## Topic Info

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| **info\_id** | mod\_behaviour |

## Note banner

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behaviour focused objectives vary greatly; they may be qualitative or quantitative (e.g., diel activity patterns, mating, boldness, predation, foraging, activity patterns, vigilance, parental care \[{{ rtxt\_caravaggi\_et\_al\_2022 }}; {{ rtxt\_wearn\_gloverkapfer\_2017 }}\]).

vigilance - Schuttler et al. 2017

## Overview

```{include} include/00\_coming\_soon.md

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## In-depth

```{include} include/00\_coming\_soon.md

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## Figures

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| **Image** | **file\_name** | **Caption (if applicable)** | **ref\_id** |
|  | caravaggi\_et\_al\_2017\_fig1\_clipped.png | \*\*Caravaggi et al. (2017) - Fig. 1.\*\* Examples of animal behaviour captured by camera traps:  :::{dropdown}  (A) Scent marking by an American black bear (\*Ursus americanus\*); (B) intraspecific competition in moose (\*Alces alces\*); (C) interspecific interactions between a European hare (\*Lepus europaeus\*; anti-predator response), a common buzzard (\*Buteo buteo\*; avoidance and attempted predation) and a hooded crow (\*Corvus cornix\*; anti-predator behaviour) captured on video (available at 10.6084/m9.figshare.4508369); (D) predation of a European rabbit (\*Oryctolagus cuniculus\*) by a red fox (\*Vulpes vulpes\*); (E) investigation of a squirrel feeding station by a pine marten (\*Martes martes\*); (F) nut caching by a grey squirrel (\*Sciurus carolinensis\*). Images provided by A.C. Burton (a, b), A. Caravaggi (c, d) and C.M.V. Finlay (e, f).  ::: | caravaggi\_et\_al\_2017 |
|  | caravaggi\_et\_al\_2020\_fig1\_clipped.png | \*\*Caravaggi et al. (2020) - Fig 1.\*\* Examples of mammals detecting camera traps and/or olfactory cues associated with camera traps.  :::{dropdown}  (a) Chimpanzee, \*Pan troglodytes\*; (b) African elephant, \*Loxodonta africana\*; (c) sitatunga, \*Tragelaphus spekii\*; (d) moose, \*Alces alces\*; (e) Eurasian lynx, \*Lynx lynx\*; (f) polar bear, \*Ursus maritimus\*; (g) roe deer, \*Capreolus capreolus\*; (h) African leopard, \*Panthera pardus\*; (i) mountain gorilla, \*Gorilla beringei\*; (j) red fox, \*Vulpes vulpes\*; (k) wolverine, \*Gulo gulo\*; (l) grizzly bear, \*Ursus arctos\*; (m) spotted hyena, \*Crocuta crocuta\*; (n) red deer, \*Cervus elaphus\*; (o) grey wolf, \*Canis lupus\*. Images provided by Ammie K. Kalan (a–c,i), T. R. H. (d,e), D. R. (f,o), S. G. (g,n), A. C. (h,j), J. T. F. (k,l), A. G. (m). Visit <https://doi.org/10.6084/m9.figshare.c.4593902.v1> for selected source video.  ::: | caravaggi\_et\_al\_2020 |
|  | delisle\_et\_al\_2023\_fig1.jpg | \*\*Delisle et al. (2023) - Fig 1\*\* Conceptual movement paths in which animals exhibit a variety of different reactive behaviours towards camera traps: (A) attraction towards the camera trap; (B) freezing normal travel; (C) fleeing in response to being detected by the camera trap; and (d) fleeing in response to the presence of the camera trap regardless of being detected. Panels depicting actual animals exhibiting a variety of reactive behaviours towards camera traps: (A) white-tailed deer (\*Odocoileus virginianus\*) that is attracted towards the camera trap; (B) white-tailed deer that freezes in front of a camera trap; and (C) coyote (\*Canis latrans\*) that flees in response to being detected by a camera trap. | delisle\_et\_al\_2023 |
|  | delisle\_et\_al\_2023\_fig2.jpg | \*\*Delisle et al. (2023) - Fig 2\*\* The average density estimates (animals/km<sup>2</sup> ± 95% confidence intervals [CI]) from detections of simulated animals at camera traps across 100 total simulations for each reaction type.  :::{dropdown}  Densities were estimated using camera trap distance sampling (CTDS; a) and the random encounter model (REM; b). Simulated populations contained a fraction of the population (reactive individuals in the population [%]) that froze in response to cameras (Freezing), fled from the camera when the camera detected the individual (Fleeing if detected), fled from the camera regardless of being detected by the camera (Fleeing) and were attracted to cameras (Attraction). Additionally, we simulated a population that did not contain any reactive individuals (None). For each density estimate, we enacted a specific method to reduce bias associated with reactive movement (Method). Methods for CTDS included doing nothing (Naïve), removing detections of reactive individuals from consideration (Removal), ignoring the hazard rate key function (Ignore HR), combining Ignore HR and Removal, and using the ratio of average number of detections of reactive and nonreactive individuals as a multiplier (Multiplier). Methods for REM included doing nothing (Naïve), removing reactive encounters when estimating the speed parameter (Removal for speed), removing reactive encounters when estimating the speed parameter and the effective detection distance (Removal for speed +EDD) and removing reactive encounters when estimating the speed parameter, effective detection distance and the encounter rate (Removal for speed +EDD + ER). The grey dotted line represents true density (10 animals/km<sup>2</sup>). Some density estimates are above the upper limit of the y-axis due to severe bias (see Tables S1 and S2 for these estimates and the extent of their confidence intervals in the Supporting Information).  ::: | delisle\_et\_al\_2023 |
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## Video

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| vid5\_caption | vid5\_url | vid5\_ref\_id |
| vid6\_caption | vid6\_url | vid6\_ref\_id |

## Shiny

Shiny name = Diel.Niche Shinyapp

Shiny caption = RShiny implementation of Diel.Niche. See Gerber et al. A model-based hypothesis framework to define and estimate the diel niche via the `Diel.Niche' R package. <br>{{ rbib\_gerber\_et\_al\_2023 }}

Shiny URL = <https://shiny.uri.edu/bgerber/DielNiche/>

Shiny name = Zone of Influence Effect Size and Buffer Distance Calculator

Shiny caption =This tool can identify optimal buffer distances for recreational features, such as hiking trails, in natural areas inhabited by grizzly bears and wolves, using the outputs of camera trap modelling work from the Canadian Rockies of Alberta. The models assessed the impact of faraway human use on trails relative to human use at a focal location to estimate the zone of influence of human use on each of these wary species.<br>{{ rbib\_thompson\_2024 }}

Shiny URL = https://pthompson234.shinyapps.io/calculate-zoi/

## Analytical tools & resources

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| **Type** | **Name** | **Note** | **URL** | **ref\_id** |
| Paper | A model-based hypothesis framework to define and estimate the diel niche via the ‘Diel.Niche’ R package | /- | <https://www.biorxiv.org/content/10.1101/2023.06.21.545898v1> | gerber\_et\_al\_2023 |
| R package | Diel-Niche-Modeling | "An R package to evaluate hypotheses of diel phenotypes based on empirical data and estimate the probabilitiy of activity during the crepuscular, daytime, and nighttime periods." | <https://github.com/diel-project/Diel-Niche-Modeling> | gerber\_et\_al\_2023 |
| R Shiny | Diel.Niche Shinyapp | "RShiny implementation of Diel.Niche. See Gerber et al. A model-based hypothesis framework to define and estimate the diel niche via the `Diel.Niche' R package." | <https://shiny.celsrs.uri.edu/bgerber/DielNiche/> | gerber\_et\_al\_2023 |
| Tutorial | An Introduction to Camera Trap Data Management and Analysis in R > Chapter 14 Behavior |  | <https://bookdown.org/c\_w\_beirne/wildCo-Data-Analysis/behavior.html> | wildco\_lab\_2021e |
| R Package | 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/package=activity> | rowcliffe\_2023 |
| Article | A simple statistical guide for the analysis of behaviour when data are constrained due to practical or ethical reasons |  | <https://www.researchgate.net/publication/289569231\_A\_simple\_statistical\_guide\_for\_the\_analysis\_of\_behaviour\_when\_data\_are\_constrained\_due\_to\_practical\_or\_ethical\_reasons> | garamszegi\_2016 |
| Article / Tutorial / R Code | A “How-to” Guide for Estimating Animal Diel Activity Using Hierarchical Models | Companion manuscript, tutorial and R Code;  "The tutorial includes step-by-step examples on how to use trigonometric and cyclic cubic spline hierarchical models to analyze activity patterns from time-stamped data. We present case studies based on camera-trap data, but these approaches can be applied to data collected via other static sensors (e.g., acoustic recorders)." ({{ rtxt\_iannarilli\_et\_al\_2024b }}). | - <b>Article</b>: <https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2656.14213?af=R><br>- <b>Tutorial</b>: <https://hms-activity.netlify.app/><br>- <b>R Code</b>: <https://github.com/FabiolaIannarilli/HMs\_Activit> | iannarilli\_et\_al\_2024a; rtxt\_iannarilli\_et\_al\_2024b |
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## References / Glossary

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| **ref\_id** |  |
| { rbib\_caravaggi\_et\_al\_2017 }}  {{ rbib\_caravaggi\_et\_al\_2020 }}  {{ rbib\_gerber\_et\_al\_2023 }}  {{ rbib\_meek\_et\_al\_2014b }}  {{ rbib\_wildco\_lab\_2021d }} |  |

## Notes

* The focus of the study could be on a particular location (such as a lekking site or a fruiting tree) or on a particular species. However, as for the study types we have considered above, the starting point is to establish what the key assumptions of the modelling are, and then design the sampling appropriately with this in mind.
* For example, imagine you are interested in the rate at which a given behaviour occurs in a species (e.g. vigilance: Schuttler et al. 2017), and how this differs across major habitat types in your study area. If your aim was to make inferences about the population in your study area as a whole, then you would want to take a representative sample of individuals, and you would want to observe them at random locations and random times of the day. All of this could be achieved using random sampling points, stratified by habitat type, with camera traps set to trigger throughout the 24 hr period. Cameras would ideally be sufficiently spaced apart to obtain samples from lots of different individuals (e.g. 1 km apart, depending on the species). Similarly, the number of sampling points, and how long each is sampled for, would have to be sufficient in order to obtain a reasonable number of behavioural observations in each habitat type (> 20 per {{ strata\_tl\_pl }} would be a sensible minimum target). The length of the study would ideally not be too long, for example restricted to a single season, so as to provide a snapshot of the prevalence of the behaviour in different habitat types in the absence of any temporal trends in the behaviour (temporal or seasonal trends could be a focus of follow-up surveys). This basic approach to sampling design for a behavioural study would be suitable for the study of activity patterns, which is a common use of camera traps. In this case, some aspects of sample size have been investigated (Ridout & Linkie 2009; Rowcliffe et al. 2014). This work suggests that a sample size of 20-25 observations will offer useful insights into activity patterns over a 24 hr period, but that larger samples (> 100) will be needed to characterise the activity patterns with any reasonable level of precision, especially if the pattern has a complicated shape (Ridout & Linkie 2009; Rowcliffe et al. 2014).
* species interactions and niche partitioning via comparisons of co-occurrence and activity patterns (de Almeida Jacomo et al. 2004; Kukielka et al. 2013; Farris et al. 2014; Wang et al. 2015; Bu et al. 2016; Cusack et al. 2016; Sweitzer and Furnas 2016).

##### POPULATE – MOD

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::::::{tab-item} Overview  
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::::::{tab-item} In-depth  
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::::::{tab-item} Visual resources

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\*\*Caravaggi et al. (2017) - Fig. 1.\*\* Examples of animal behaviour captured by camera traps:

:::{dropdown}

(A) Scent marking by an American black bear (\*Ursus americanus\*); (B) intraspecific competition in moose (\*Alces alces\*); (C) interspecific interactions between a European hare (\*Lepus europaeus\*; anti-predator response), a common buzzard (\*Buteo buteo\*; avoidance and attempted predation) and a hooded crow (\*Corvus cornix\*; anti-predator behaviour) captured on video (available at 10.6084/m9.figshare.4508369); (D) predation of a European rabbit (\*Oryctolagus cuniculus\*) by a red fox (\*Vulpes vulpes\*); (E) investigation of a squirrel feeding station by a pine marten (\*Martes martes\*); (F) nut caching by a grey squirrel (\*Sciurus carolinensis\*). Images provided by A.C. Burton (a, b), A. Caravaggi (c, d) and C.M.V. Finlay (e, f).

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\*\*Caravaggi et al. (2020) - Fig 1.\*\* Examples of mammals detecting camera traps and/or olfactory cues associated with camera traps.

:::{dropdown}

(a) Chimpanzee, \*Pan troglodytes\*; (b) African elephant, \*Loxodonta africana\*; (c) sitatunga, \*Tragelaphus spekii\*; (d) moose, \*Alces alces\*; (e) Eurasian lynx, \*Lynx lynx\*; (f) polar bear, \*Ursus maritimus\*; (g) roe deer, \*Capreolus capreolus\*; (h) African leopard, \*Panthera pardus\*; (i) mountain gorilla, \*Gorilla beringei\*; (j) red fox, \*Vulpes vulpes\*; (k) wolverine, \*Gulo gulo\*; (l) grizzly bear, \*Ursus arctos\*; (m) spotted hyena, \*Crocuta crocuta\*; (n) red deer, \*Cervus elaphus\*; (o) grey wolf, \*Canis lupus\*. Images provided by Ammie K. Kalan (a–c,i), T. R. H. (d,e), D. R. (f,o), S. G. (g,n), A. C. (h,j), J. T. F. (k,l), A. G. (m). Visit <https://doi.org/10.6084/m9.figshare.c.4593902.v1> for selected source video.

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\*\*Delisle et al. (2023) - Fig 1\*\* Conceptual movement paths in which animals exhibit a variety of different reactive behaviours towards camera traps: (A) attraction towards the camera trap; (B) freezing normal travel; (C) fleeing in response to being detected by the camera trap; and (d) fleeing in response to the presence of the camera trap regardless of being detected. Panels depicting actual animals exhibiting a variety of reactive behaviours towards camera traps: (A) white-tailed deer (\*Odocoileus virginianus\*) that is attracted towards the camera trap; (B) white-tailed deer that freezes in front of a camera trap; and (C) coyote (\*Canis latrans\*) that flees in response to being detected by a camera trap.  
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\*\*Delisle et al. (2023) - Fig 2\*\* The average density estimates (animals/km<sup>2</sup> ± 95% confidence intervals [CI]) from detections of simulated animals at camera traps across 100 total simulations for each reaction type.

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Densities were estimated using camera trap distance sampling (CTDS; a) and the random encounter model (REM; b). Simulated populations contained a fraction of the population (reactive individuals in the population [%]) that froze in response to cameras (Freezing), fled from the camera when the camera detected the individual (Fleeing if detected), fled from the camera regardless of being detected by the camera (Fleeing) and were attracted to cameras (Attraction). Additionally, we simulated a population that did not contain any reactive individuals (None). For each density estimate, we enacted a specific method to reduce bias associated with reactive movement (Method). Methods for CTDS included doing nothing (Naïve), removing detections of reactive individuals from consideration (Removal), ignoring the hazard rate key function (Ignore HR), combining Ignore HR and Removal, and using the ratio of average number of detections of reactive and nonreactive individuals as a multiplier (Multiplier). Methods for REM included doing nothing (Naïve), removing reactive encounters when estimating the speed parameter (Removal for speed), removing reactive encounters when estimating the speed parameter and the effective detection distance (Removal for speed +EDD) and removing reactive encounters when estimating the speed parameter, effective detection distance and the encounter rate (Removal for speed +EDD + ER). The grey dotted line represents true density (10 animals/km<sup>2</sup>). Some density estimates are above the upper limit of the y-axis due to severe bias (see Tables S1 and S2 for these estimates and the extent of their confidence intervals in the Supporting Information).

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::::::{tab-item} Shiny apps/Widgets  
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::::{dropdown} Diel.Niche Shinyapp  
RShiny implementation of Diel.Niche. See Gerber et al. A model-based hypothesis framework to define and estimate the diel niche via the `Diel.Niche' R package. <br>{{ rbib\_gerber\_et\_al\_2023 }}

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::::  
::::{dropdown} Zone of Influence Effect Size and Buffer Distance Calculator  
This tool can identify optimal buffer distances for recreational features, such as hiking trails, in natural areas inhabited by grizzly bears and wolves, using the outputs of camera trap modelling work from the Canadian Rockies of Alberta. The models assessed the impact of faraway human use on trails relative to human use at a focal location to estimate the zone of influence of human use on each of these wary species.<br>{{ rbib\_thompson\_2024 }}

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:::::{tab-item} Analytical tools & Resources  
| Type | Name | Note | URL |Reference |  
|:----------------|:-------------------------------|:----------------------------------------------------------------|:----------------------|:----------------------------------------|  
| Paper | A model-based hypothesis framework to define and estimate the diel niche via the ‘Diel.Niche’ R package | /- | <https://www.biorxiv.org/content/10.1101/2023.06.21.545898v1> | {{ rbib\_gerber\_et\_al\_2023 }} |  
| R package | Diel-Niche-Modeling | "An R package to evaluate hypotheses of diel phenotypes based on empirical data and estimate the probabilitiy of activity during the crepuscular, daytime, and nighttime periods." | <https://github.com/diel-project/Diel-Niche-Modeling> | {{ rbib\_gerber\_et\_al\_2023 }} |  
| R Shiny | Diel.Niche Shinyapp | "RShiny implementation of Diel.Niche. See Gerber et al. A model-based hypothesis framework to define and estimate the diel niche via the `Diel.Niche' R package." | <https://shiny.celsrs.uri.edu/bgerber/DielNiche/> | {{ rbib\_gerber\_et\_al\_2023 }} |  
| Tutorial | An Introduction to Camera Trap Data Management and Analysis in R > Chapter 14 Behavior | | <https://bookdown.org/c\_w\_beirne/wildCo-Data-Analysis/behavior.html> | {{ rbib\_wildco\_lab\_2021e }} |  
| R Package | 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/package=activity> | {{ rbib\_rowcliffe\_2023 }} |  
| Article | A simple statistical guide for the analysis of behaviour when data are constrained due to practical or ethical reasons | | <https://www.researchgate.net/publication/289569231\_A\_simple\_statistical\_guide\_for\_the\_analysis\_of\_behaviour\_when\_data\_are\_constrained\_due\_to\_practical\_or\_ethical\_reasons> | {{ rbib\_garamszegi\_2016 }} |  
| Article / Tutorial / R Code | A “How-to” Guide for Estimating Animal Diel Activity Using Hierarchical Models | Companion manuscript, tutorial and R Code;

"The tutorial includes step-by-step examples on how to use trigonometric and cyclic cubic spline hierarchical models to analyze activity patterns from time-stamped data. We present case studies based on camera-trap data, but these approaches can be applied to data collected via other static sensors (e.g., acoustic recorders)." ({{ rtxt\_iannarilli\_et\_al\_2024b }}). | - <b>Article</b>: <https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2656.14213?af=R><br>- <b>Tutorial</b>: <https://hms-activity.netlify.app/><br>- <b>R Code</b>: <https://github.com/FabiolaIannarilli/HMs\_Activit> | {{ rbib\_iannarilli\_et\_al\_2024a; rtxt\_iannarilli\_et\_al\_2024b }} |  
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<!-- END\_RESOURCE\_TABLE -->  
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::::::{tab-item} References  
{ rbib\_caravaggi\_et\_al\_2017 }}

{{ rbib\_caravaggi\_et\_al\_2020 }}

{{ rbib\_gerber\_et\_al\_2023 }}

{{ rbib\_meek\_et\_al\_2014b }}

{{ rbib\_wildco\_lab\_2021d }}   
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