sense of which category is the most appropriate for your study and Target Species.

> Select “Unknown” if you’re not sure.

:::{admonition} How does that work?

:class: note

\*\*How does that work? \*\*

Individuals and/or species are not always detected when they are present (i.e., detected "imperfectly”; ({{ ref\_intext\_mackenzie\_et\_al\_2004 }}). Missed detections occur or many reasons, including due characteristics of the environment (e.g., due to cover of vegetation), the time period (e.g., seasons), characteristics of the species (e.g., cryptic nature or small size), etc. \*\*The question here is asking about detection probability as it relates to the characteristics of the species (not the species in a particular habitat type or during a specific season).\*\*

```{image} ../03\_images/03\_image\_files/det.gif

:width: 200px

:align: center

```

:::{image} ../03\_images/03\_image\_files/det.gif

:width: 400px

:align: center

:::

\*\*Why do we care?\*\*

We care about this because when you fail to detect an individual/species that was, in fact, present, this is called a “false absence”, which may lead to incorrect conclusions from the data. Understanding and correcting for sources of this type of error is often thought of in terms of probabilities (i.e., "detection probability" aka detectability).

:::

:::{admonition} It’s not an exact science

:class: warning

\

Since detectability is affected by many other processes, detectability is best incorporated from models that use your data since this will result in the best suited information to inform your design; however, when you are first designing your study, this is not possible…..[insert more here]

:::

:::{admonition} Analysis aside

:class: seealso

\

Many sources of detection error can be accounted for in analysis; this is done by assessing the relationships between the characteristics of the environment that we might expect to affect detection (e.g., cover of shrubs in front of the camera), and information on where (and when) the species was and was not detected. For example, there were consistently fewer detections on cameras placed in high shrub cover.

By assessing the relationships at locations repeatedly sampled over time, we begin to unravel the relationship between the environmental characteristics and missed detections on your cameras. We can then use this information to determine if we have sampled long enough (i.e., do we have enough information to differentiate between missed detections and true absences) and/or correct for this error in analysis by incorporating these effects in our models.

#### :::::::::

#### ::::::{tab-item} AdvancedBefore study design choices are made, there is one critical concept to understand in remote camera research, which may impact study design choices at all levels of the data hierarchy. Reliable use of remote cameras to detect wildlife species hinges on the [assumption](/09\_gloss\_ref/09\_glossary.md#mods\_modelling\_assumption) that what is captured on the cameras accurately reflects what is present on the landscape. However, species are often detected "imperfectly," meaning that they are not always detected when they are present (i.e., [imperfect detection](/09\_gloss\_ref/09\_glossary.md#imperfect\_detection); e.g., due to cover of vegetation, cryptic nature or small size) ({{ ref\_intext\_mackenzie\_et\_al\_2004 }}). [Imperfect detection](/09\_gloss\_ref/09\_glossary.md#imperfect\_detection) can occur because the camera failed to capture an individual present at the site or because the animal was simply not present during the [survey](/09\_gloss\_ref/09\_glossary.md#survey) period ({{ ref\_intext\_martin\_et\_al\_2005 }}).

[Imperfect detection](/09\_gloss\_ref/09\_glossary.md#imperfect\_detection) results in “false absences” and may lead to incorrect conclusions from the data. Understanding and correcting for sources of “false absences” is often thought of in terms of probabilities. [Detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) is the probability (likelihood) that an individual from the population of interest is included in the count at time or location \*i\* ({{ ref\_intext\_mackenzie\_kendall\_2002 }}). [Detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) can be influenced through multiple processes and at multiple scales. Understanding the sources of “false absences” and factors that affect [detection probabilities](/09\_gloss\_ref/09\_glossary.md#detection\_probability) is an essential step when designing a study, deploying cameras and analyzing camera data.

**The** [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) of an animal by a camera depends on three \*\*conditional probabilities (Pr) of detection\*\* that may operate alone or potentially in combination ([Figure 1](#TOC\_surv\_guidelines\_fig\_1)).

(TOC\_surv\_guidelines\_fig\_1)=

```{figure} ../03\_images/03\_image\_files/rcsc\_et\_al\_2024\_detection\_probability\_2023\_05\_04\_clipped.jpg

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:columns: 10

<font size="2">\*\*RCSC et al. (2024) - Fig. 1.\*\* Three conditional probabilities (Pr) of detection that may impact the [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) of an animal (or species) by a camera (adapted from Moeller et al. \[2023\], Hofmeester et al. \[2019\], and Findlay et al. \[2020\]).</font>

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<span style="color:white">...</font>

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[Detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) can be affected by species-specific characteristics, [Camera Model](/09\_gloss\_ref/09\_glossary.md#camera\_model) specifications and set-up, and environmental variables ({{ ref\_intext\_hofmeester\_et\_al\_2019 }}). For example, \*\*species-specific characteristics\*\* (individuals or populations), such as body size (e.g., {{ ref\_intext\_obrien\_et\_al\_2011 }}), behaviour (e.g., {{ ref\_intext\_caravaggi\_et\_al\_2020 }}; {{ ref\_intext\_rowcliffe\_et\_al\_2011 }}), and rarity can influence [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability), with larger, bolder and more common species generally having higher [detection rates](/09\_gloss\_ref/09\_glossary.md#detection\_rate). [\*\*Camera Model\*\*](/09\_gloss\_ref/09\_glossary.md#camera\_model) \*\*specifications and set-up\*\*, such as the [Trigger Sensitivity](/09\_gloss\_ref/09\_glossary.md#settings\_trigger\_sensitivity), [Camera Height](/09\_gloss\_ref/09\_glossary.md#camera\_height), or [angle](/09\_gloss\_ref/09\_glossary.md#camera\_angle) may affect [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) in that smaller species might not be detected or identifiable if the [Trigger Sensitivity](/09\_gloss\_ref/09\_glossary.md#settings\_trigger\_sensitivity) is low, or the [Camera Height](/09\_gloss\_ref/09\_glossary.md#camera\_height) or [angle](/09\_gloss\_ref/09\_glossary.md#camera\_angle) is too high. The [Camera Direction](/09\_gloss\_ref/09\_glossary.md#camera\_direction) could impact the probability of an animal triggering a camera if it is directed towards an object that impedes the [Field of View (FOV)](/09\_gloss\_ref/09\_glossary.md#field\_of\_view) or image quality (e.g. due to sun glare). \*\*Environmental factors\*\* (e.g., vegetation cover, snow depth) may affect [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) and occurrence (e.g., {{ ref\_intext\_becker\_et\_al\_2022 }}; {{ ref\_intext\_hofmeester\_et\_al\_2019 }}; {{ ref\_intext\_iknayan\_et\_al\_2014 }}; {{ ref\_intext\_steenweg\_et\_al\_2019 }}). For example, a low number of detections in a densely vegetated site might be because of poor camera visibility or avoidance of this habitat by the species of interest.

Hofmeester et al. (2019) suggested there are \*\*six scales (orders) that may impact\*\* [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) and that should be considered within an explicit time period (adapted from Hofmeester et al. \[2019\]; [Figure 2](#TOC\_surv\_guidelines\_fig\_2)):

1) \*\*Distribution range\*\* (1st order; i.e., the physical or geographical range of a species)

2) \*\*Landscape\*\* (2nd order; i.e., the location of an individual’s home range within the geographic range)

3) \*\*Habitat patch\*\* (3rd order; i.e., usage of habitat components within an individual’s home range)

4) \*\*Microsite\*\* (4th order; usage of microhabitats such as food items/feeding patches/nest sites/movement trails, etc. within a habitat)

5) \*\*Camera specification / set-up\*\* (5th order; i.e., factors that affect the probability that an animal [triggers](/09\_gloss\_ref/09\_glossary.md#trigger\_event) the camera if present)

6) \*\*Image\*\* (6th order; i.e., factors that affect correct identification of animals or individuals)

(TOC\_surv\_guidelines\_fig\_2)=

```{figure} ../03\_images/03\_image\_files/rcsc\_et\_al\_2024\_detectionprob\_hofmeester\_et\_al\_2019\_fig1\_clipped.png

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:columns: 10

<font size="2">\*\*Figure 2.\*\* Spatial scales (1-6) and processes that determine the [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) ({{ ref\_intext\_hofmeester\_et\_al\_2019 }}; abbreviated figure caption).</font>

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It is important to consider how all these factors and scales will impact study design. Unmeasured variation in [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) can result in the inability to differentiate the effects of [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) \*vs.\* habitat preference ({{ ref\_intext\_jennelle\_et\_al\_2002 }}) and, in turn, cause erroneous estimates of occurrence and abundance ({{ ref\_intext\_burton\_et\_al\_2015 }}; {{ ref\_intext\_denes\_et\_al\_2015 }}; {{ ref\_intext\_kays\_et\_al\_2021 }}).

#### Factors that influence [detection probability](/09\_gloss\_ref/09\_glossary.md#detection\_probability) at the microsite and camera specification / set-up scales are likely to result in the largest biases and thus warrant the most consideration (see Hofmeester et al. [2019] for details). Therefore, it is particularly important to consider \*how\* to place cameras to avoid such biases. Deploying cameras in a consistent fashion (e.g., carefully ensuring that cameras are always set at the same [Camera Height](/09\_gloss\_ref/09\_glossary.md#camera\_height), orientation ([direction](/09\_gloss\_ref/09\_glossary.md#camera\_direction)), and [angle](/09\_gloss\_ref/09\_glossary.md#camera\_angle) is essential.::::::

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

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###### ::::{grid-item-card} {{ ref\_intext\_rcsc\_et\_al\_2024 }}

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```

<font size="2">\*\*RCSC et al. (2024) - Fig. 1.\*\* Three conditional probabilities (Pr) of detection that may impact the detection probability of an animal (or species) by a camera (adapted from Moeller et al. [2023], Hofmeester et al. [2019], and Findlay et al. [2020]).</font>

###### ::::

###### ::::{grid-item-card} {{ ref\_intext\_rcsc\_et\_al\_2024 }}

```{figure} ../03\_images/03\_image\_files/rcsc\_et\_al\_2024\_detectionprob\_hofmeester\_et\_al\_2019\_fig1\_clipped.png

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```

<font size="2">\*\*RCSC et al. (2024) - Fig. 2.\*\* Spatial scales (1-6) and processes that determine the detection probability (Hofmeester et al., 2019; abbreviated figure caption).</font>

###### ::::

###### ::::{grid-item-card} {{ ref\_intext\_tourani\_et\_al\_2020 }}

```{figure} ../03\_images/03\_image\_files/tourani\_et\_al\_2020\_fig1\_clipped.png

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```

<font size="2">\*\*Tourani et al., (2020) - Fig. 1\*\* Conceptual diagram showing different aspects of detectability during camera trap surveys and the modulating effect of biological characteristics. In addition to direct impacts on detectability, a longer visit and a closer image of focal species increase the chance of identifying the visitor, thereby increasing detectability. [Colour figure can be viewed at zslpublications.onlinelibrary.wiley.com].</font>

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###### ::::{grid-item-card} {{ ref\_intext\_iknayan\_et\_al\_2014 }}

```{figure} ../03\_images/03\_image\_files/iknayan\_et\_al\_2014\_fig2\_clipped.png

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<font size="2">\*\*Iknayan et al., (2020) - Fig. 2\*\* - Categories of species at surveyed sites resulting from imperfect detection and how they change with different temporal and spatial sampling strategies. (A) The true (unknown) species pool of a metacommunity represented at a site comprises species that have been detected there (green bin), those that have not yet been detected at the site but have been detected at other surveyed sites (yellow bin), and those that have not yet been detected at this or any site but occur in the region (white bin). (B) As temporal and spatial replication (i.e., sampling effort) increases, knowledge of the species pool changes for both the site (green bins) and the metacommunity (green + yellow + white bins). When a site is surveyed few times, the relative size of each bin depends on the factors affecting detectability (Figure 1). If there are few sites and few surveys per site, a large portion of the metacommunity may not be detected (white bin of upper left rectangle), either at the site or at other sites. As the number of surveys per site increases (temporal replication) but not the number of sites surveyed (i.e., little spatial replication), the total number of species detected per site increases (green bin in upper right rectangle), mostly as a result of detecting species that are likely to occur at other sites (yellow bin). When the total number of sites surveyed increases (spatial replication) but not the number of surveys (i.e., little temporal replication), the number of species undetected in the region decreases (white bin in lower left rectangle), but the number of species detected per site remains the same (green bin). As both the number of surveys per site and the number of sites surveyed increase, a greater proportion of species in the metacommunity will be known (green + yellow bins in lower right rectangle), either from being directly detected at the site (green bin) or by being detected at other sites (yellow bin).</font>

###### ::::

###### ::::{grid-item-card} {{ ref\_intext\_oconnell\_et\_al\_2011 }}

```{figure} ../03\_images/03\_image\_files/oconnell\_et\_al\_2011\_fig6\_1\_clipped.png

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```

<font size="2">\*\*O’Connell et al. (2011) - Fig. 6.1\*\* The cumulative likelihood of capturing an individual with a Pr(detection) per sampling occasion = \*p\* over \*K\* = 1 ... 30 sampling occasions. As \*p\* and \*K\* increase, the likelihood of detection approaches 1.</font>

###### ::::

###### ::::{grid-item-card} {{ ref\_intext\_findlay\_et\_al\_2020 }}

```{figure} ../03\_images/03\_image\_files/findlay\_et\_al\_2020\_fig1\_clipped.png

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```

<font size="2">\*\*Findlay et al. (2020) - Fig. 1\*\* The sequential processes required to detect an animal on a cameratrap given that it is present. Failure of any of these processes leads to a false-negative; therefore, detection success requires a positive outcome from all the component processes. Specific terminology we use in this study to quantify these processes is also shown. ‘Detection probability’ can thus be considered the product of a series of conditional probabilities representing each of these processes.</font>

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###### ::::{grid-item-card} {{ ref\_intext\_findlay\_et\_al\_2020 }}

```{figure} ../03\_images/03\_image\_files/findlay\_et\_al\_2020\_fig8\_clipped.png

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```

<font size="2">\*\*Findlay et al. (2020) - Fig. 8\*\* Hypothesized mechanism showing how distance to camera-trap (CT) can interact with animal speed to influence registration probability. Registration probability is positively affected by distance due to the larger area within the field-of-view at greater distances. Conversely, faster moving animals can completely pass through the small width of the field-ofview close to the CT before the camera takes an image</font>

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

```{figure} ../03\_images/03\_image\_files/burton\_et\_al\_2015\_fig1.jpg

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```

<font size="2">\*\*Burton et al. (2015) - Fig. 1.\*\* The detection of animals by camera traps is affected by ecological and observational processes occurring at both the local scale of the camera trap detection zone and the broader scale of the surrounding landscape. Explicitly accounting for these underlying processes is an important challenge for wildlife surveys with camera traps. (Image by Jeff Dixon).</font>

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

```{figure} ../03\_images/03\_image\_files/figure9\_filename.png

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<font size="2">figure9\_caption</font>

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<font size="2">figure10\_caption</font>

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<font size="2">figure11\_caption</font>

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<font size="2">figure12\_caption</font>

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###### ::::{grid-item-card} {{ ref\_intext\_turlapaty\_2014 }}

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frameborder="0"

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

allowfullscreen>

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<font size="2">Probability of Detection: Eg 01</font>

###### ::::

###### ::::{grid-item-card} {{ ref\_intext\_vid2\_ref\_id }}

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<font size="2">vid2\_caption</font>

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allowfullscreen>

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<font size="2">vid5\_caption</font>

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###### ::::{grid-item-card} {{ ref\_intext\_vid6\_ref\_id }}

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allowfullscreen>

</iframe>

<font size="2">vid6\_caption</font>

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

##### :::::{card}

::::{dropdown} \*\*Probabilistic detection calculator (online application)\*\*

Online application used as an aid in sampling planning; calculates the probability of detecting disease (or other similar feature) with the given within-group prevalence and sample size for both finite and infinite group sizes. The detection means that at least one of the samples is detected positive. The sensitivity of the testing method can also be taken into account in the case of an imperfect test. <br><br> Additional information can be found here: <https://zenodo.org/records/13120206><br><br>

({{ ref\_intext\_mikkela\_2024 }})

<iframe

width="100%"

height="900"

src="https://detcal-shiny.2.rahtiapp.fi/"

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allowfullscreen>

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::::{dropdown} smsPOMDP

A Shiny r app to solve the problem of when to stop managing or surveying species under imperfect detection. <br><br> Additional information can be found here: <https://github.com/conservation-decisions/smsPOMDP> or <https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.13501><br><br>

({{ ref\_intext\_pascal\_et\_al\_2020 }})

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

| Type | Name | Note | URL |Reference |

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

| R package | detect: analyzing wildlife data with detection error | The R package implements models to analyze site occupancy and count data models with detection error. The package development was supported by the Alberta Biodiversity Monitoring Institute and the Boreal Avian Modelling (BAM) Project. | <https://github.com/psolymos/detect>;<br><https://peter.solymos.org/detect> | {{ ref\_bib\_solymos\_et\_al\_2024 }} |

| R Shiny app | Probabilistic detection calculator (online application) | Online application used as an aid in sampling planning; calculates the probability of detecting disease (or other similar feature) with the given within-group prevalence and sample size for both finite and infinite group sizes.<br><br> Additional information can be found here: <https://zenodo.org/records/13120206>. | Shiny app: <https://detcal-shiny.2.rahtiapp.fi/>;<br>

Related documents: <https://zenodo.org/records/13120206> | {{ ref\_bib\_mikkela\_2024 }} |

| resource3\_type | resource3\_name | resource3\_note | resource3\_url | {{ ref\_bib\_resource3\_ref\_id }} |

| resource4\_type | resource4\_name | resource4\_note | resource4\_url | {{ ref\_bib\_resource4\_ref\_id }} |

| resource5\_type | resource5\_name | resource5\_note | resource5\_url | {{ ref\_bib\_resource5\_ref\_id }} |

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

| resource13\_type | resource13\_name | resource13\_note | resource13\_url | {{ ref\_bib\_resource13\_ref\_id }} |

| resource14\_type | resource14\_name | resource14\_note | resource14\_url | {{ ref\_bib\_resource14\_ref\_id }} |

| resource15\_type | resource15\_name | resource15\_note | resource15\_url | {{ ref\_bib\_resource15\_ref\_id }} |

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

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

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

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

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

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

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

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

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

{{ ref\_bib\_iknayan\_et\_al\_2014 }}

{{ ref\_bib\_jennelle\_et\_al\_2002 }}

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

{{ ref\_bib\_mackenzie\_kendall\_2002 }}

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{{ ref\_bib\_mackenzie\_et\_al\_2004 }}

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

{{ ref\_bib\_mikkela\_2024 }}

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

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

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

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

{{ ref\_bib\_shannon\_et\_al\_2014 }}

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

{{ ref\_bib\_tobler\_powell\_2013 }}

{{ ref\_bib\_tourani\_et\_al\_2020 }}</font>

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