Inferring interactions from camera trap data with the multivariate Hawkes process

Lisa Nicvert *FRB-CESAB, Montpellier*

@lisanicvert.bsky.social

Lisa Nicvert

CESCO seminar "café scienti"

13/01/2025

About me

Here icons: Freepik from Flaticon | Other drawings: © own work

About me

Lyon, France

Dijon, France

Engineer undergraduate studies

2015-2017

Engineer degree

2017-2020
Biostatistics and bioinformatics

Masters degree

2019-2020
Ecology, evolution, genomics

Here icons: Freepik from Flaticon | Other drawings: © own work

About me

Lyon, France

Masters degree

2019-2020
Ecology, evolution, genomics

Engineer degree

2017-2020
Biostatistics and bioinformatics

Dijon, France

Engineer undergraduate studies

2015-2017

PhD in statistical ecology LBBE

October 2020- July 2024

Here icons: Freepik from Flaticon | Other drawings: © own work

About me

Dijon, France

Engineer undergraduate studies

2015-2017

Lyon, France

Engineer degree

2017-2020

Biostatistics and bioinformatics

Masters degree

2019-2020

Ecology, evolution, genomics

PhD in statistical ecology

October 2020- July 2024

Montpellier, France

Postdoc

November 2024 - 2026

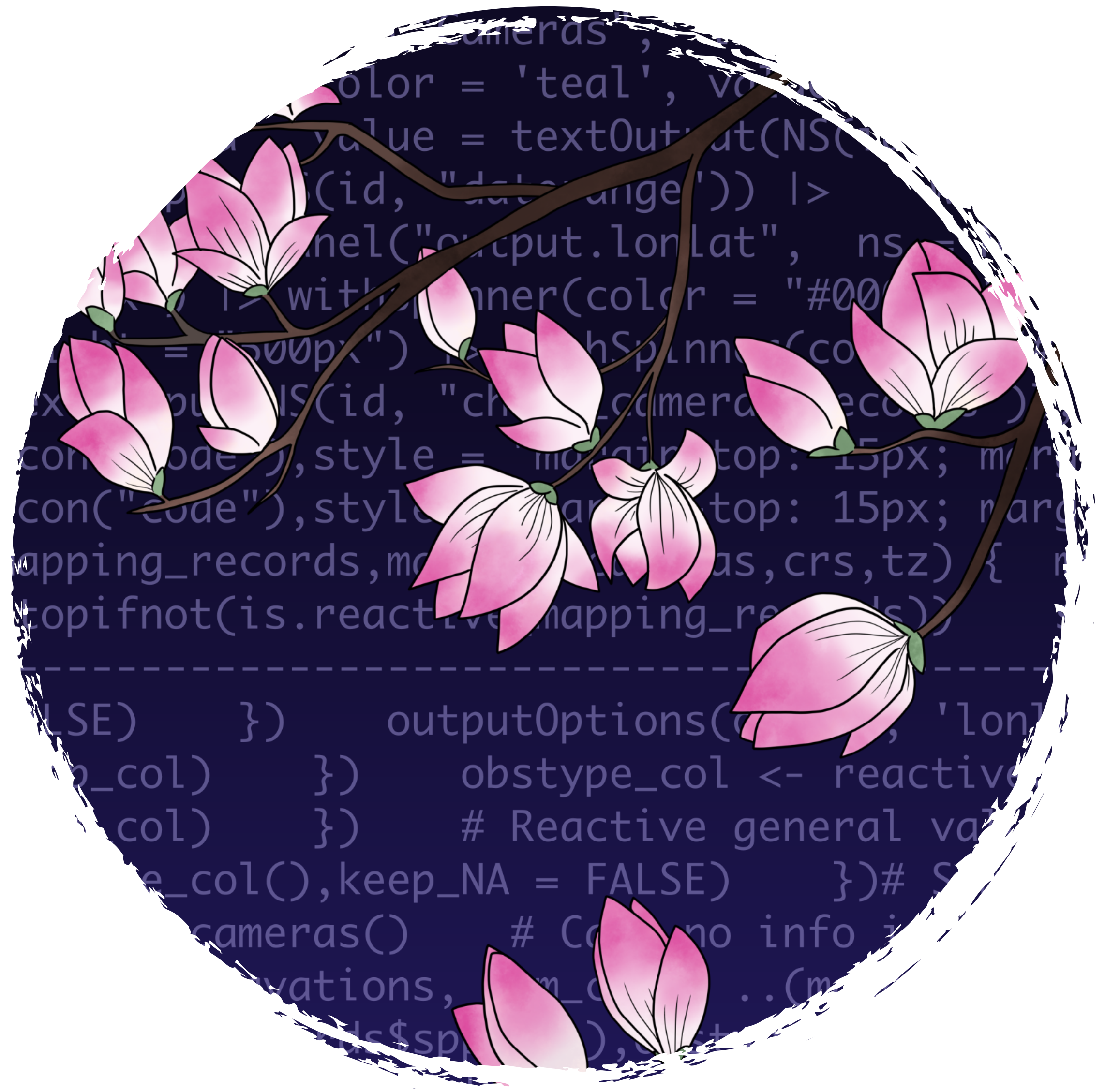
Here icons: Freepik from Flaticon | Other drawings: © own work

PhD in statistical ecology

Statistical methods and software tools to analyze and infer ecological networks and process multi-species data

PhD in statistical ecology

Statistical methods and software tools to analyze and infer ecological networks and process multi-species data

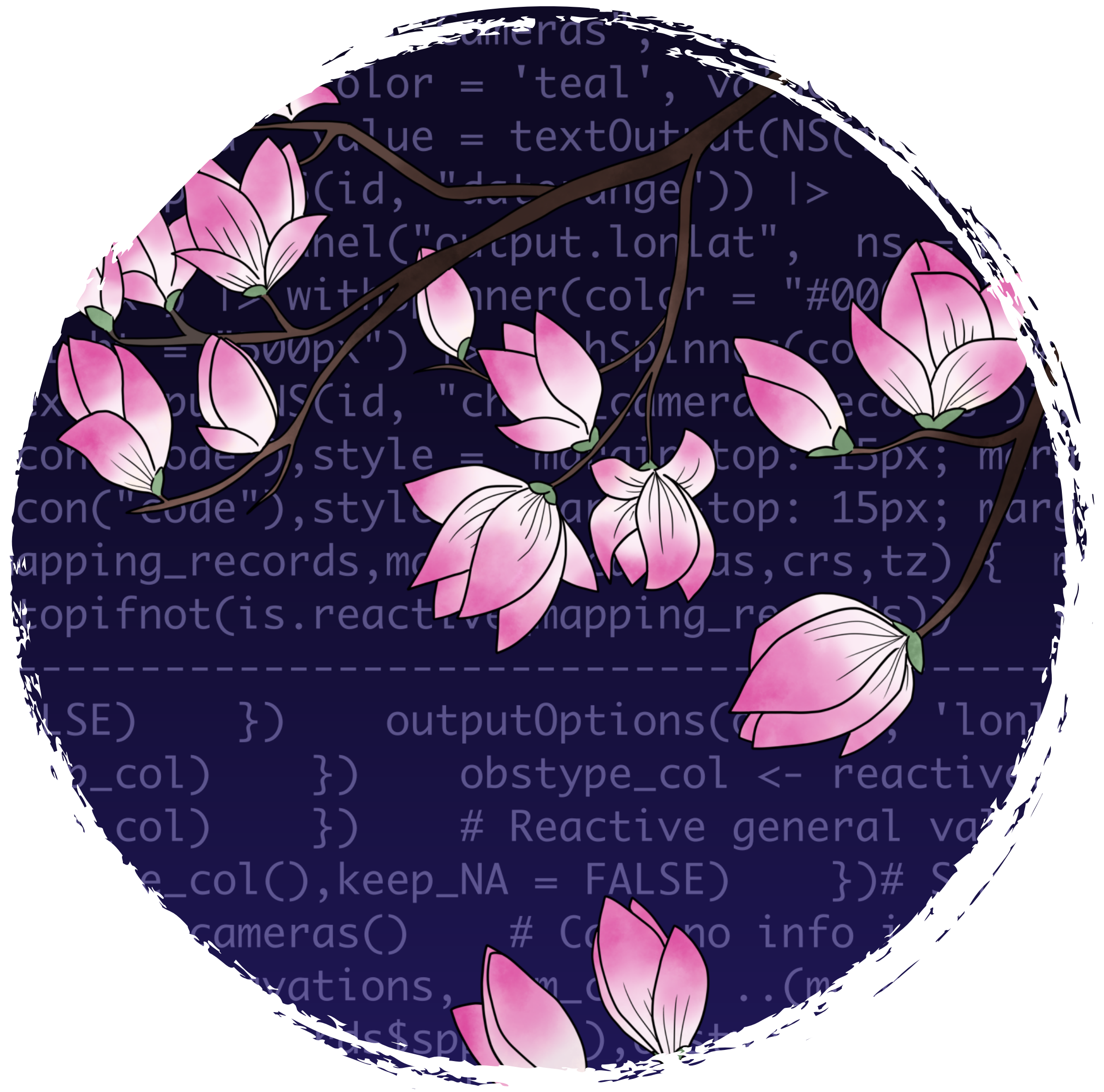


Drawings: © Own work

PhD in statistical ecology

Statistical methods and software tools to analyze and infer ecological networks and process multi-species data

Trait matching
in ecological networks



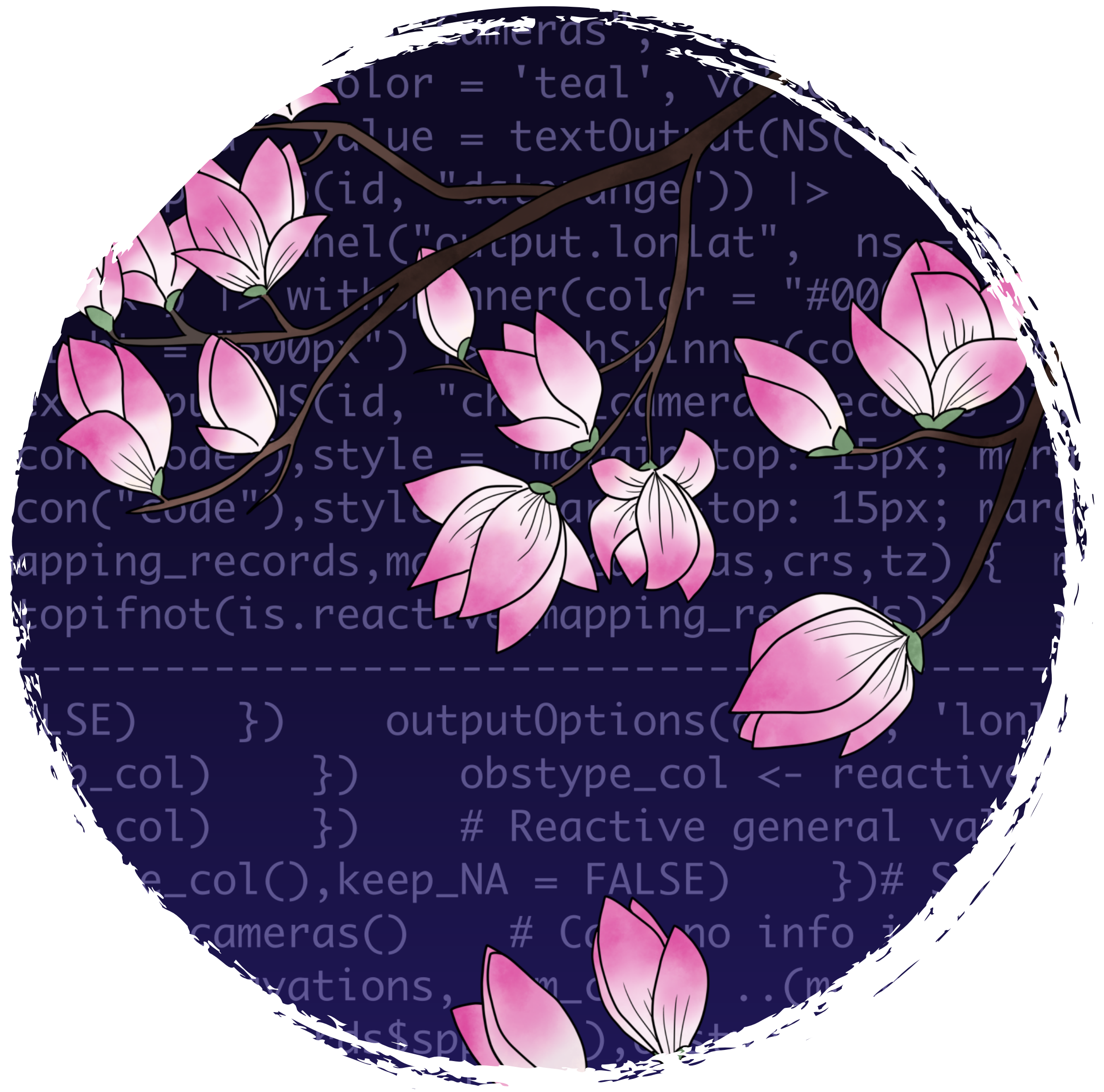
Drawings: © Own work

PhD in statistical ecology

Statistical methods and software tools to analyze and infer ecological networks and process multi-species data

Trait matching
in ecological networks

Attraction-avoidance
between species



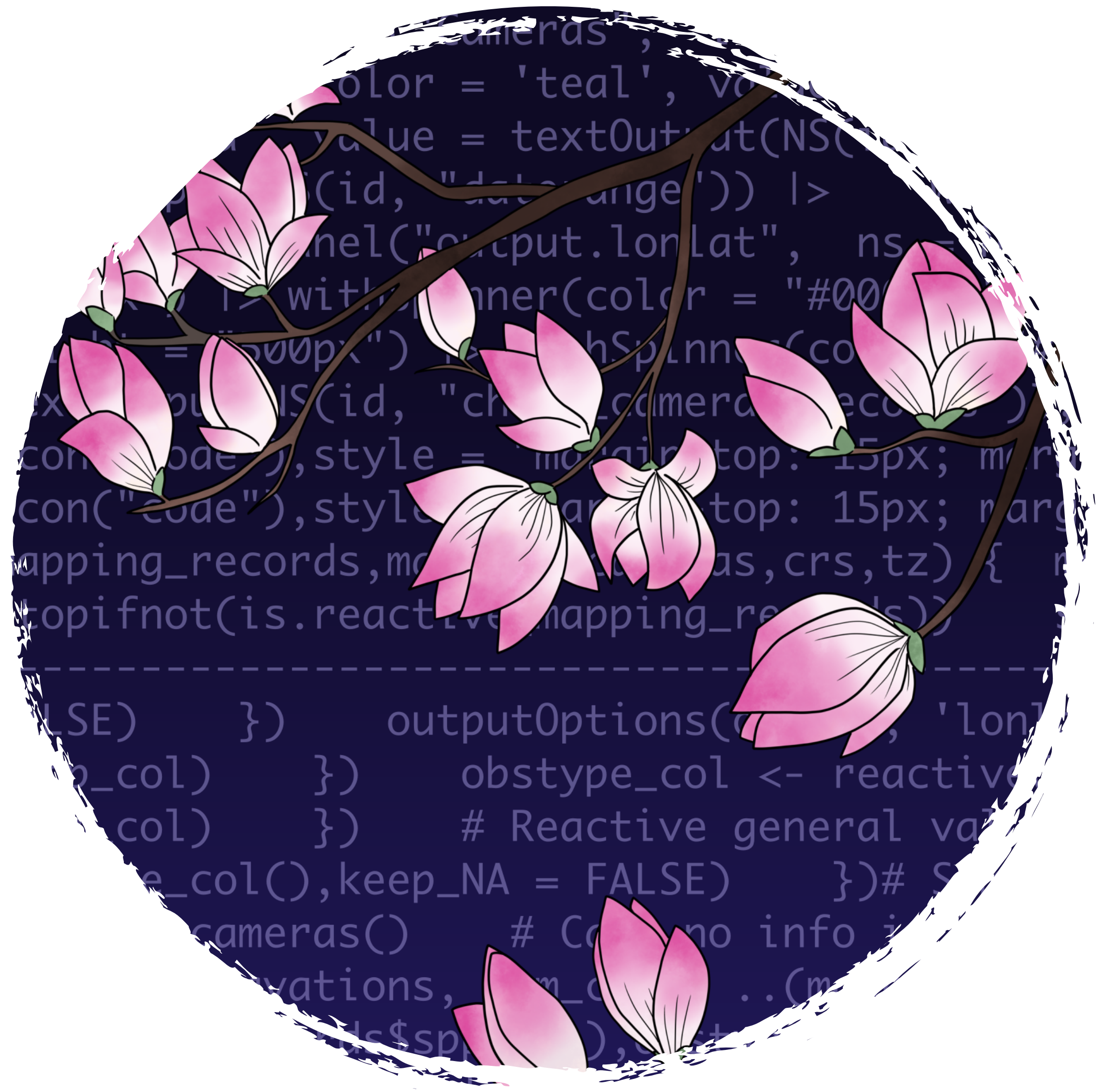
PhD in statistical ecology

Statistical methods and software tools to analyze and infer ecological networks and process multi-species data

Trait matching
in ecological networks

Attraction-avoidance
between species

Software tools to
analyze ecological data



Drawings: © Own work

PhD in statistical ecology

Statistical methods and software tools to analyze and infer ecological networks and process multi-species data

ARTICLE

ECOLOGY
ECOLOGICAL SOCIETY OF AMERICA

Using the multivariate Hawkes process to study interactions between multiple species from camera trap data

Lisa Nicvert[1] | Sophie Donnet[2] | Mark Keith[3] | Mike Peel[4,5,6] | Michael J. Somers[3] | Lourens H. Swanepoel[7] | Jan Venter[8,9] | Hervé Fritz[9,10] | Stéphane Dray[1]

Introduction

Interspecific interactions = effect of a species on another one

Figure 1.3 from my PhD thesis. *Silhouette images from Phylopic by Andy Wilson (Meneris tulbaghia), Beth Reinke (Nazca booby), Jon Hill (blue-footed booby), Jonathan Wells (Plasmodium falciparum), and NASA (Homo sapiens sapiens), others are in the public domain.*

Introduction

Interspecific interactions = effect of a species on another one

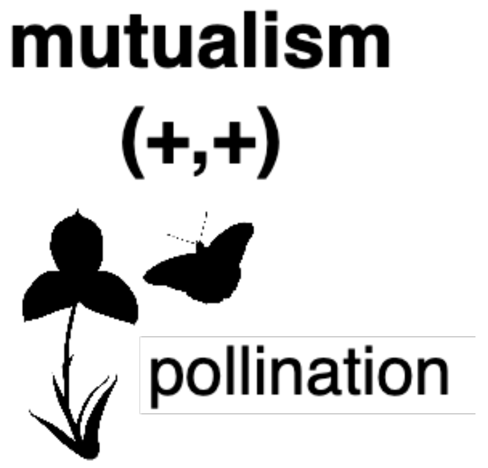


Figure 1.3 from my PhD thesis. Silhouette images from Phylopic by Andy Wilson (Meneris tulbaghia), Beth Reinke (Nazca booby), Jon Hill (blue-footed booby), Jonathan Wells (Plasmodium falciparum), and NASA (Homo sapiens sapiens), others are in the public domain.

Introduction

Interspecific interactions = effect of a species on another one

Figure 1.3 from my PhD thesis. *Silhouette images from Phylopic by Andy Wilson (Meneris tulbaghia), Beth Reinke (Nazca booby), Jon Hill (blue-footed booby), Jonathan Wells (Plasmodium falciparum), and NASA (Homo sapiens sapiens), others are in the public domain.*

Introduction

Interspecific interactions = effect of a species on another one

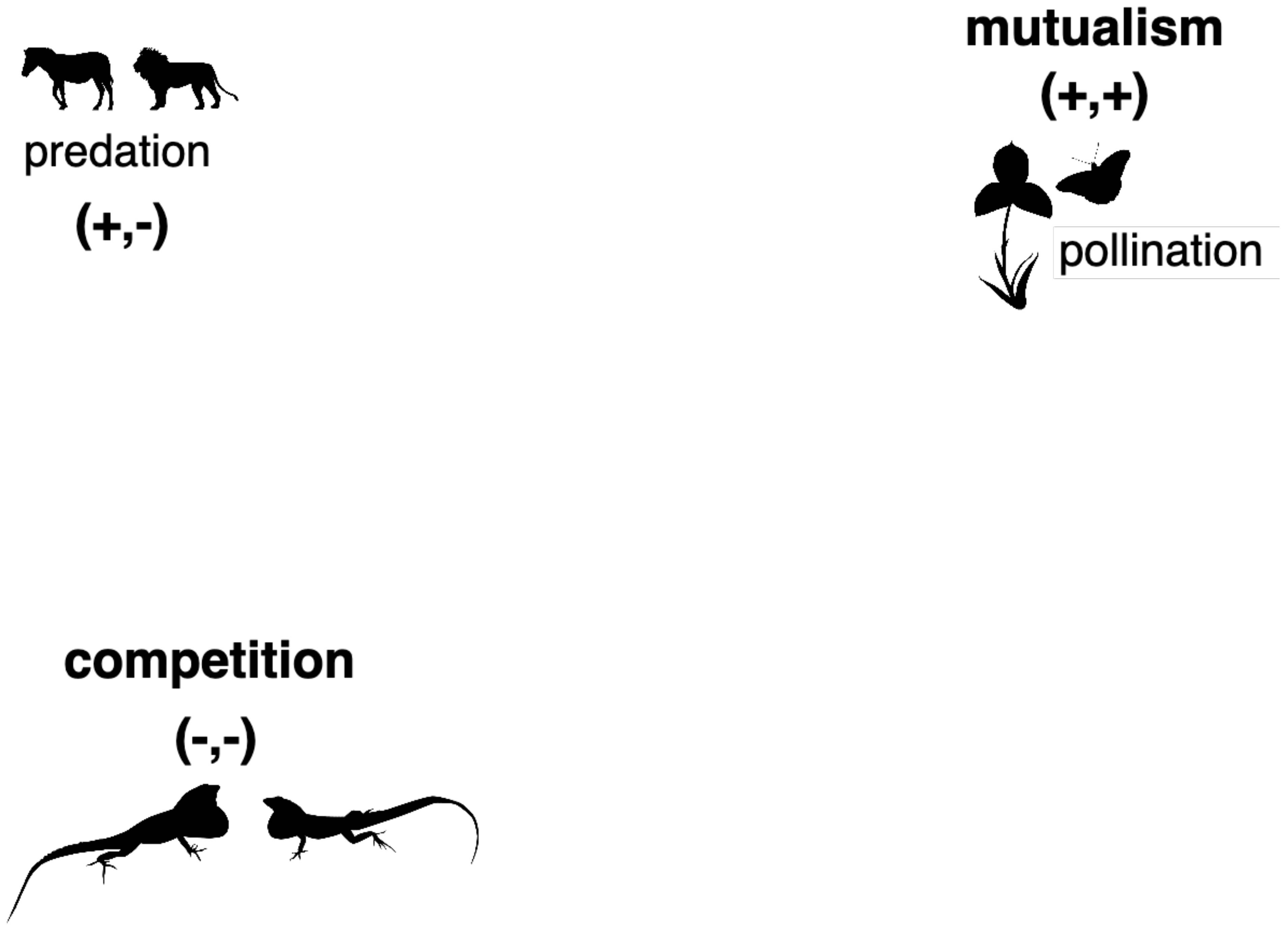


Figure 1.3 from my PhD thesis. Silhouette images from Phylopic by Andy Wilson (Meneris tulbaghia), Beth Reinke (Nazca booby), Jon Hill (blue-footed booby), Jonathan Wells (Plasmodium falciparum), and NASA (Homo sapiens sapiens), others are in the public domain.

Introduction

Interspecific interactions = effect of a species on another one

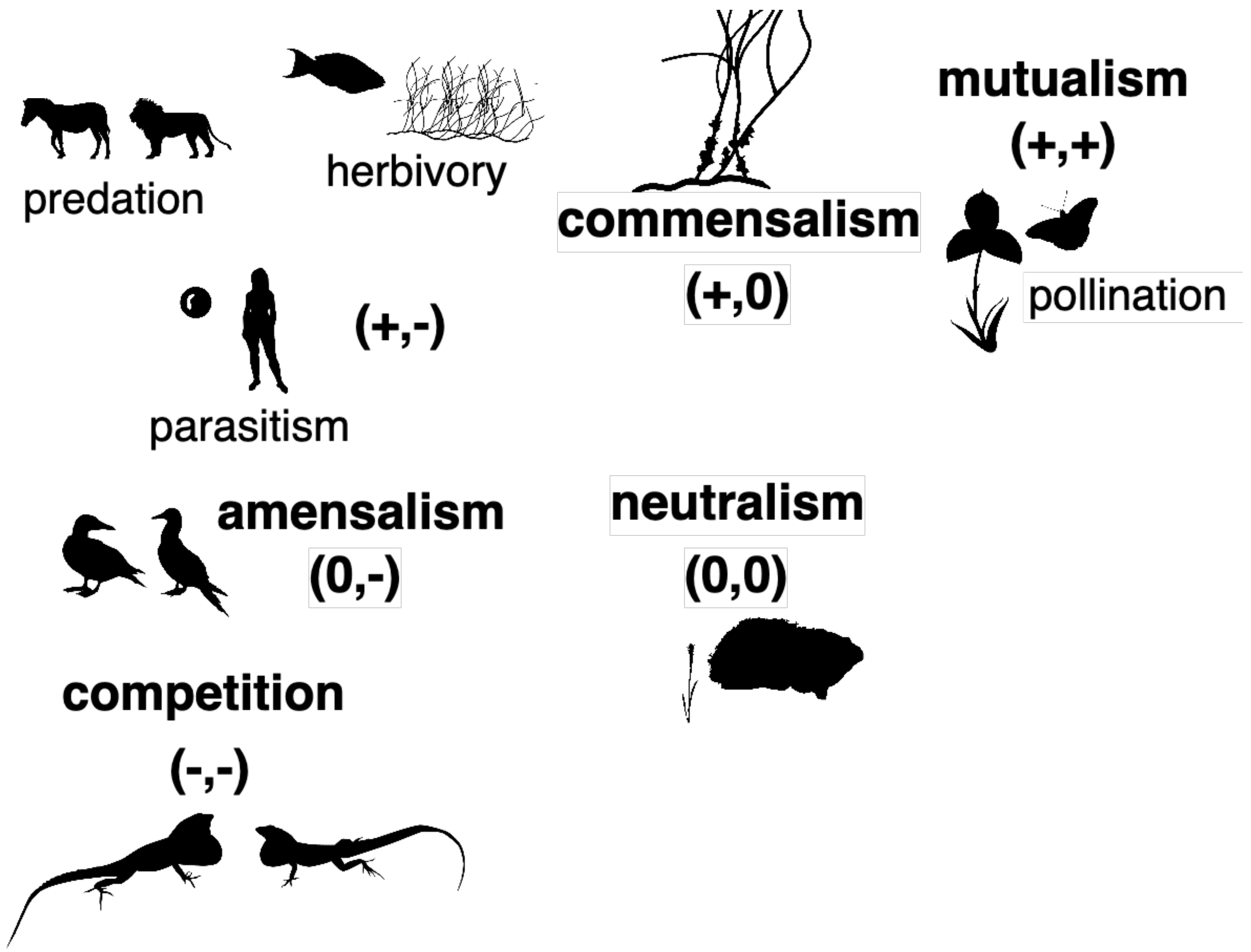


Figure 1.3 from my PhD thesis. *Silhouette images from Phylopic by Andy Wilson (Meneris tulbaghia), Beth Reinke (Nazca booby), Jon Hill (blue-footed booby), Jonathan Wells (Plasmodium falciparum), and NASA (Homo sapiens sapiens), others are in the public domain.*

Introduction

Interspecific interactions = effect of a species on another one

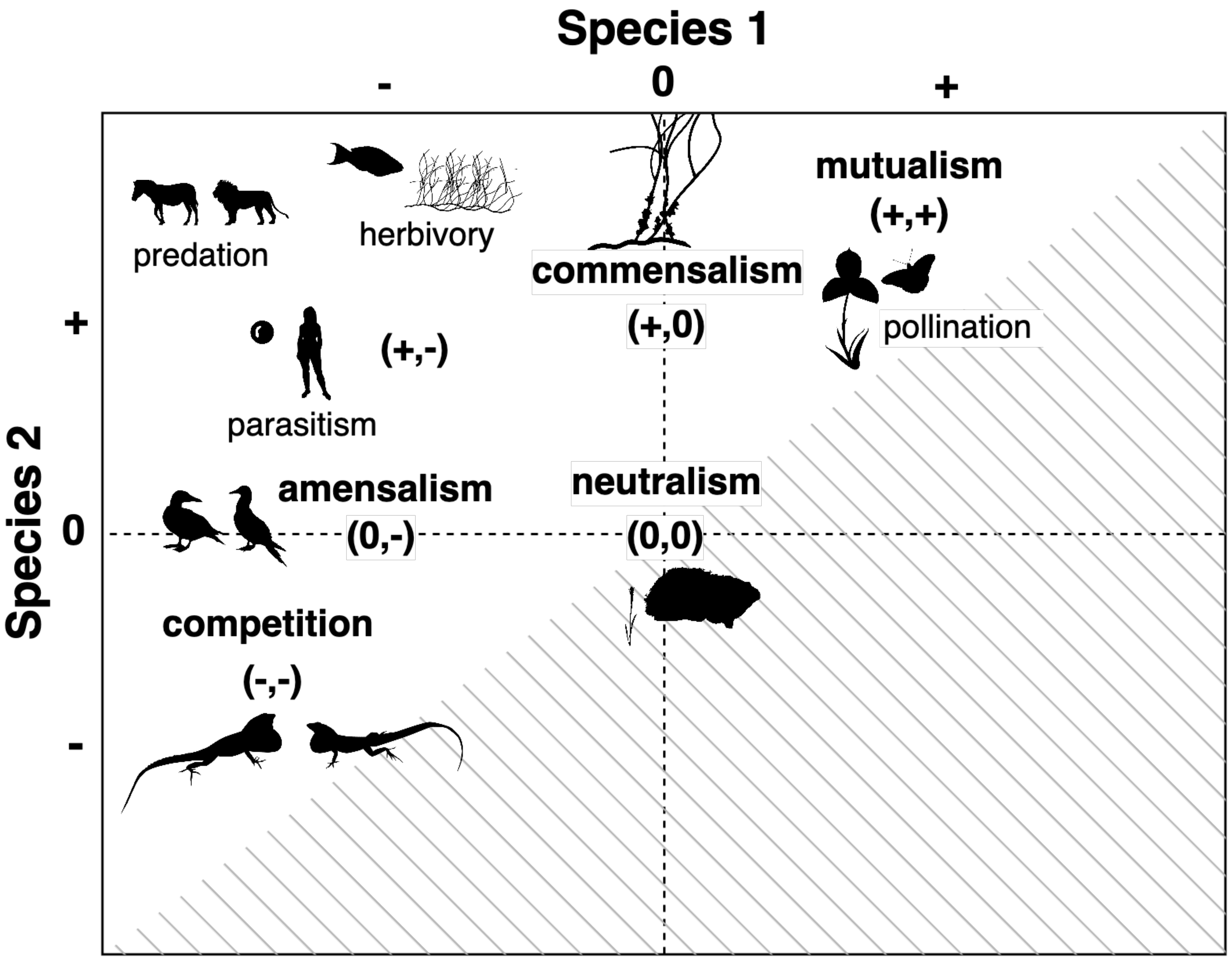


Figure 1.3 from my PhD thesis. *Silhouette images from Phylopic by Andy Wilson (Meneris tulbaghia), Beth Reinke (Nazca booby), Jon Hill (blue-footed booby), Jonathan Wells (Plasmodium falciparum), and NASA (Homo sapiens sapiens), others are in the public domain.*

Introduction
Interactions and species distributions

Interactions → distributions?

Introduction

Interactions and species distributions

Interactions → distributions?

Diamond's checkerboard pattern

Diamond 1975

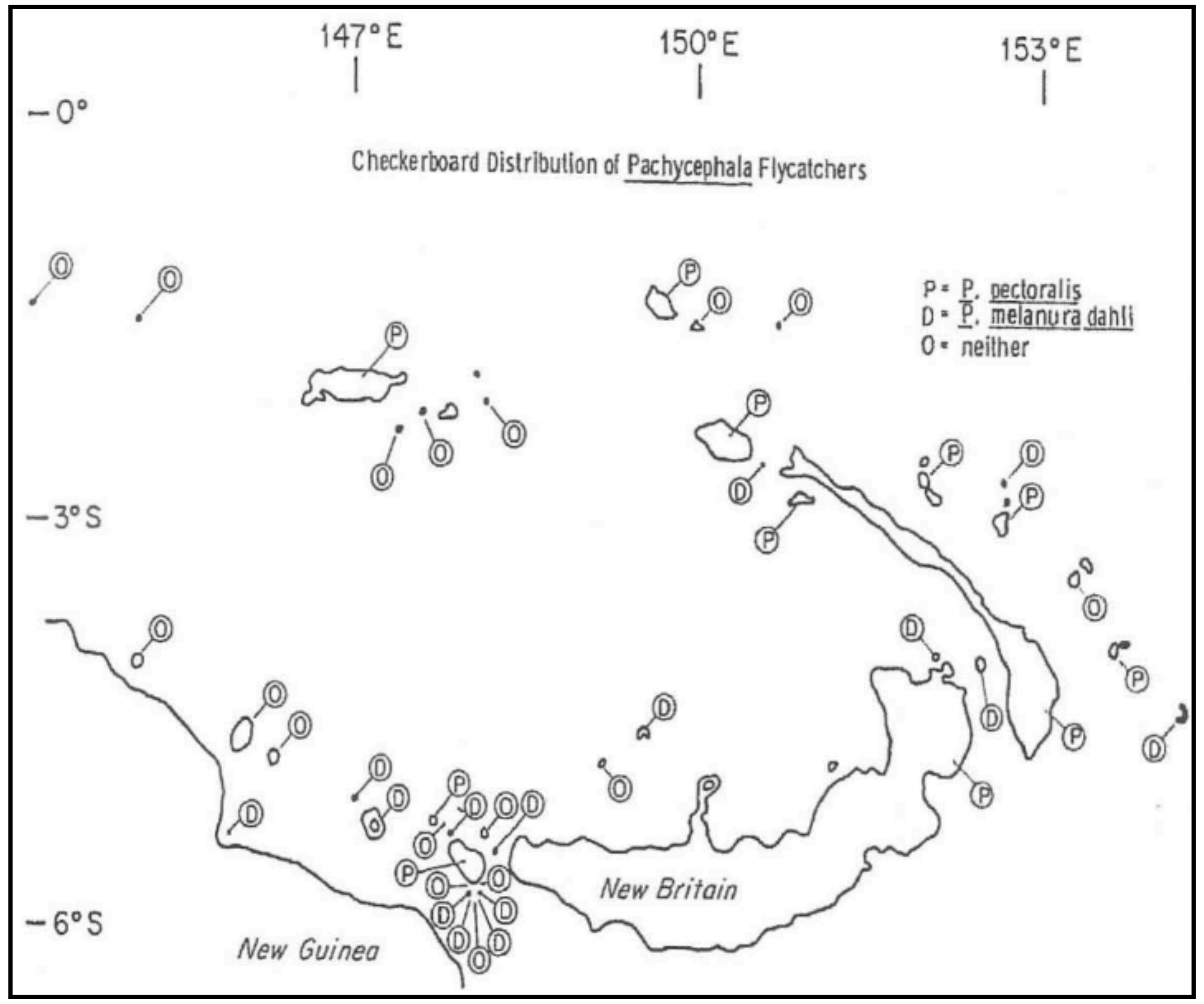


Figure 21 from Diamond, 1975

Introduction

Interactions and species distributions

Interactions → distributions?

Diamond's checkerboard pattern

Diamond 1975

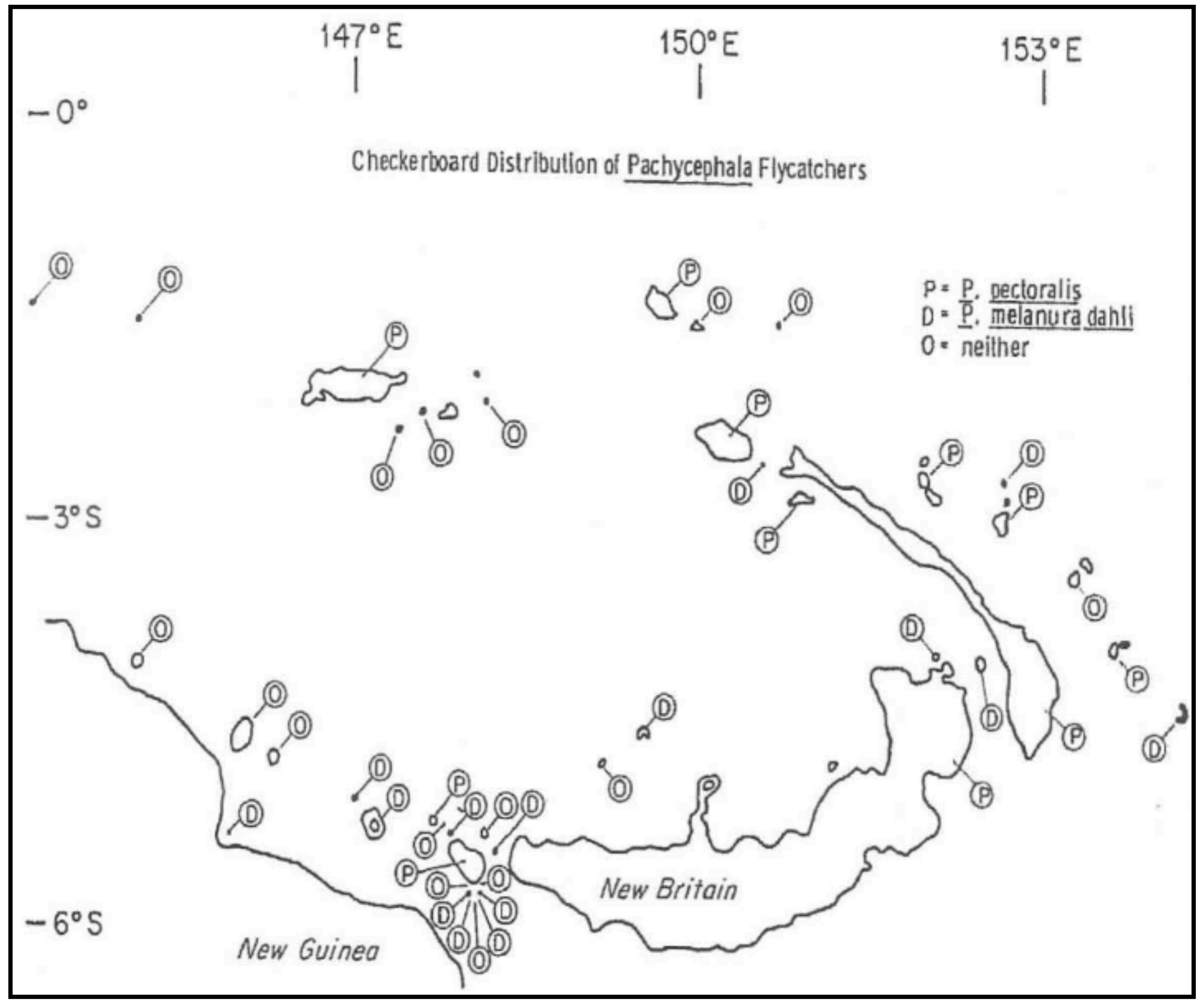


Figure 21 from Diamond, 1975

THE ASSEMBLY OF SPECIES COMMUNITIES: CHANCE OR COMPETITION?[1]

EDWARD F. CONNOR[2,3]
Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903 USA

AND

DANIEL SIMBERLOFF
Department of Biological Sciences, Florida State University, Tallahassee, Florida 32306 USA

The checkered history of checkerboard distributions

EDWARD F. CONNOR,[1,4] MICHAEL D. COLLINS,[2] AND DANIEL SIMBERLOFF[3]

[1]*Department of Biology, San Francisco State University, 1600 Holloway Avenue, San Francisco, California 94132 USA*
[2]*Department of Biology, Rhodes College, Memphis, Tennessee 38112 USA*
[3]*Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, Tennessee 37996 USA*

Introduction
Interactions and species distributions

Interactions → distributions?

Diamond's checkerboard pattern
Diamond 1975

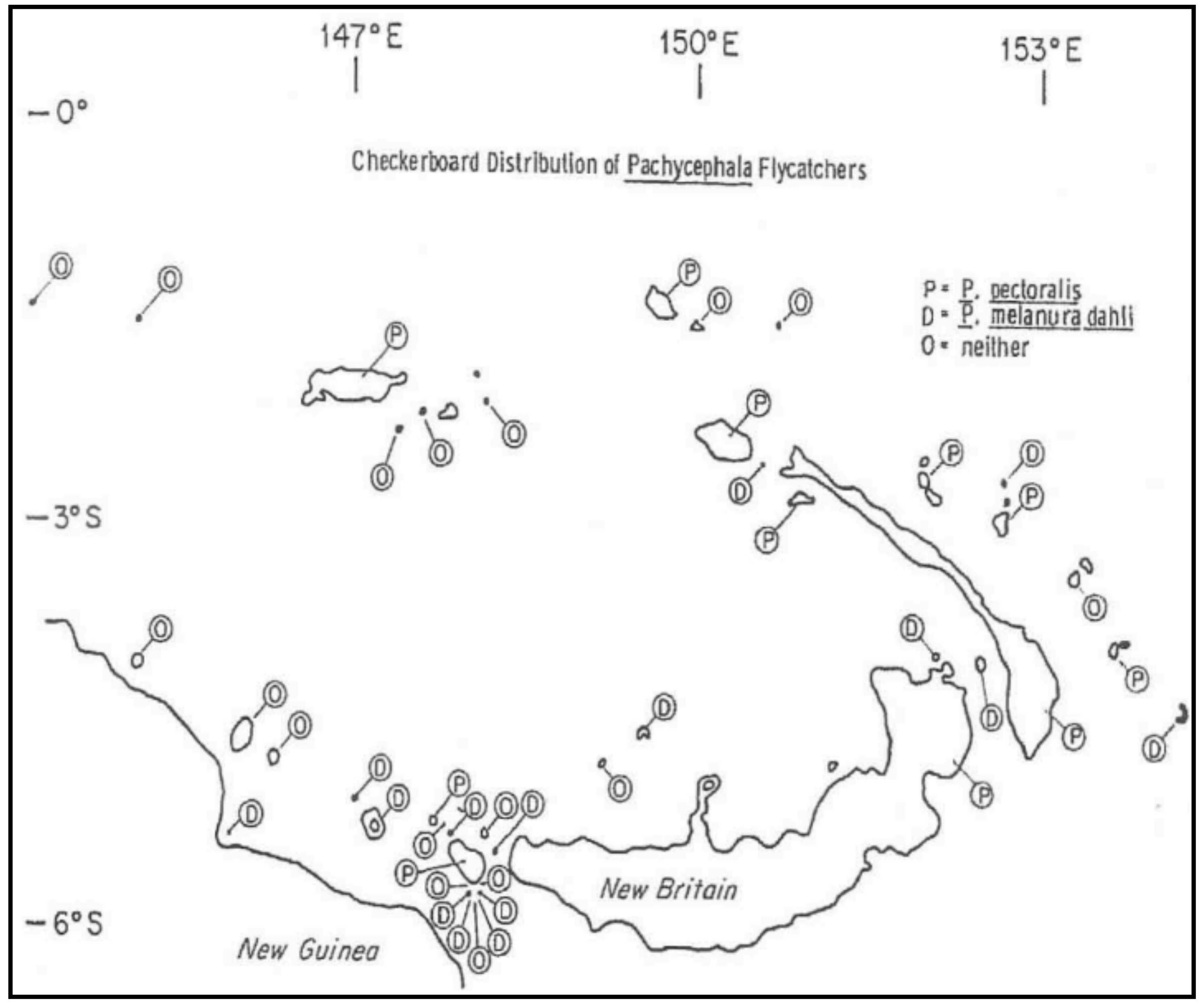


Figure 21 from Diamond, 1975

THE ASSEMBLY OF SPECIES COMMUNITIES: CHANCE OR COMPETITION?[1]

EDWARD F. CONNOR[2,3]
Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903 USA

AND

DANIEL SIMBERLOFF
Department of Biological Sciences, Florida State University, Tallahassee, Florida 32306 USA

The checkered history of checkerboard distributions

EDWARD F. CONNOR,[1,4] MICHAEL D. COLLINS,[2] AND DANIEL SIMBERLOFF[3]

[1]*Department of Biology, San Francisco State University, 1600 Holloway Avenue, San Francisco, California 94132 USA*
[2]*Department of Biology, Rhodes College, Memphis, Tennessee 38112 USA*
[3]*Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, Tennessee 37996 USA*

The checkered history of checkerboard distributions: comment

JARED DIAMOND,[1] STUART L. PIMM,[2,4] AND JAMES G. SANDERSON[3]

Introduction

Interactions and species distributions

Interactions → distributions?

Diamond

Diamond 1

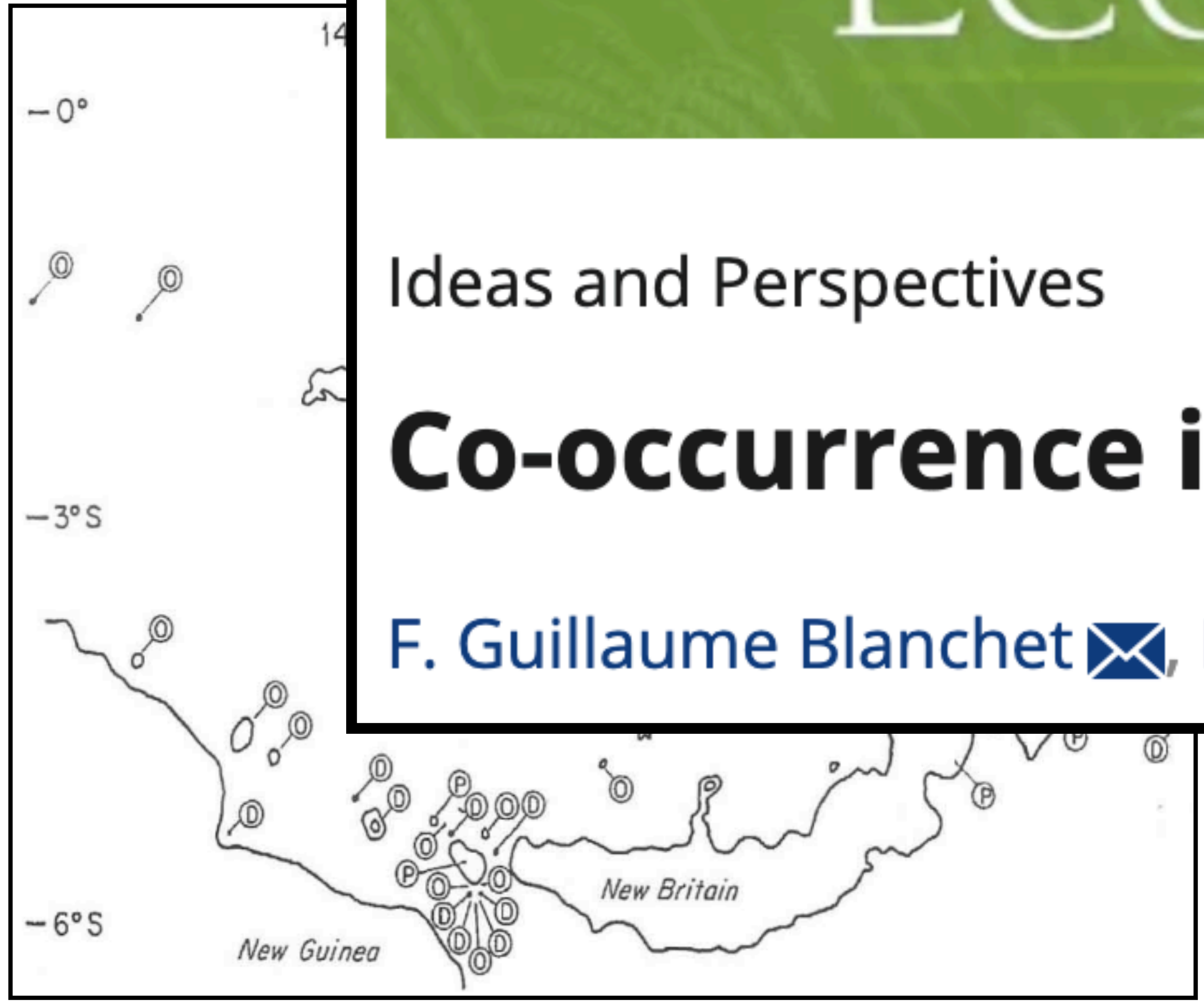


Figure 21 from Diamond, 1975

THE ASSEMBLY OF SPECIES COMMUNITIES: CHANCE OR COMPETITION?[1]

EDWARD F. CONNOR[2,3]
Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903 USA

ECOLOGY LETTERS

Ideas and Perspectives

Co-occurrence is not evidence of ecological interactions

F. Guillaume Blanchet, Kevin Cazelles, Dominique Gravel

d distributions

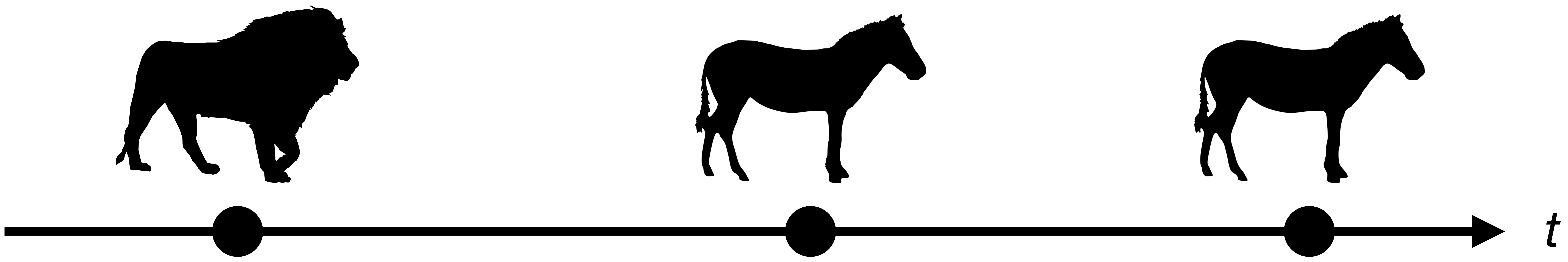
IEL SIMBERLOFF[3]
an Francisco, California 94132 USA
ee 38112 USA
noxville, Tennessee 37996 USA

JARED DIAMOND,[1] STUART L. PIMM,[2,4] AND JAMES G. SANDERSON[3]

Introduction

Interactions and species distributions

Interactions → distributions?



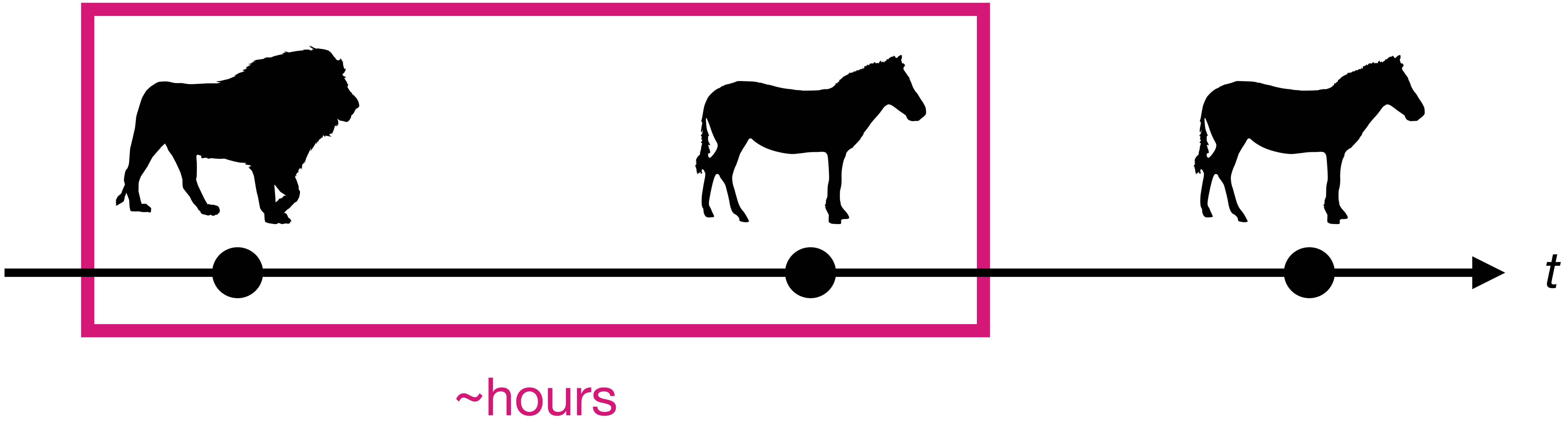
Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Introduction

Interactions and species distributions

Interactions → distributions?

1. Smaller temporal scale

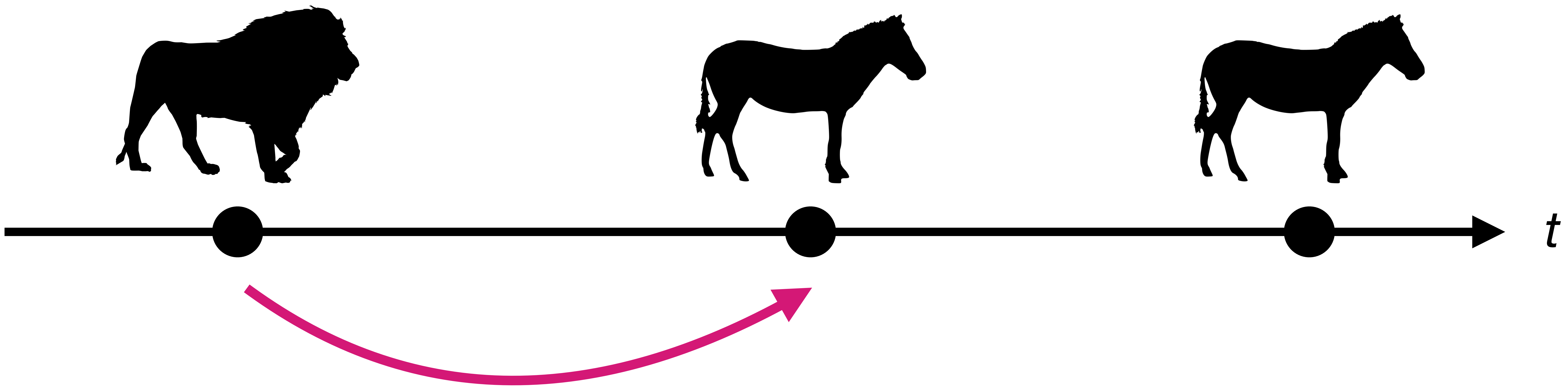


Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Introduction
Interactions and species distributions

Interactions → distributions?

1. Smaller temporal scale
2. Process-based approach



Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

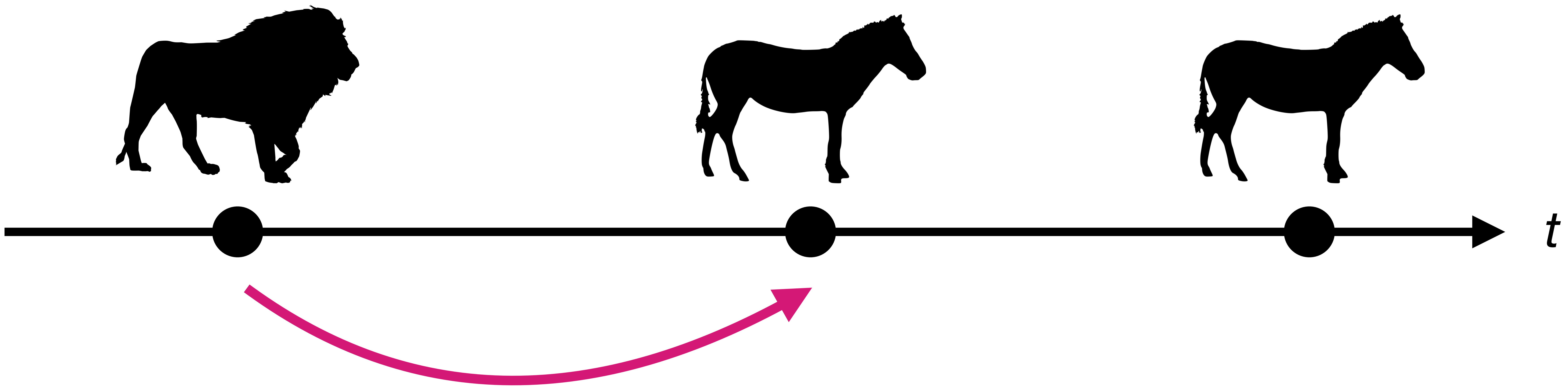
Introduction

Interactions and species distributions

Interactions → distributions?

1. Smaller temporal scale
2. Process-based approach

→ Infer interactions = effect of a species on the **distribution** of another one



Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Introduction

Camera traps = cameras with automated trigger

Camera trap in the Karoo National parc (South Africa) *© Own picture*

Introduction

Camera traps = cameras with automated trigger

Camera trap in the Karoo National parc (South Africa) *© Own picture*

Steenbok *© Snapshot Safari*

Part of a steenbok *© Snapshot Safari*

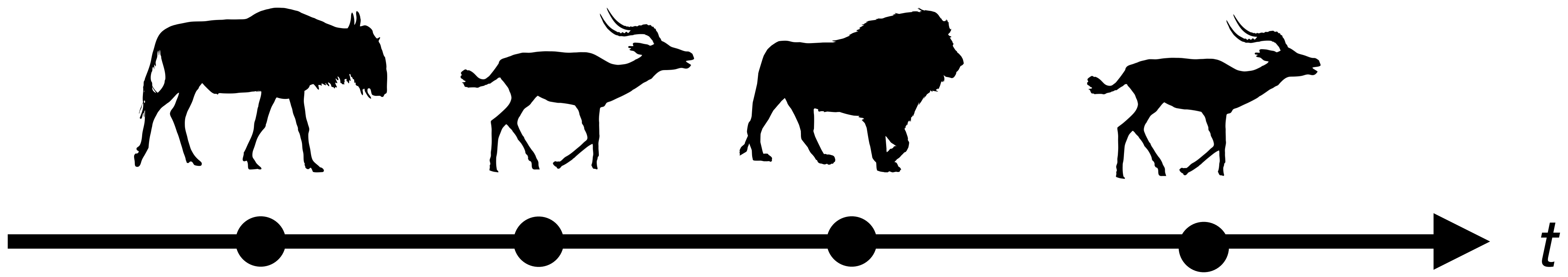
Introduction

Camera traps = cameras with automated trigger

Camera trap in the Karoo National parc (South Africa) *© Own picture*

Steenbok *© Snapshot Safari*

Part of a steenbok *© Snapshot Safari*



Silhouette images from PhyloPic by Lukasiniho (wildebeest), Margot Michaud (lion), Zimices (zebra), and an unknown author (impala).

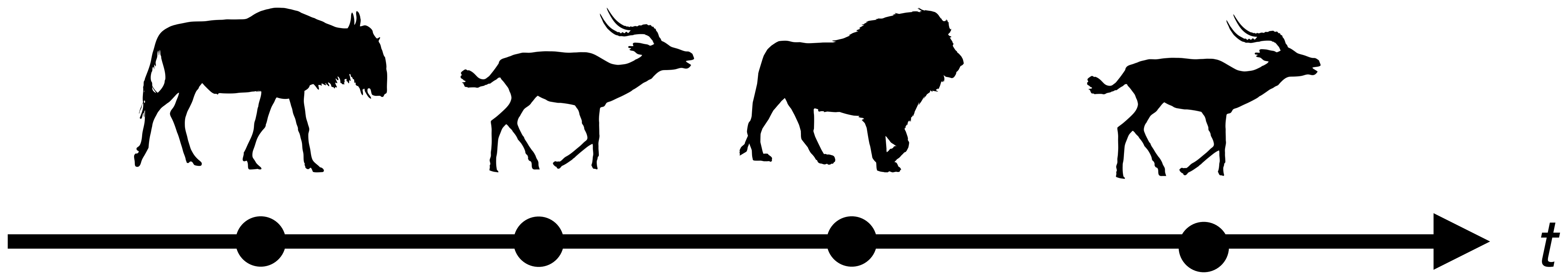
Introduction

Camera traps = cameras with automated trigger

Camera trap in the Karoo National parc (South Africa) *© Own picture*

Steenbok *© Snapshot Safari*

Part of a steenbok *© Snapshot Safari*

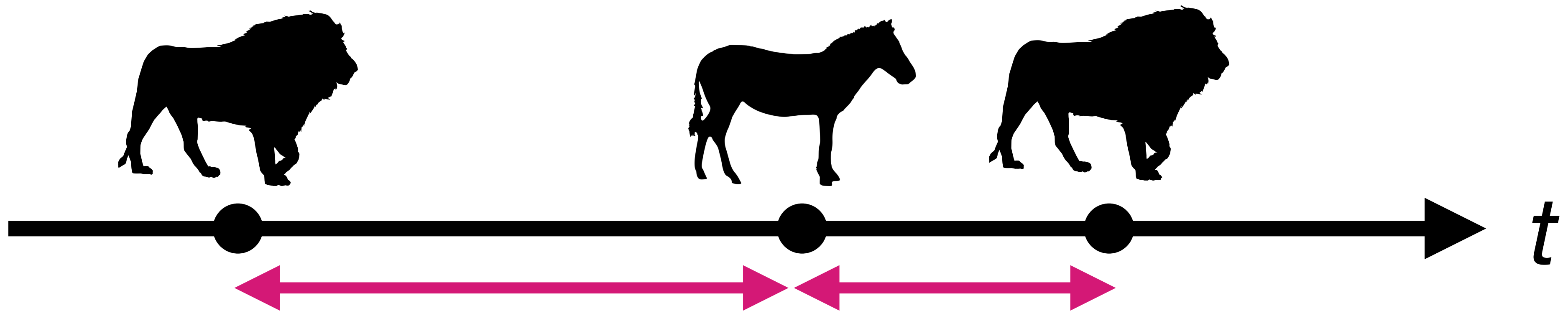


Continuous-time + multi-species data

Silhouette images from PhyloPic by Lukasiniho (wildebeest), Margot Michaud (lion), Zimices (zebra), and an unknown author (impala).

Existing methods

Introduction
Existing methods

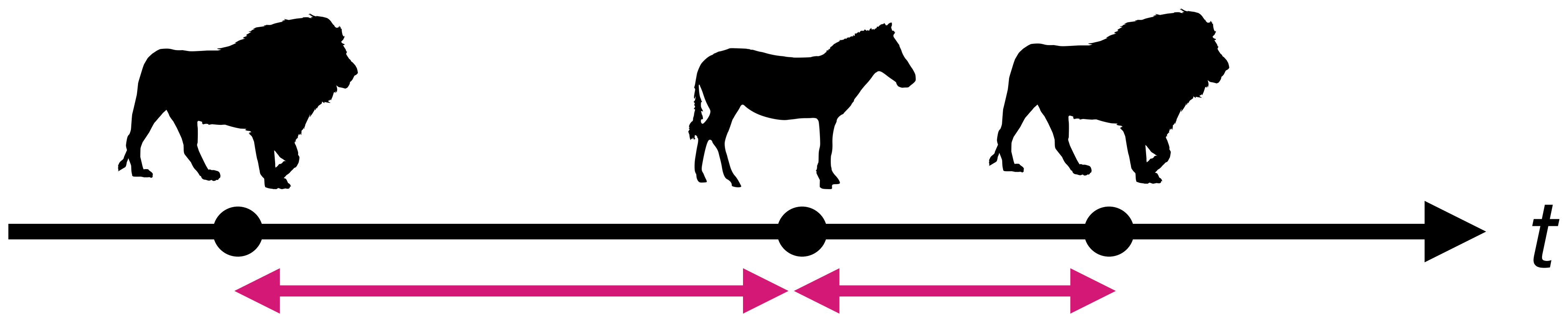


Time intervals *Harmsen et al. 2009, Parsons et al. 2016*

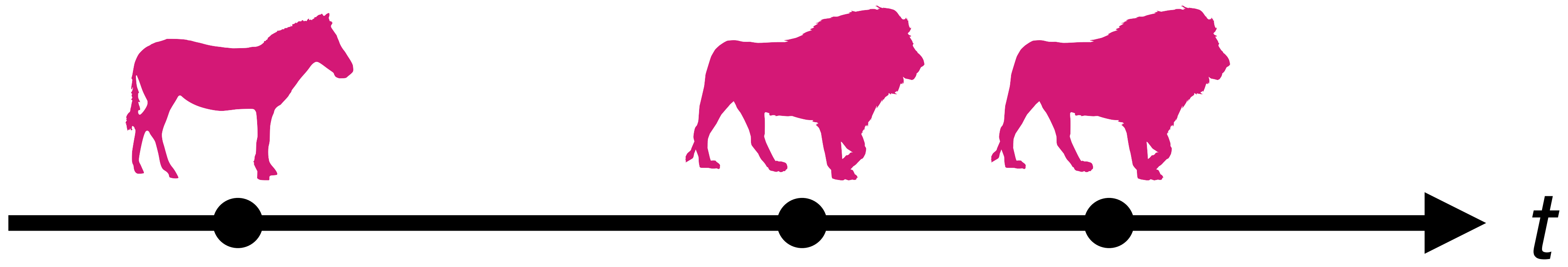
Silhouette images modified from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Introduction

Existing methods



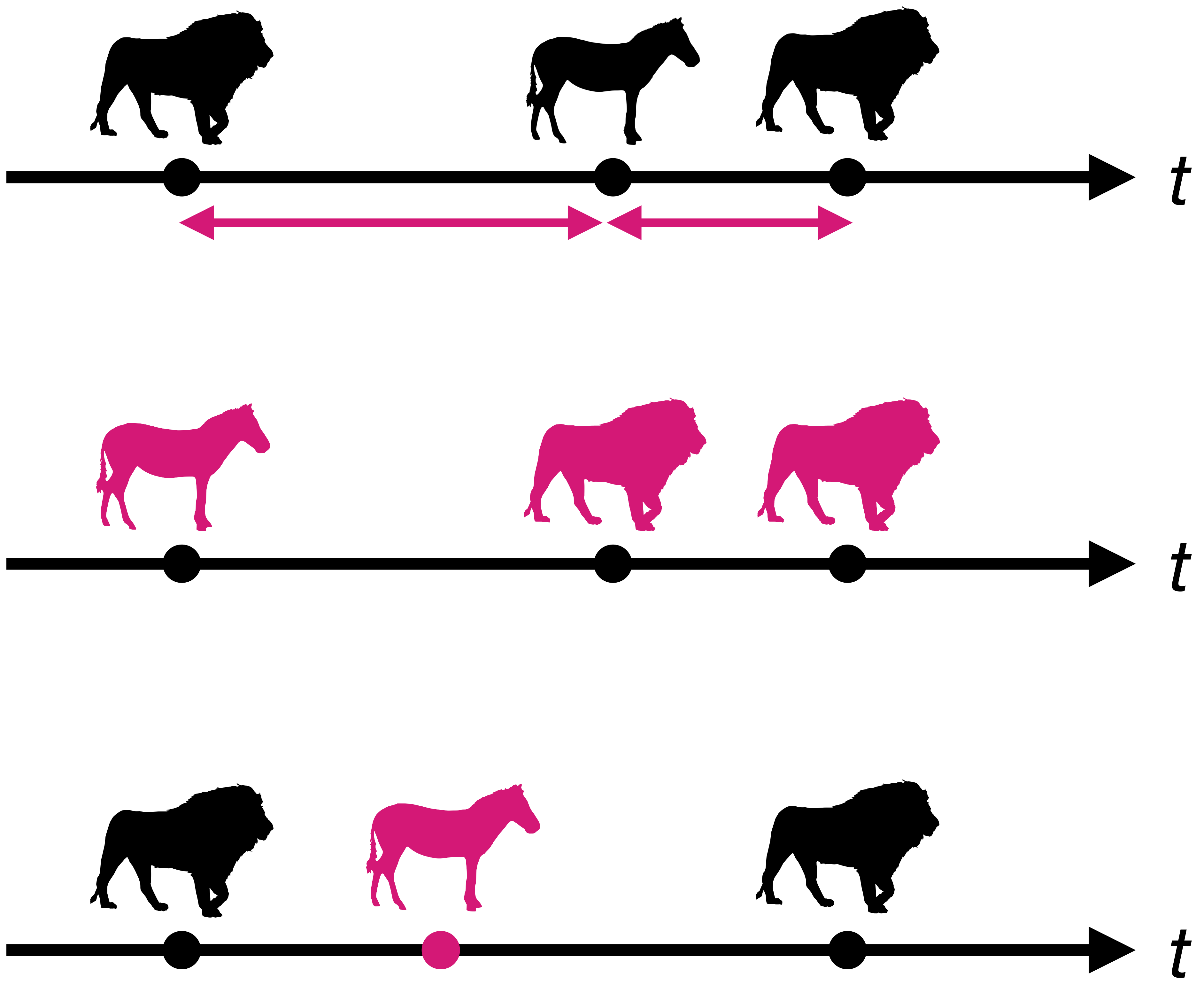
Time intervals *Harmsen et al. 2009, Parsons et al. 2016*



Permutations *Murphy et al. 2021*

Silhouette images modified from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Introduction
Existing methods



Time intervals *Harmsen et al. 2009, Parsons et al. 2016*

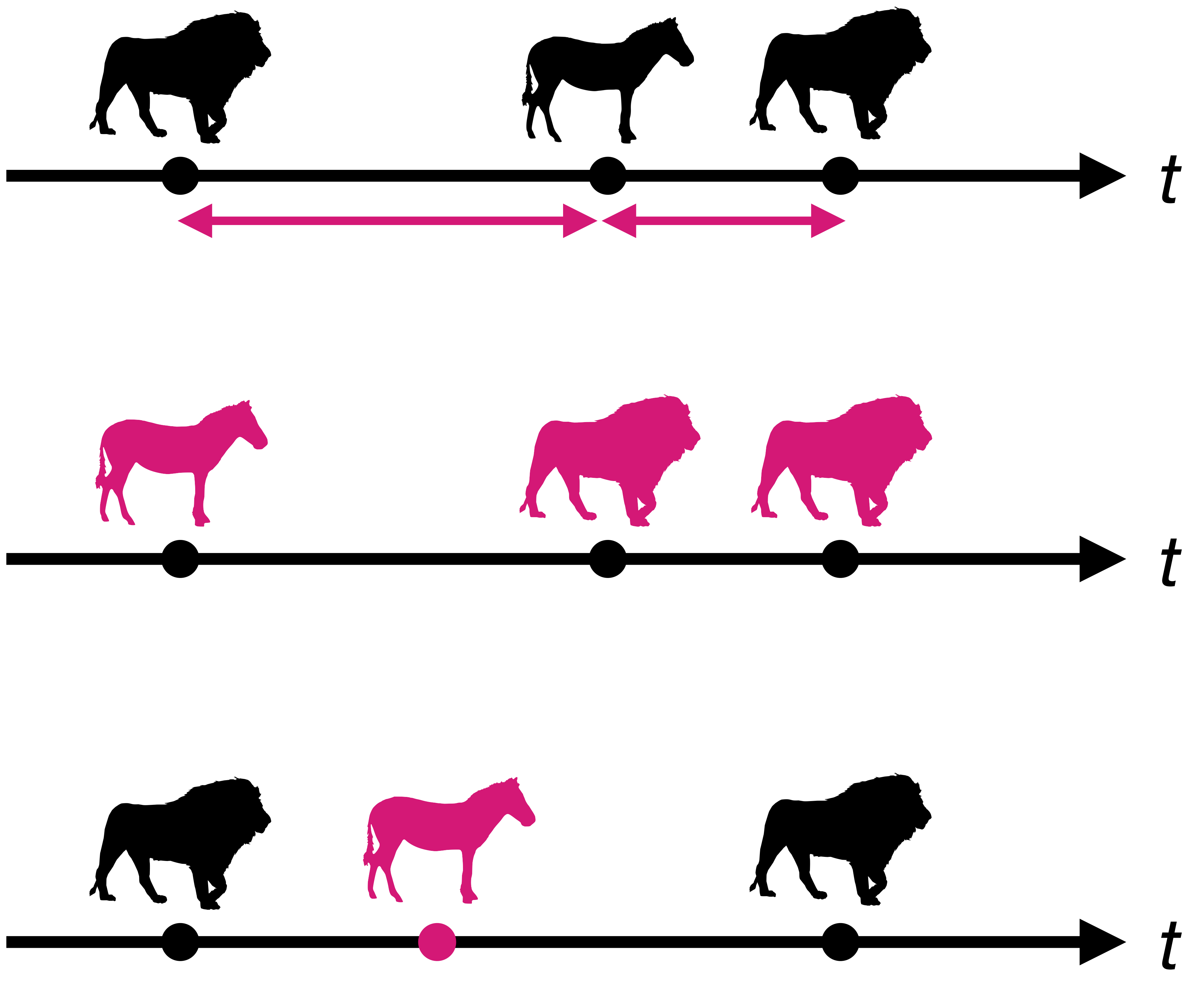
Permutations *Murphy et al. 2021*

Random records *Cusack et al. 2017, Karanth et al. 2017*

Silhouette images modified from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Introduction

Existing methods



Time intervals *Harmsen et al. 2009, Parsons et al. 2016*

Permutations *Murphy et al. 2021*

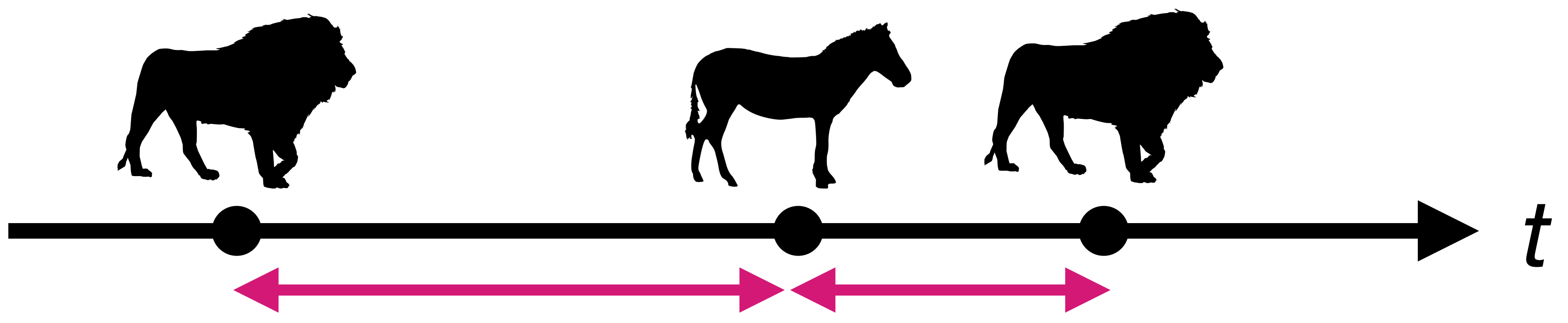
Random records *Cusack et al. 2017, Karanth et al. 2017*

- limited to 2 species
- no directionality
- difficult to interpret summary statistics

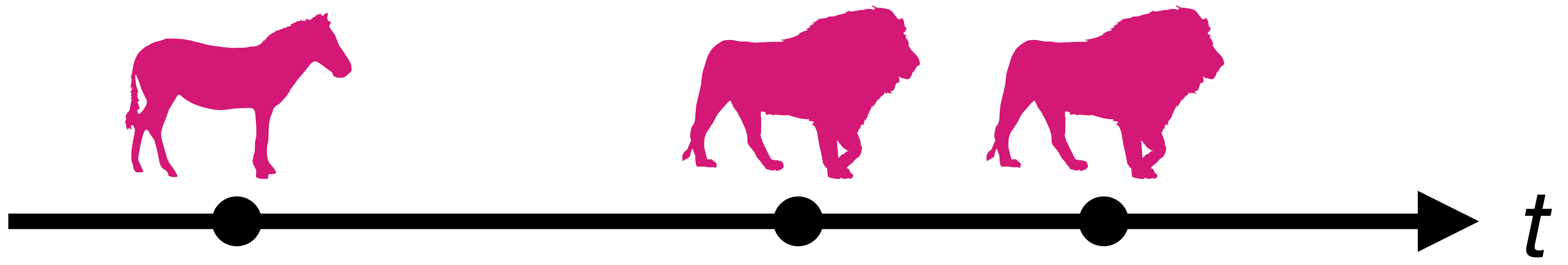
Silhouette images modified from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Introduction

Existing methods



Time intervals *Harmsen et al. 2009, Parsons et al. 2016*



Permutations *Murphy et al. 2021*

Random records *Cusack et al. 2017, Karanth et al. 2017*

- limited to 2 species
- no directionality
- difficult to interpret summary statistics

→ **point processes**
Schliep et al. 2018, Kellner et al. 2022, Ferry et al. 2024

Silhouette images modified from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Material and methods

Material and methods

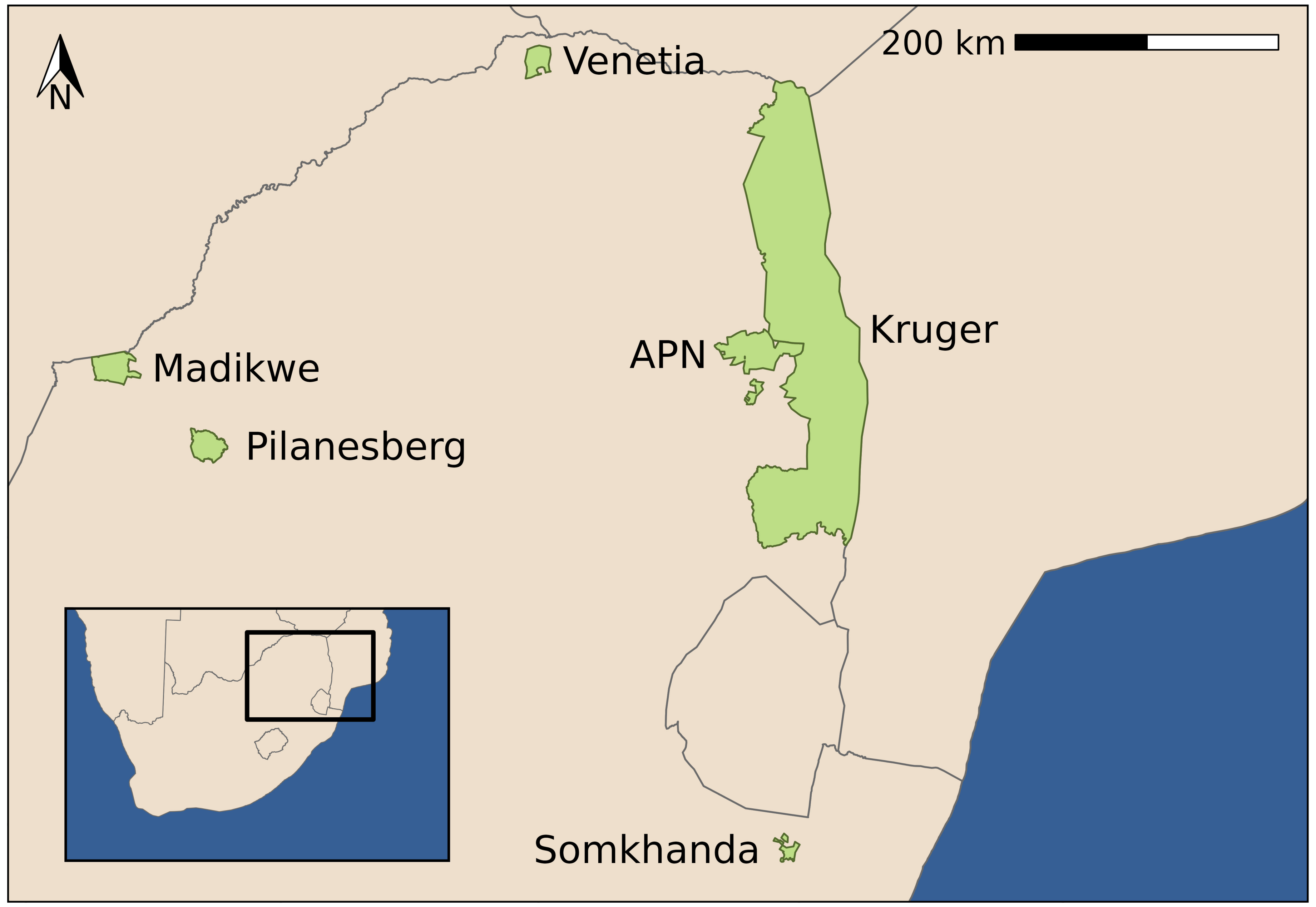
Camera trap dataset

Snapshot Safari monitoring program *(Pardo et al. 2021)*

Material and methods

Camera trap dataset

Snapshot Safari monitoring program *(Pardo et al. 2021)*

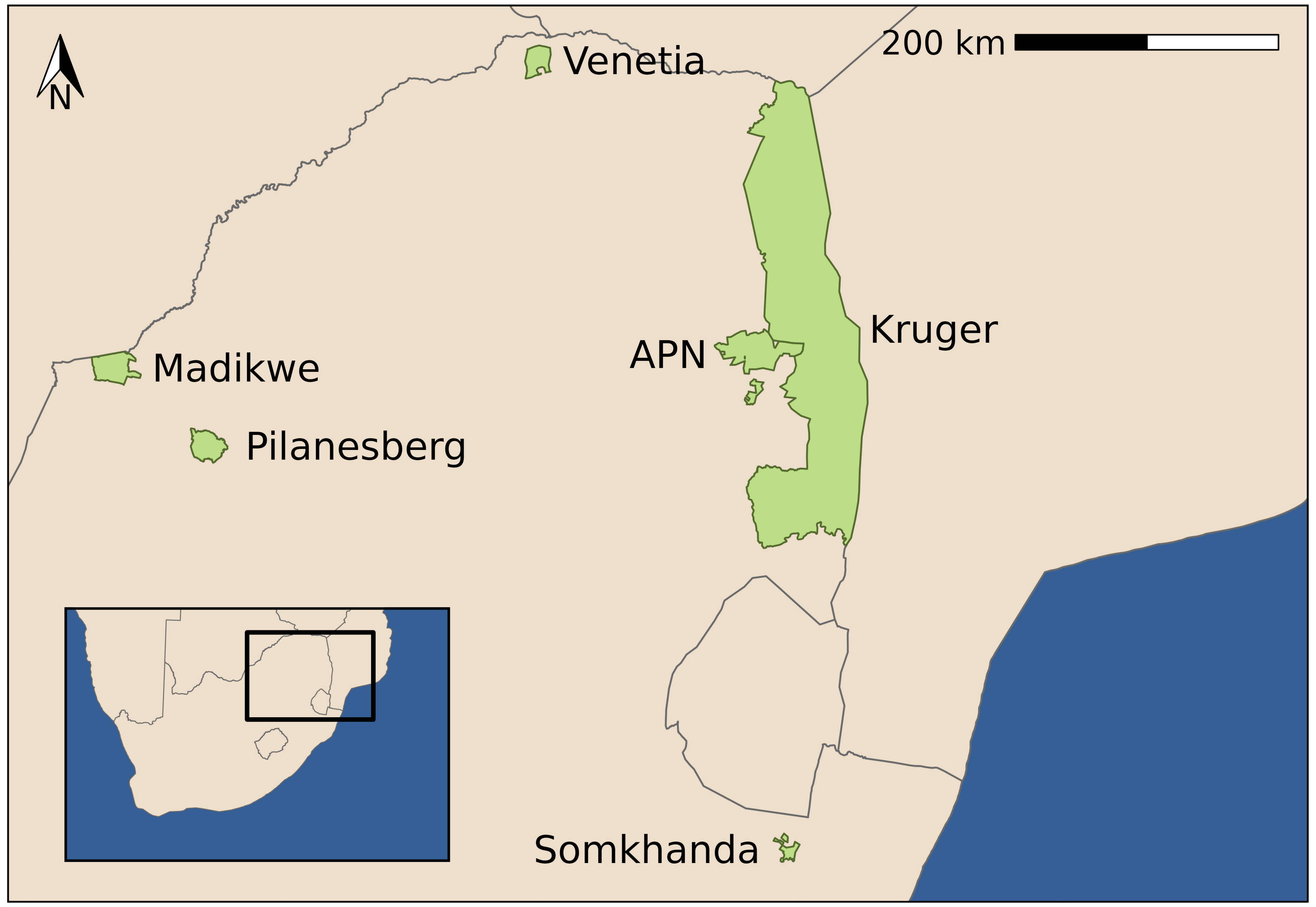


Map: Figure 1 from Nicvert et al. 2024 (data from OpenStreetMap contributors under OdbL license) | Pictures : © Snapshot Safari

Material and methods

Camera trap dataset

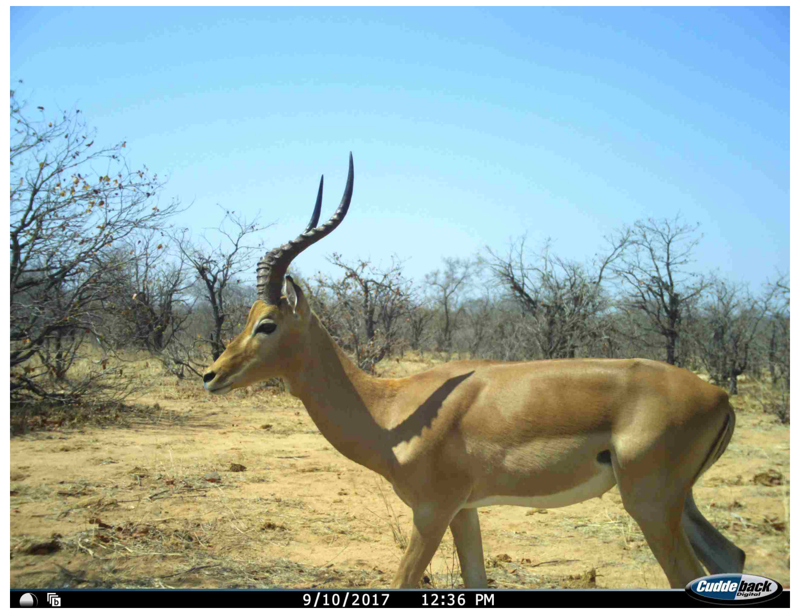
Snapshot Safari monitoring program *(Pardo et al. 2021)*



Blue wildebeest

Burchell's zebra

Greater kudu



Impala

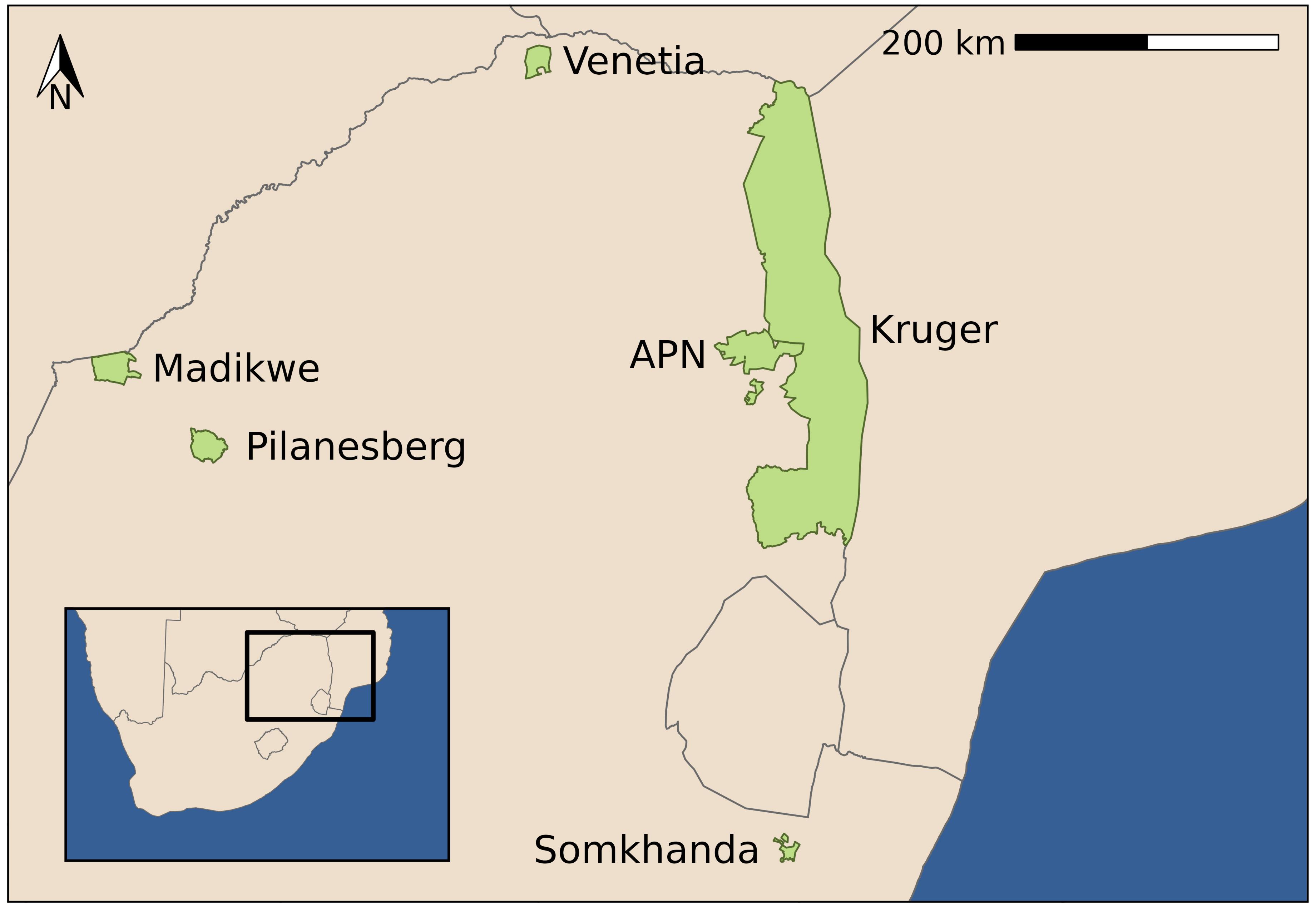
Lion

Map: Figure 1 from Nicvert et al. 2024 (data from OpenStreetMap contributors under OdbL license) | Pictures : © Snapshot Safari

Material and methods

Camera trap dataset

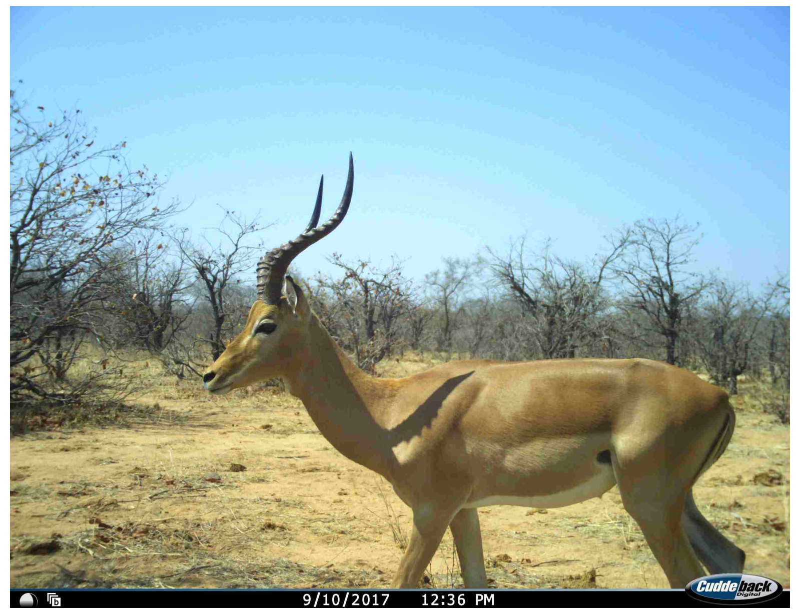
Snapshot Safari monitoring program *(Pardo et al. 2021)* → > 2 years data and 70,000 pictures



Blue wildebeest

Burchell's zebra

Greater kudu



Impala

Lion

Map: Figure 1 from Nicvert et al. 2024 (data from OpenStreetMap contributors under OdbL license) | Pictures : © Snapshot Safari

Material and methods

Hawkes process

Material and methods

Hawkes process

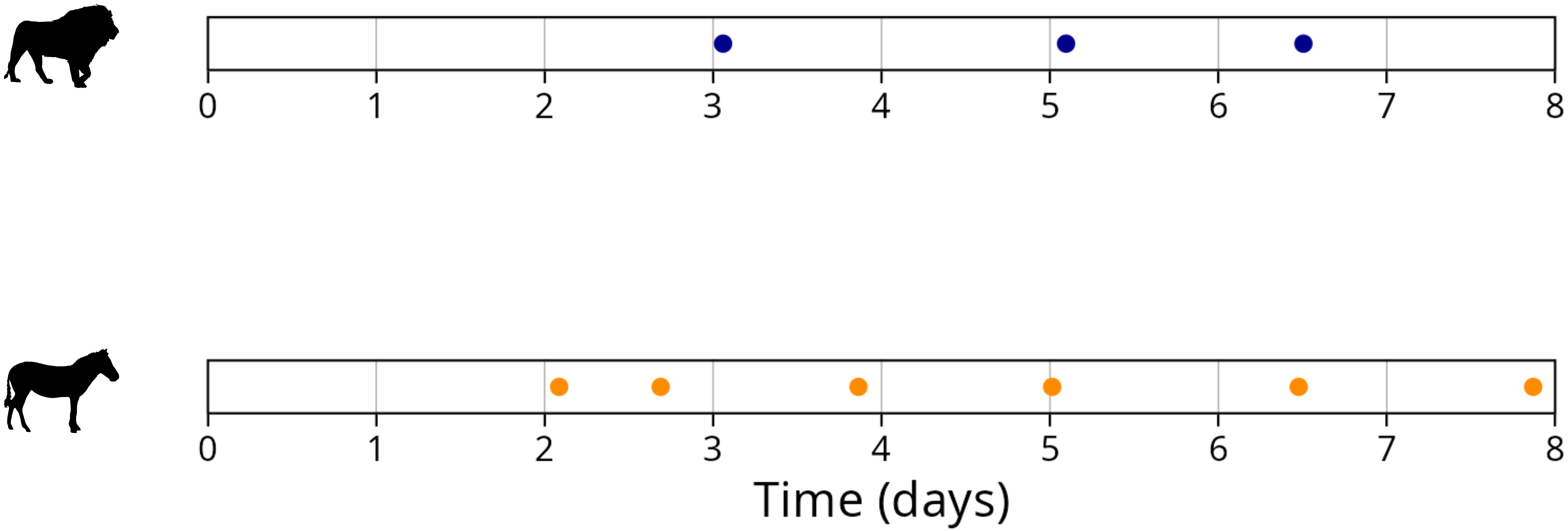
- Point process to model self-exciting events *(Hawkes 1971)*

Material and methods
Hawkes process

- Point process to model self-exciting events *(Hawkes 1971)*
- Earthquakes aftershocks, stock market prices, action potentials in neurons…

Material and methods

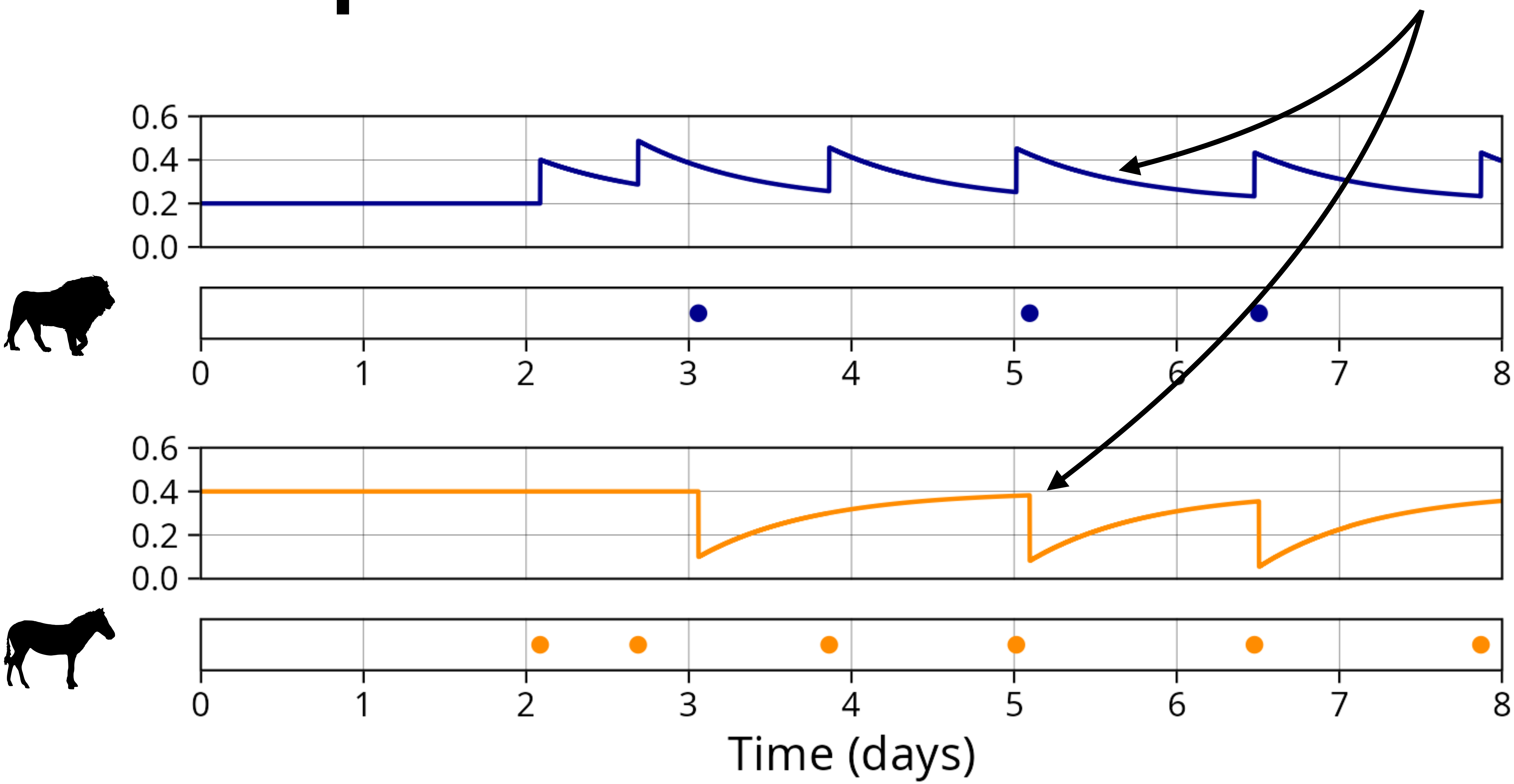
Hawkes process



Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

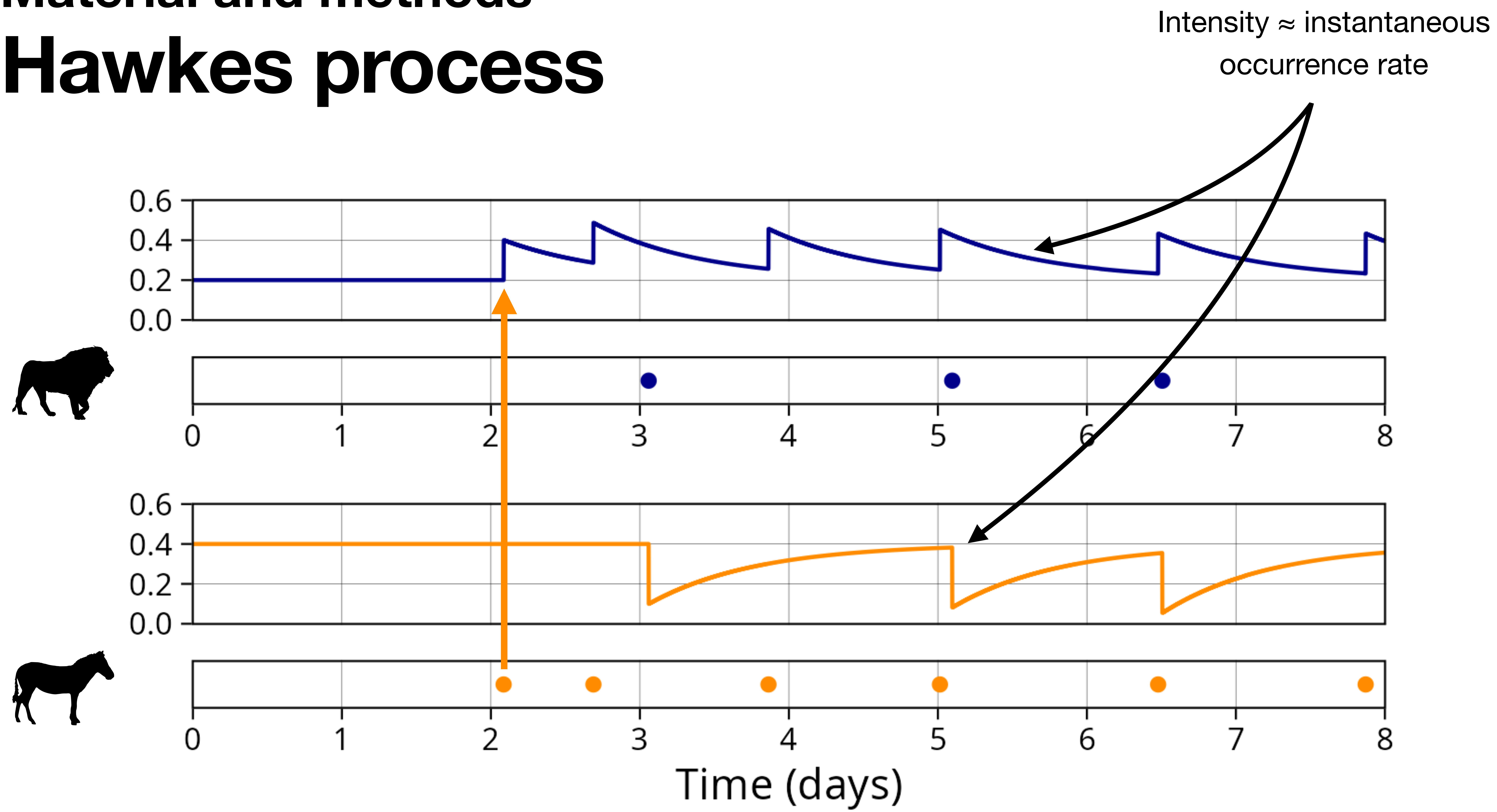
Material and methods
Hawkes process

Intensity ≈ instantaneous occurrence rate



Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

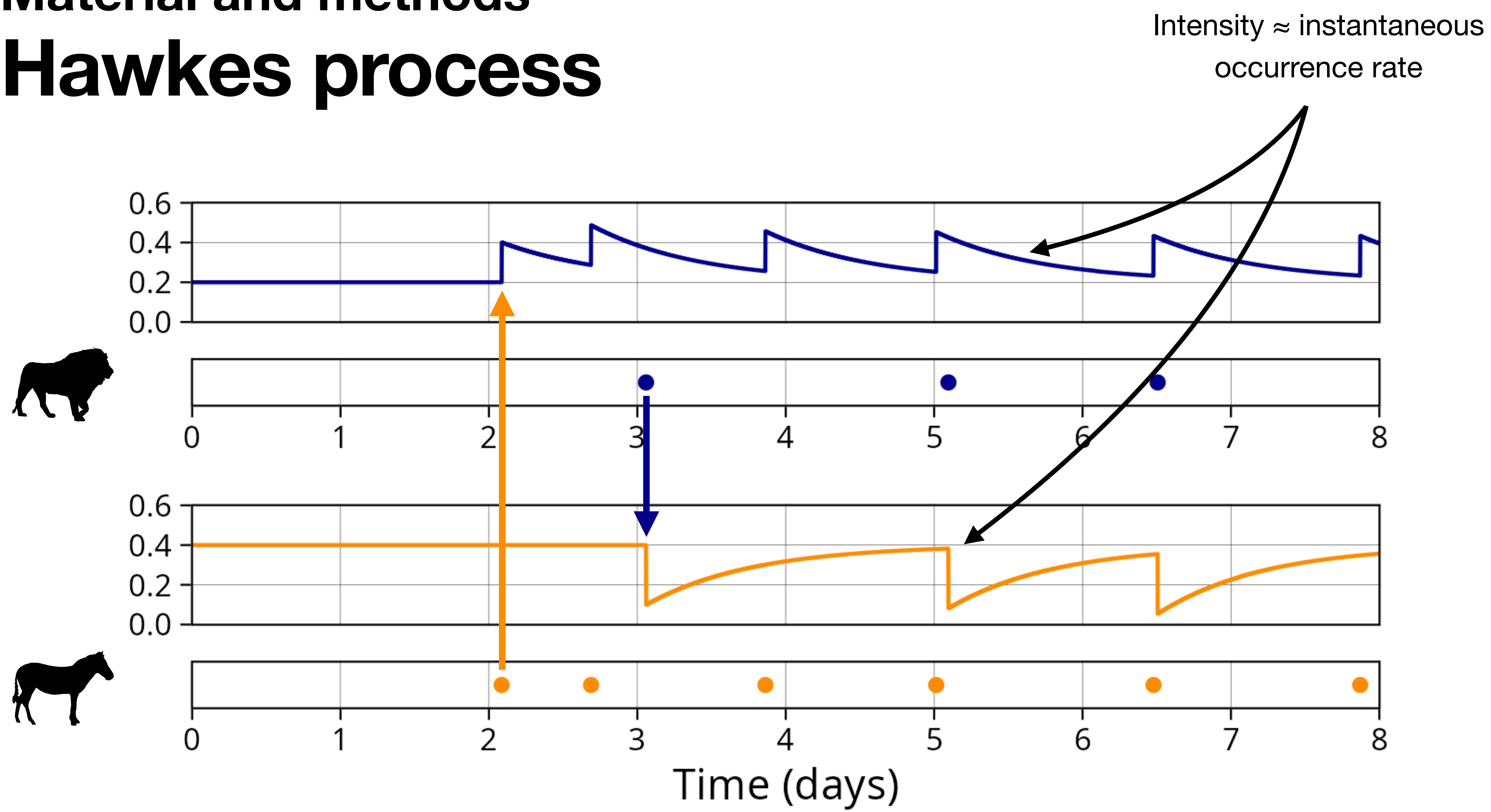
Material and methods
Hawkes process



Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Material and methods

Hawkes process



Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

Material and methods
Hawkes process

Model from *Lambert et al. (2018)*, implemented in the R package UnitEvents *Albert et al. 2021*

Material and methods
Hawkes process

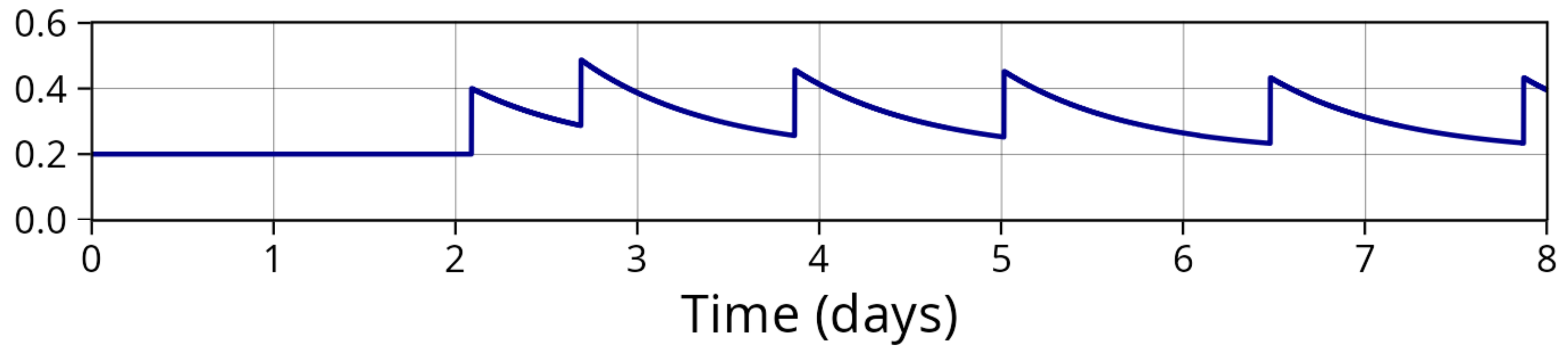
Model from *Lambert et al. (2018)*, implemented in the R package UnitEvents *Albert et al. 2021*

$$\lambda_i^l(t) = \left(\nu_i + \sum_{j=1}^{S} \sum_{m \mid T_m^{lj} < t} f_{j \to i}(t - T_m^{lj}) \right)_+$$

Material and methods

Hawkes process

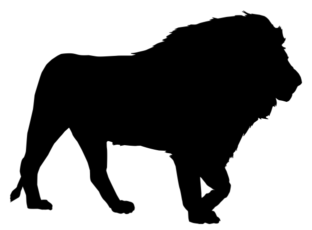
Model from *Lambert et al. (2018)*, implemented in the R package UnitEvents *Albert et al. 2021*



$$\underbrace{\lambda_i^l(t)}_{} = \left(\nu_i + \sum_{j=1}^{S} \sum_{m \mid T_m^{lj} < t} f_{j \to i}(t - T_m^{lj}) \right)_+$$

Intensity for species i

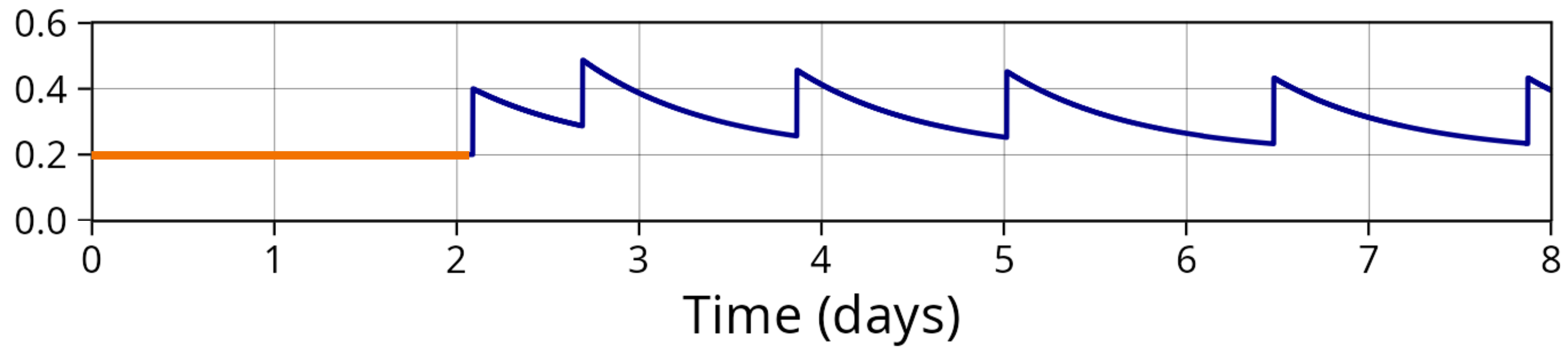
at camera trap l



Silhouette images from PhyloPic by Lukasiniho (wildebeest), Margot Michaud (lion), Robert Hering (kudu), Zimices (zebra), and an unknown author (impala).

Material and methods
Hawkes process

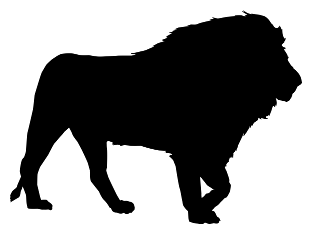
Model from *Lambert et al. (2018)*, implemented in the R package UnitEvents *Albert et al. 2021*



$$\lambda_i^l(t) = \left(\nu_i + \sum_{j=1}^{S} \sum_{m \mid T_m^{lj} < t} f_{j \to i}(t - T_m^{lj})\right)_+$$

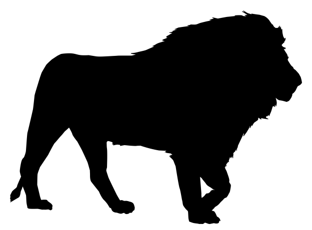
Intensity for species i

at camera trap l



Background rate

for species i

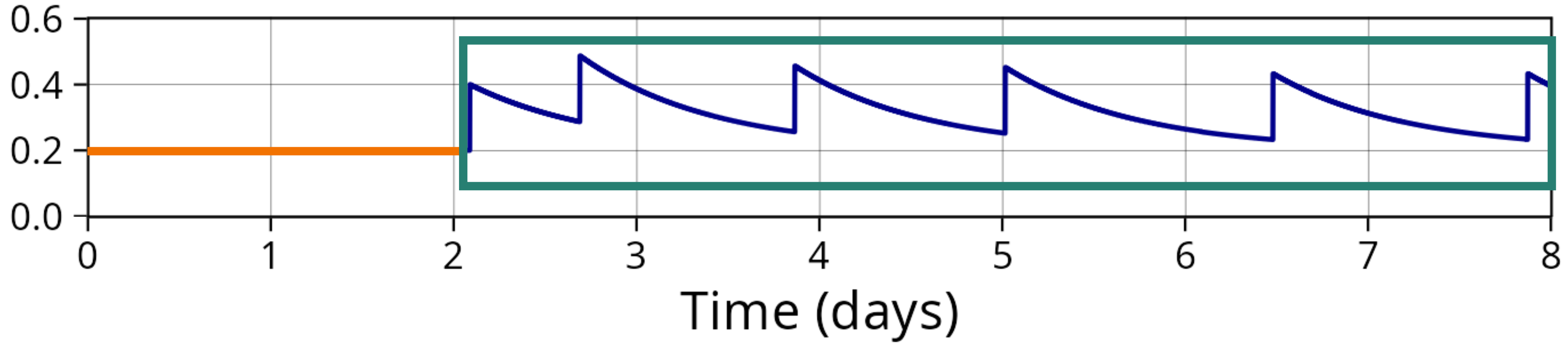


Silhouette images from PhyloPic by Lukasiniho (wildebeest), Margot Michaud (lion), Robert Hering (kudu), Zimices (zebra), and an unknown author (impala).

Material and methods

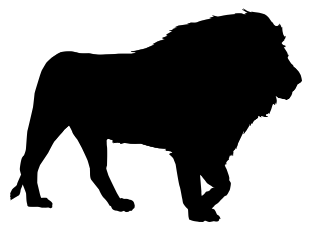
Hawkes process

Model from *Lambert et al. (2018)*, implemented in the R package UnitEvents *Albert et al. 2021*

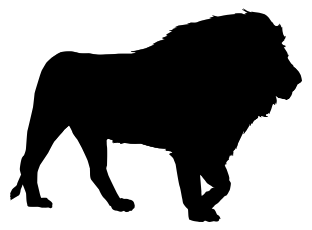


$$\lambda_i^l(t) = \left(\nu_i + \boxed{\sum_{j=1}^{S} \sum_{m \mid T_m^{lj}<t} f_{j\to i}(t - T_m^{lj})}\right)_+$$

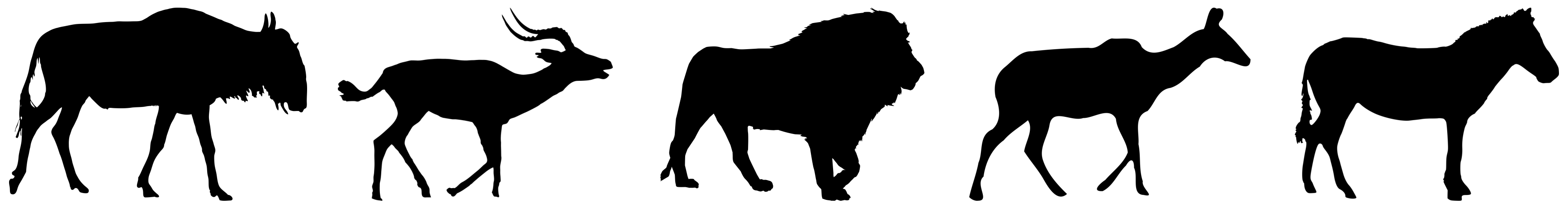
Intensity for species i at camera trap l



Background rate for species i



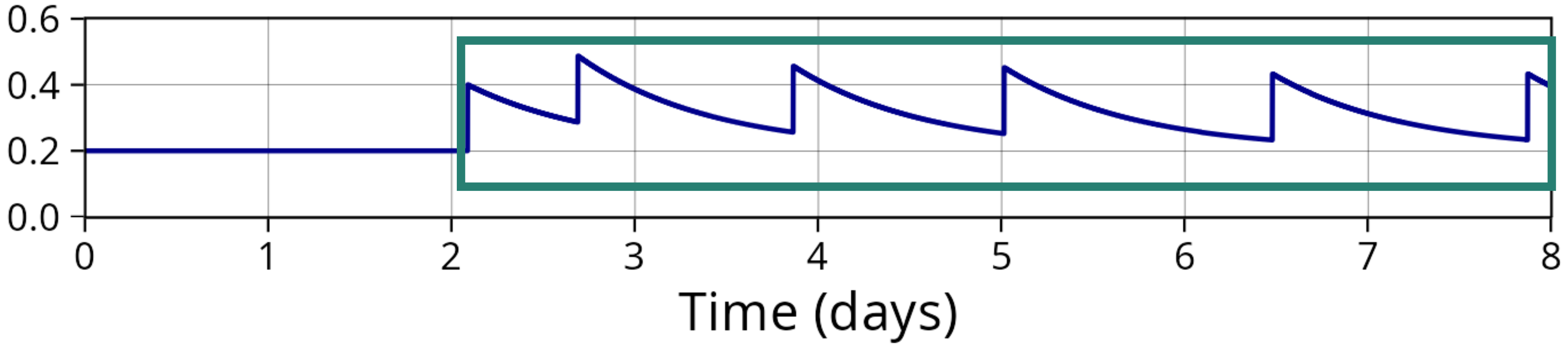
Influence of other occurrences



Silhouette images from PhyloPic by Lukasiniho (wildebeest), Margot Michaud (lion), Robert Hering (kudu), Zimices (zebra), and an unknown author (impala).

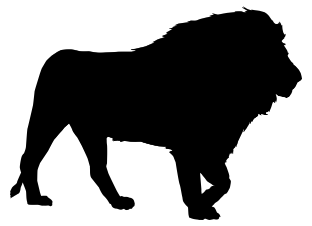
Material and methods
Hawkes process

Model from *Lambert et al. (2018)*, implemented in the R package UnitEvents *Albert et al. 2021*

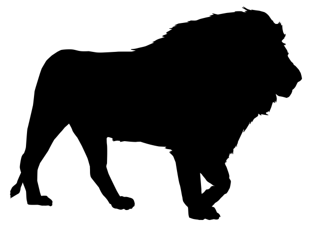


$$\lambda_i^l(t) = \left(\nu_i + \sum_{j=1}^{S} \sum_{m \mid T_m^{lj}<t} f_{j\to i}(t - T_m^{lj})\right)_+$$

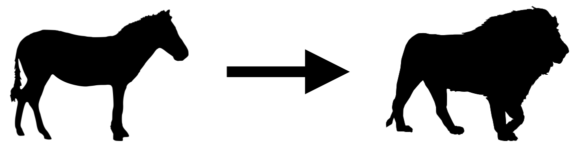
Intensity for species i at camera trap l



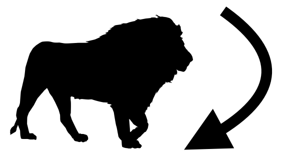
Background rate for species i



Interaction function from species j to species i



$j \neq i$

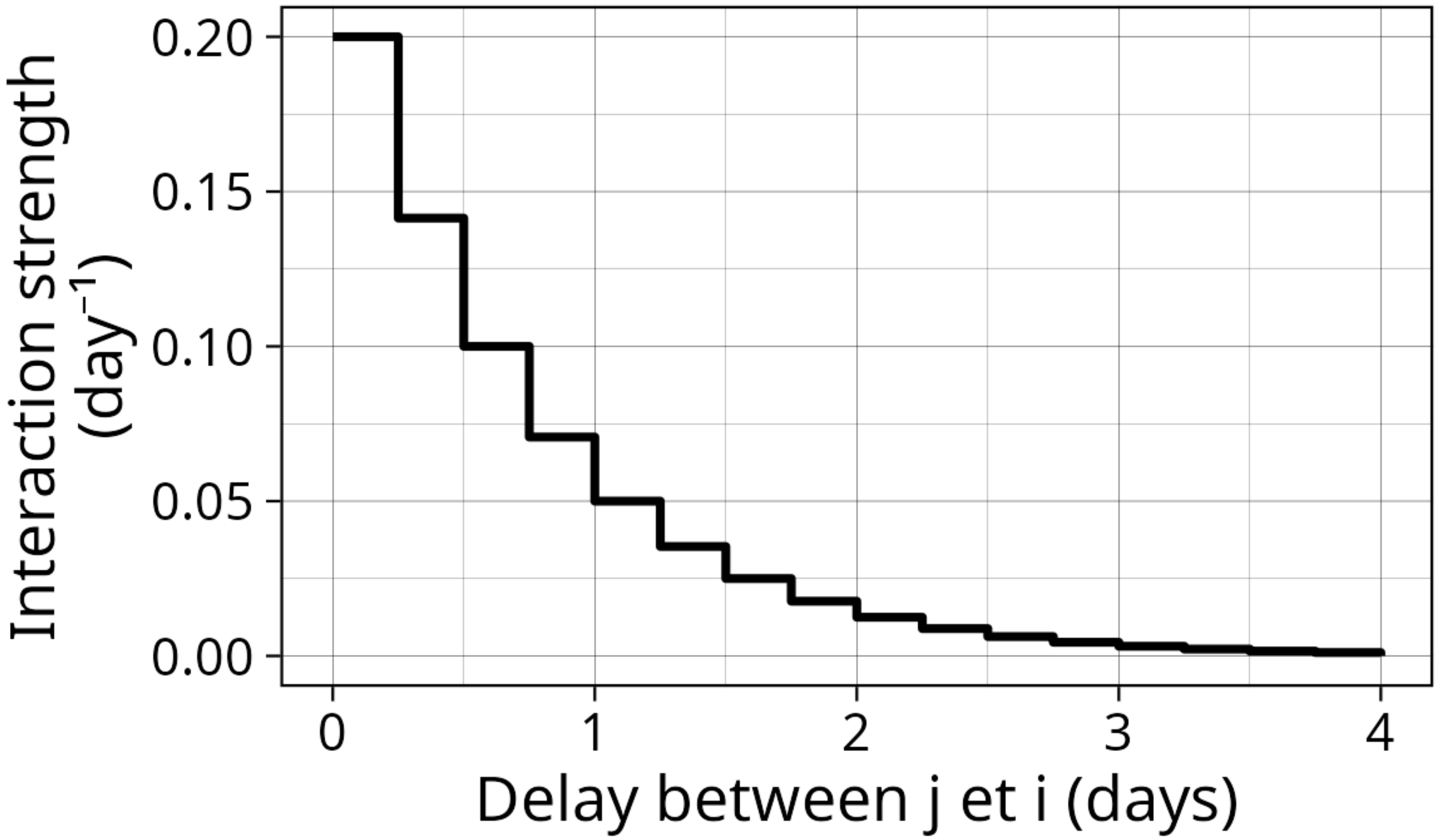


$j = i$

Silhouette images from PhyloPic by Zimices (zebra) and Margot Michaud (lion).

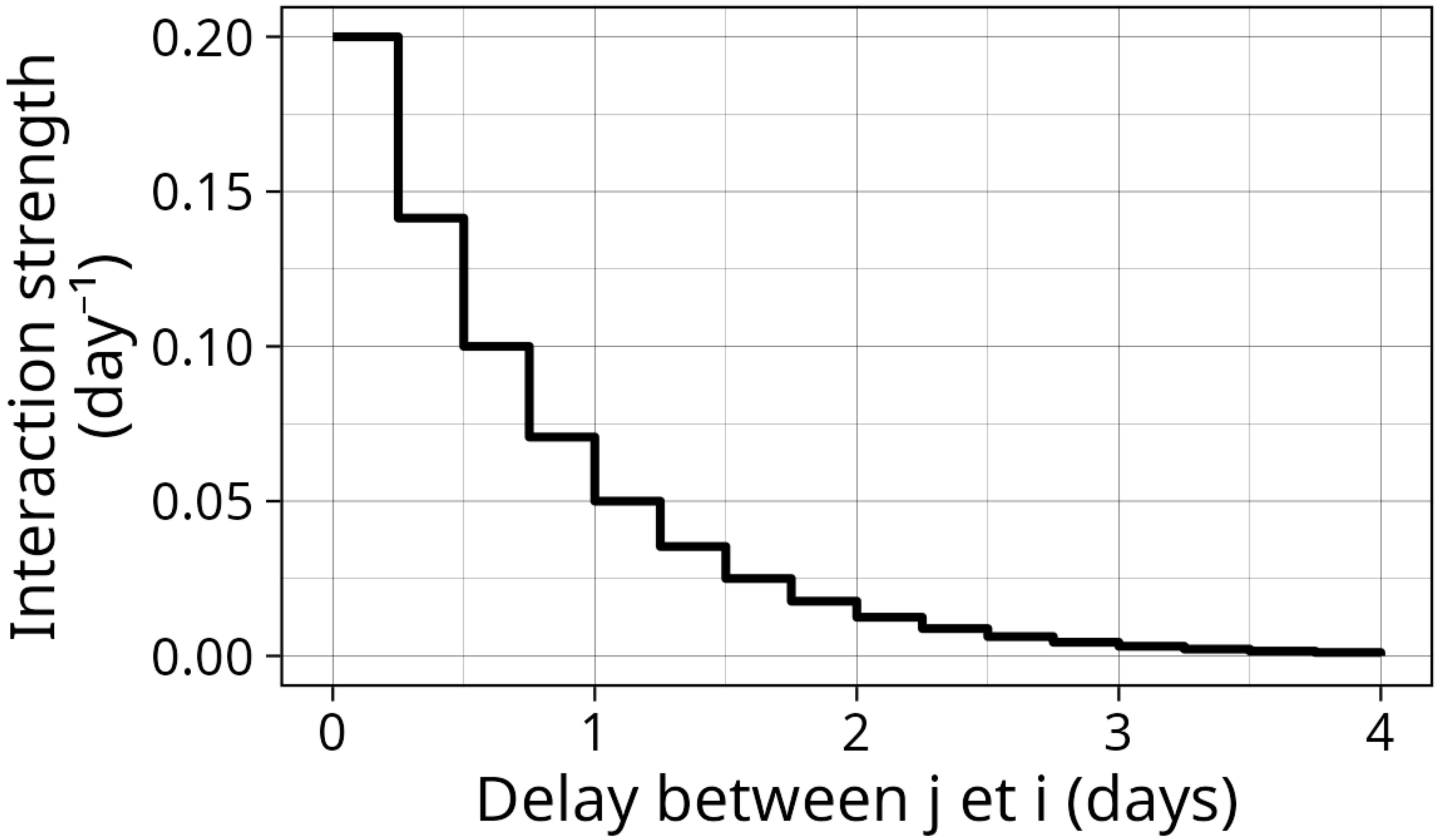
Material and methods

The interaction function $f_{j \to i}(t - T_m^{lj})$



Material and methods

The interaction function $f_{j \to i}(t - T_m^{lj})$



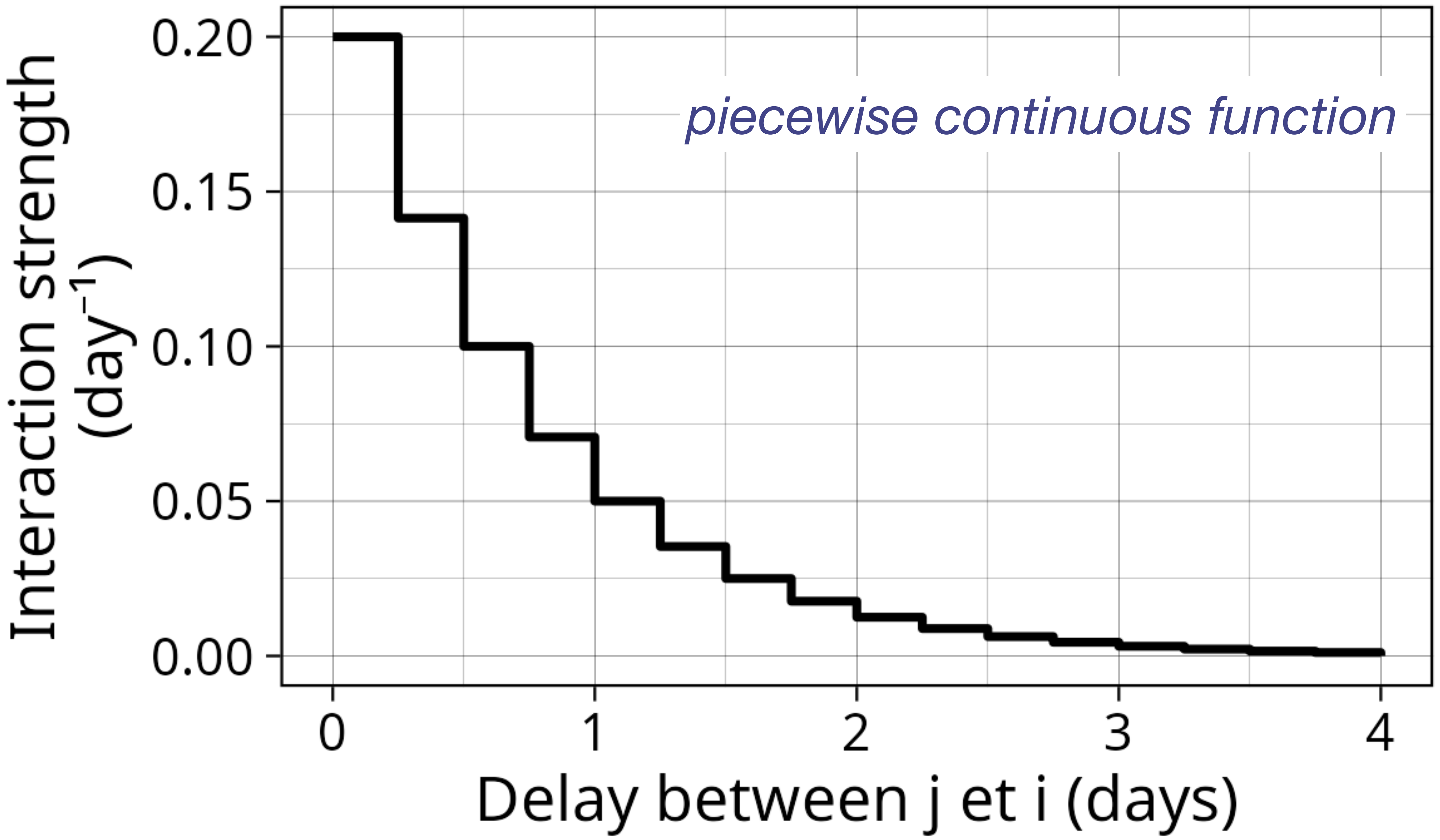
> 0 ➞ attraction of i by j

$= 0$ ➞ no effect

< 0 ➞ replusion of i by j

Material and methods

The interaction function $f_{j \to i}(t - T_m^{lj})$



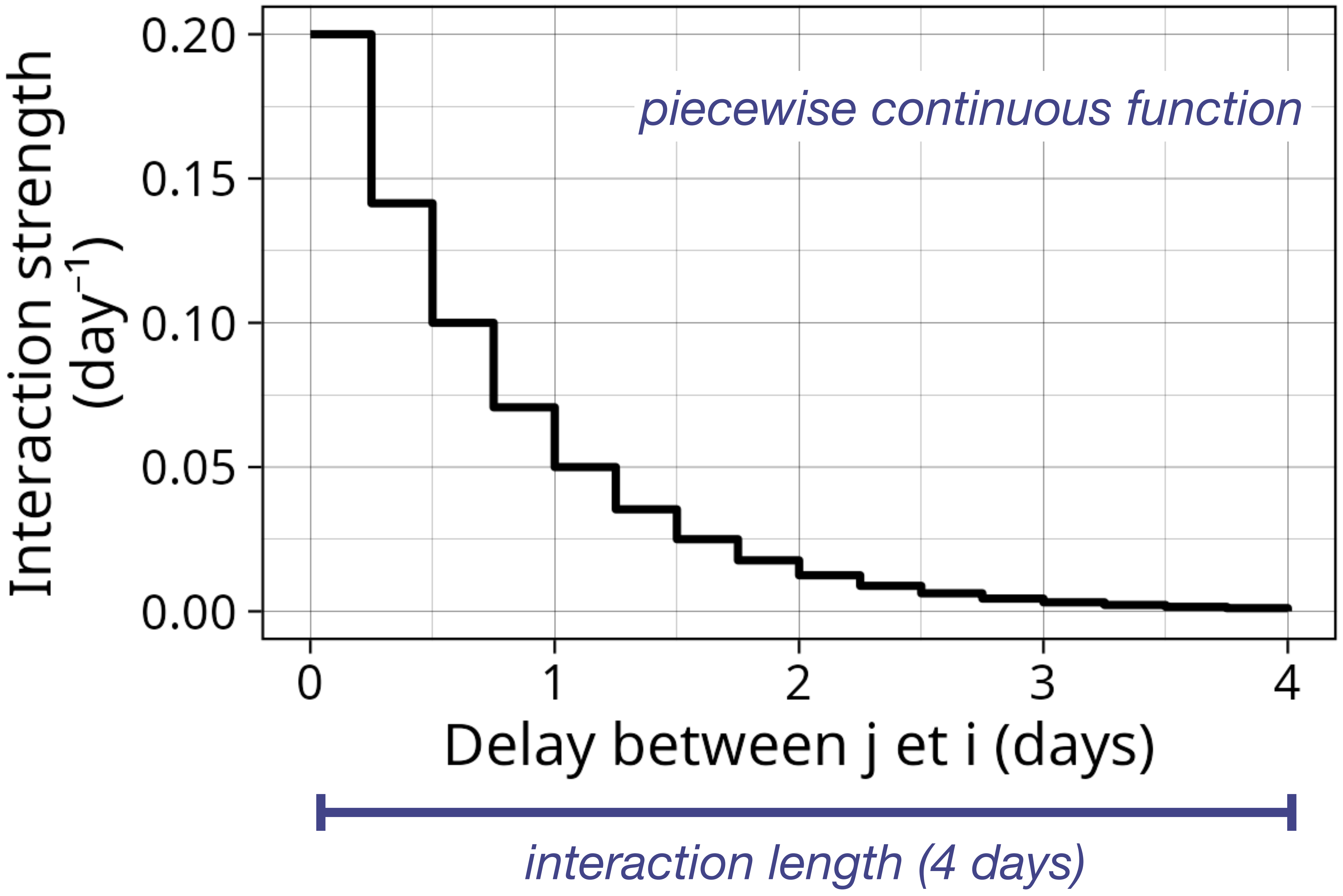
> 0 ➞ attraction of i by j

$= 0$ ➞ no effect

< 0 ➞ replusion of i by j

Material and methods

The interaction function $f_{j \to i}(t - T_m^{lj})$



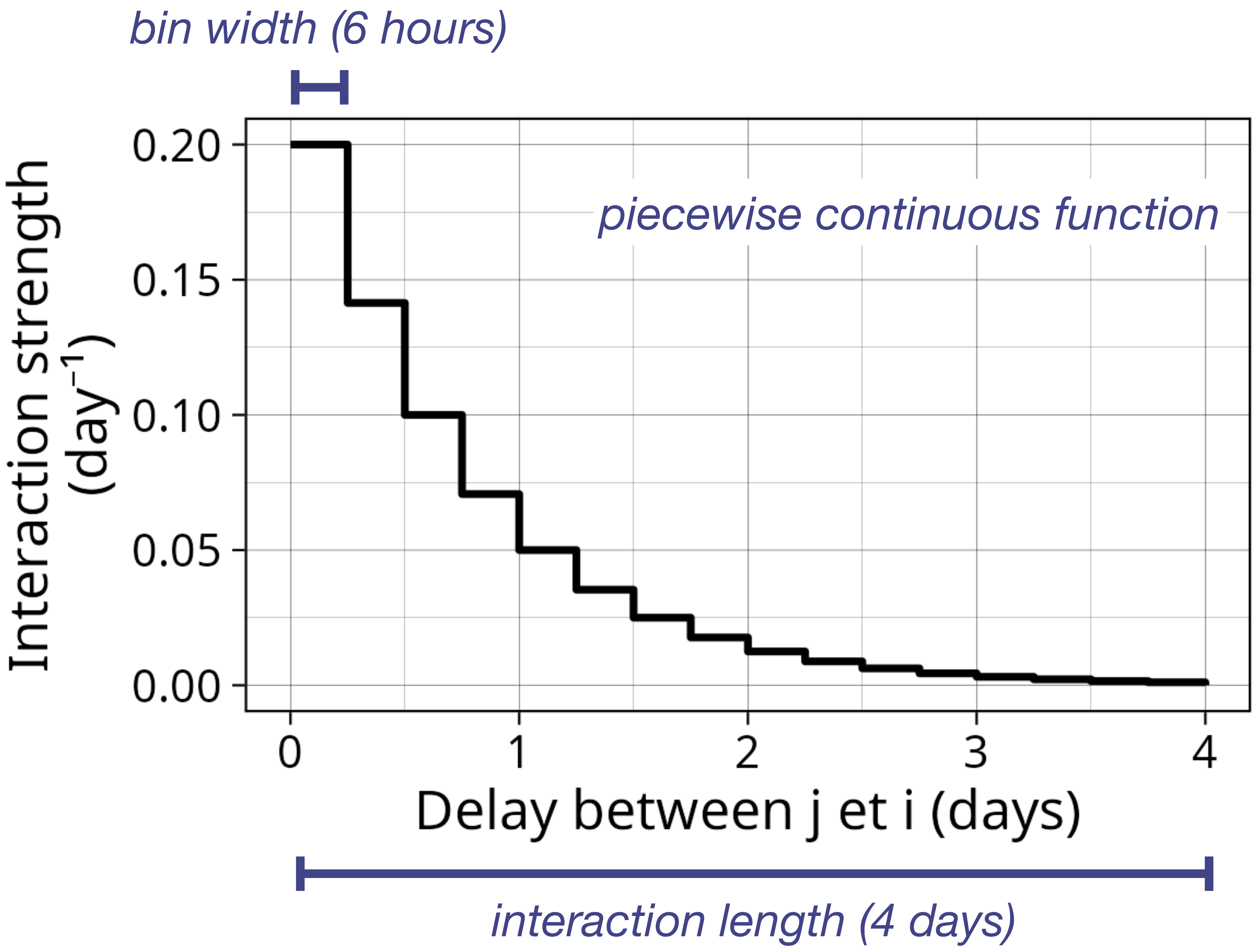
> 0 ➞ attraction of i by j

$= 0$ ➞ no effect

< 0 ➞ replusion of i by j

Material and methods

The interaction function $f_{j \to i}(t - T_m^{lj})$



> 0 ➞ attraction of i by j

$= 0$ ➞ no effect

< 0 ➞ replusion of i by j

Material and methods

Parameter fitting

$$\lambda_i^l(t) = \left(\nu_i + \sum_{j=1}^{S} \sum_{m \mid T_m^{lj} < t} f_{j \to i}(t - T_m^{lj}) \right)_+$$

Material and methods

Parameter fitting

$$\lambda_i^l(t) = \left(\nu_i + \sum_{j=1}^{S} \sum_{m \,|\, T_m^{lj} < t} f_{j \to i}(t - T_m^{lj}) \right)_+$$

LASSO-penalized least squares

Material and methods

Parameter fitting

$$\lambda_i^l(t) = \left(\nu_i + \sum_{j=1}^{S} \sum_{m \mid T_m^{lj} < t} f_{j \to i}(t - T_m^{lj}) \right)_+$$

LASSO-penalized least squares

- Least squares: parameter fitting
- LASSO penalization: model selection

Material and methods

Parameter fitting

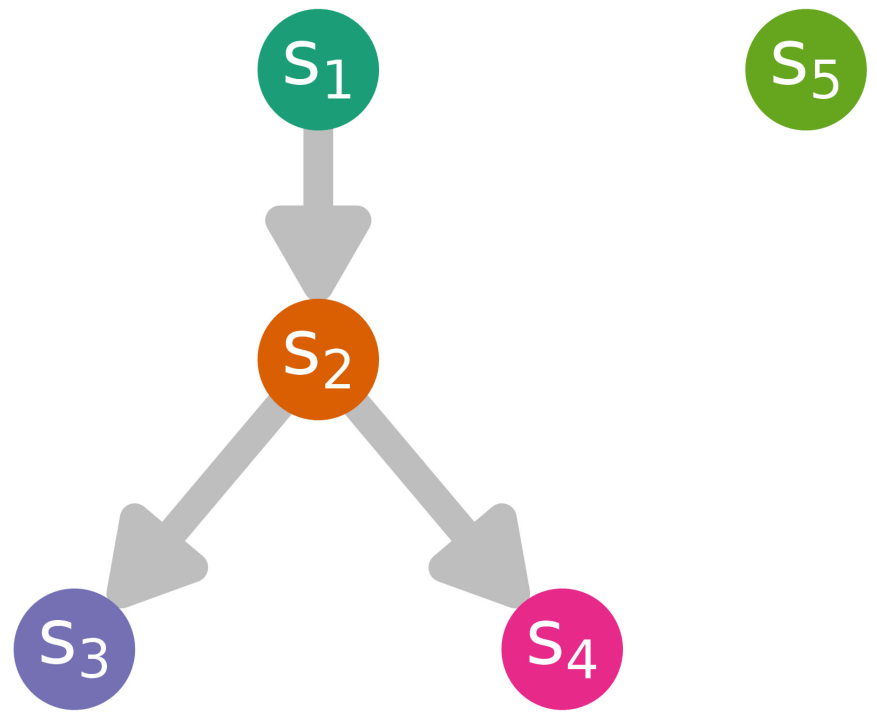
$$\lambda_i^l(t) = \left(\nu_i + \sum_{j=1}^{S} \sum_{m \mid T_m^{lj} < t} f_{j \to i}(t - T_m^{lj}) \right)_+$$

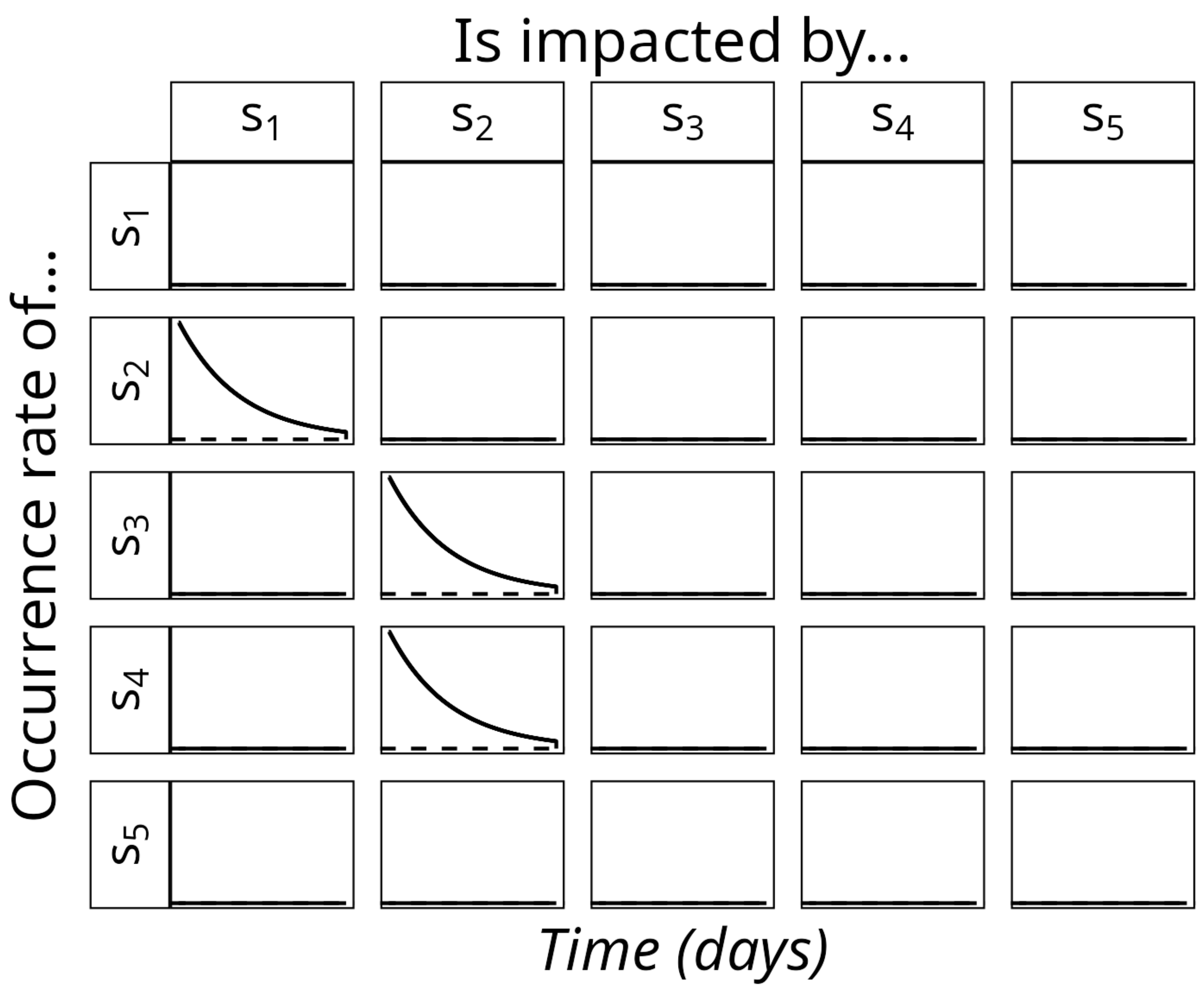
LASSO-penalized least squares

- Least squares: parameter fitting
- LASSO penalization: model selection
  - Hyperparameter $\gamma \in [0,\ 1]$ → strength of penalization
  - Simulation study → γ set to 0.5

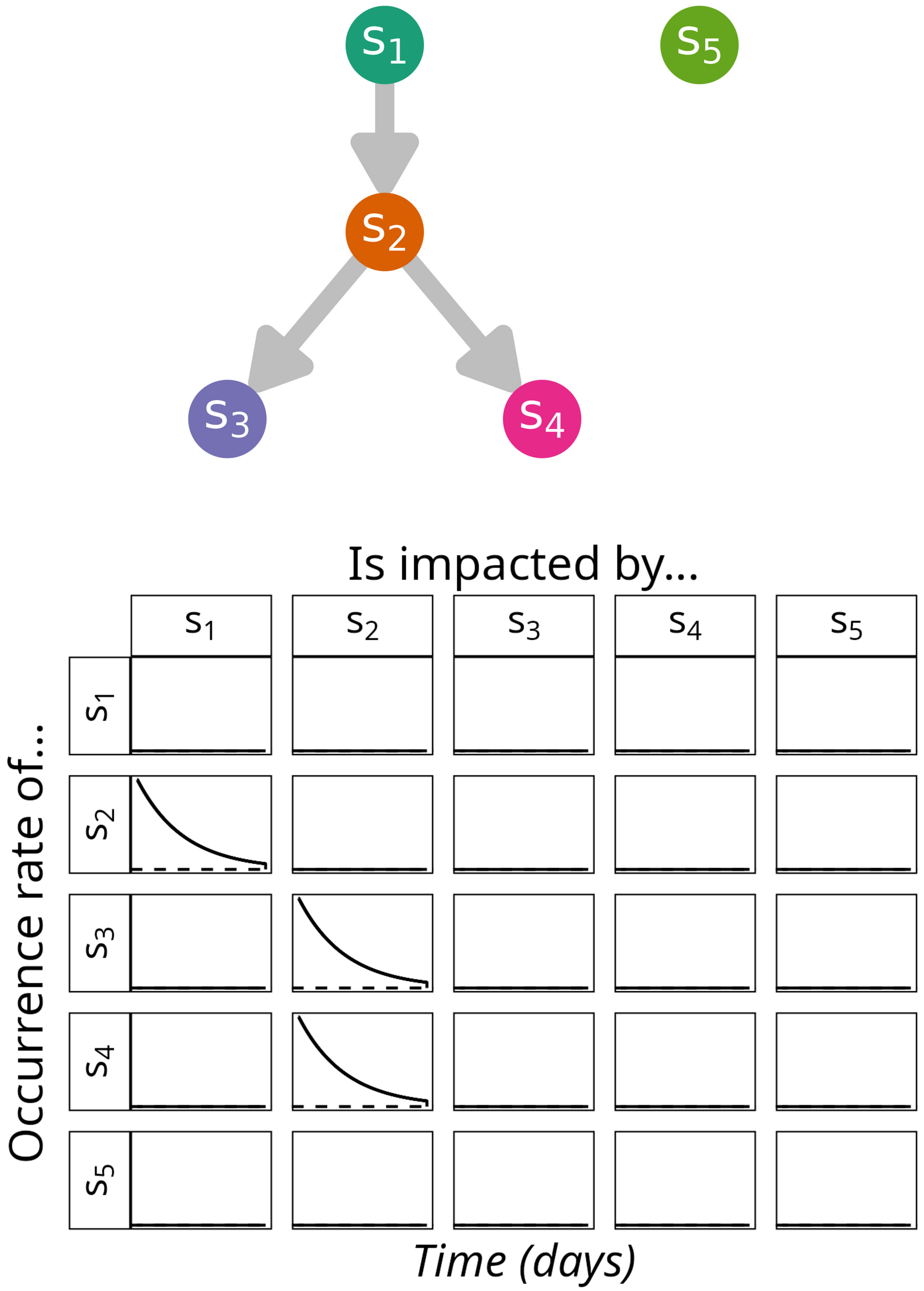
Material and methods

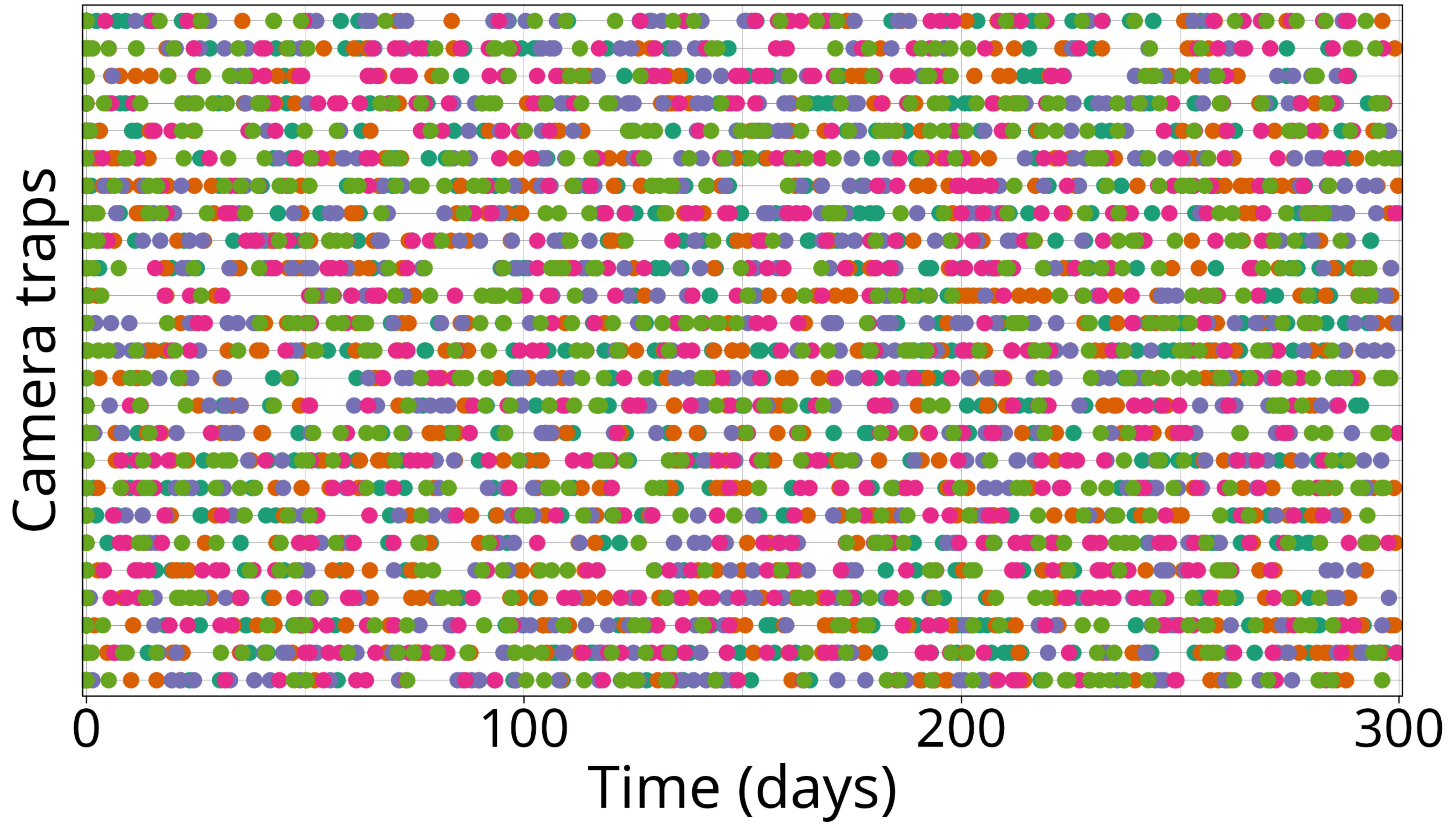
Simulation





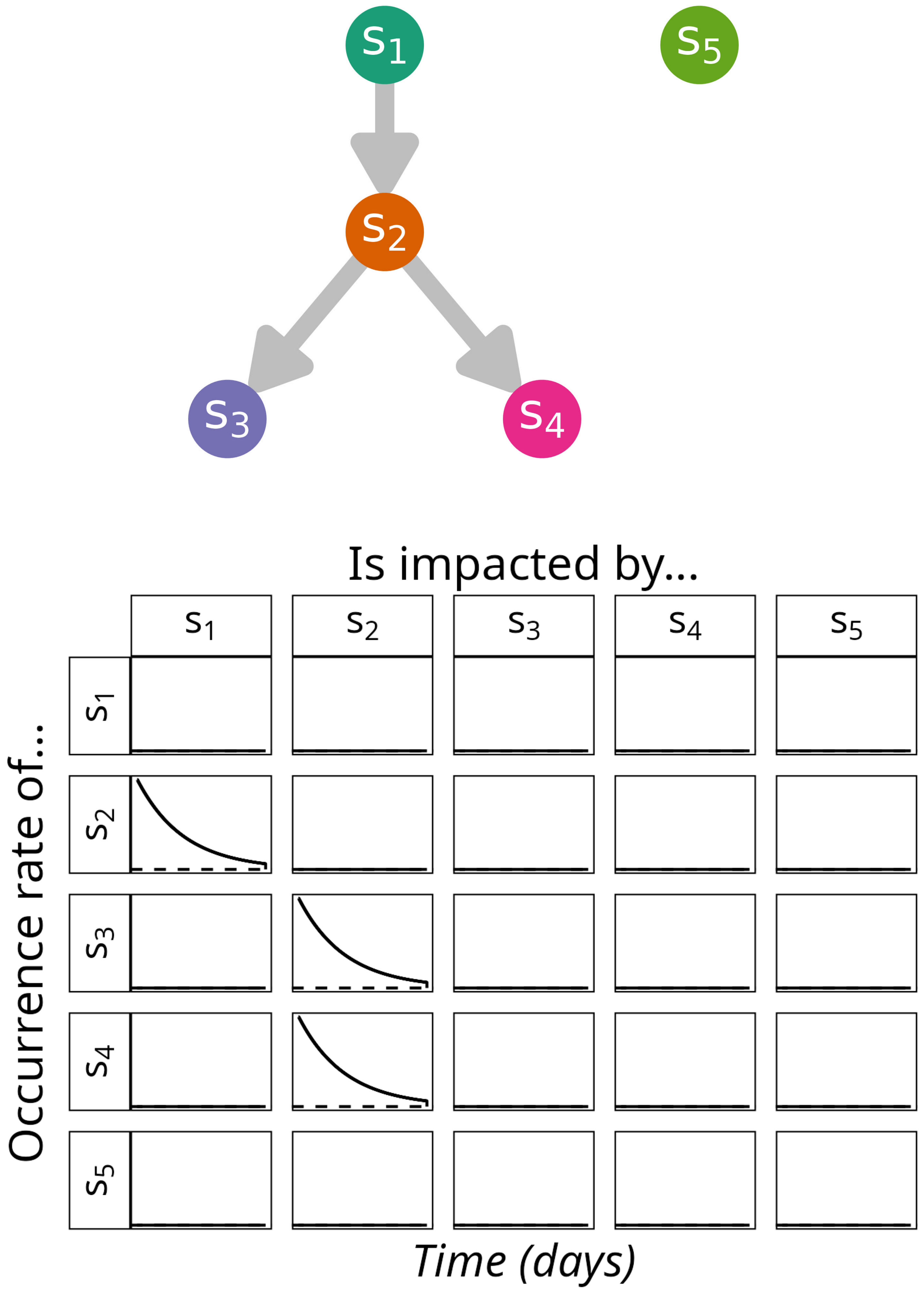
Material and methods
Simulation





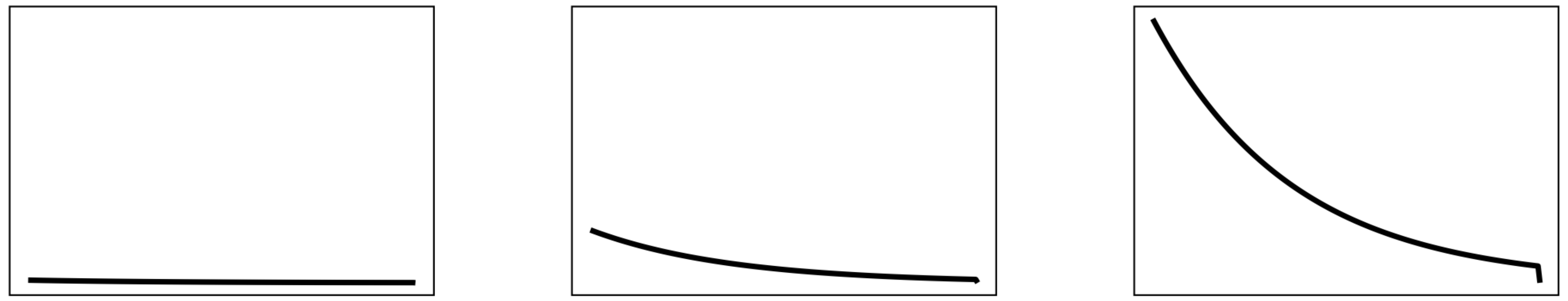
Material and methods

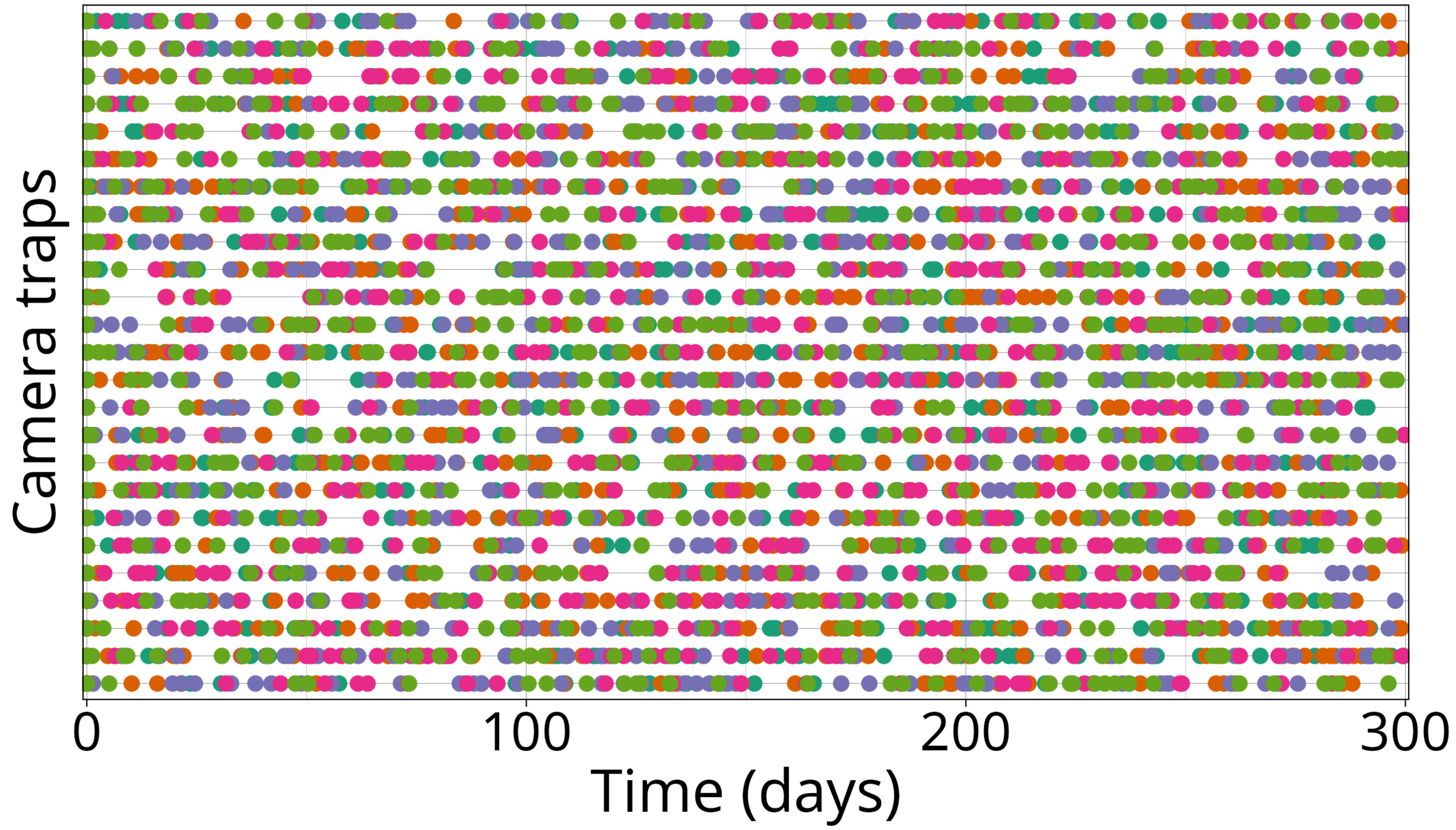
Simulation



simulation →

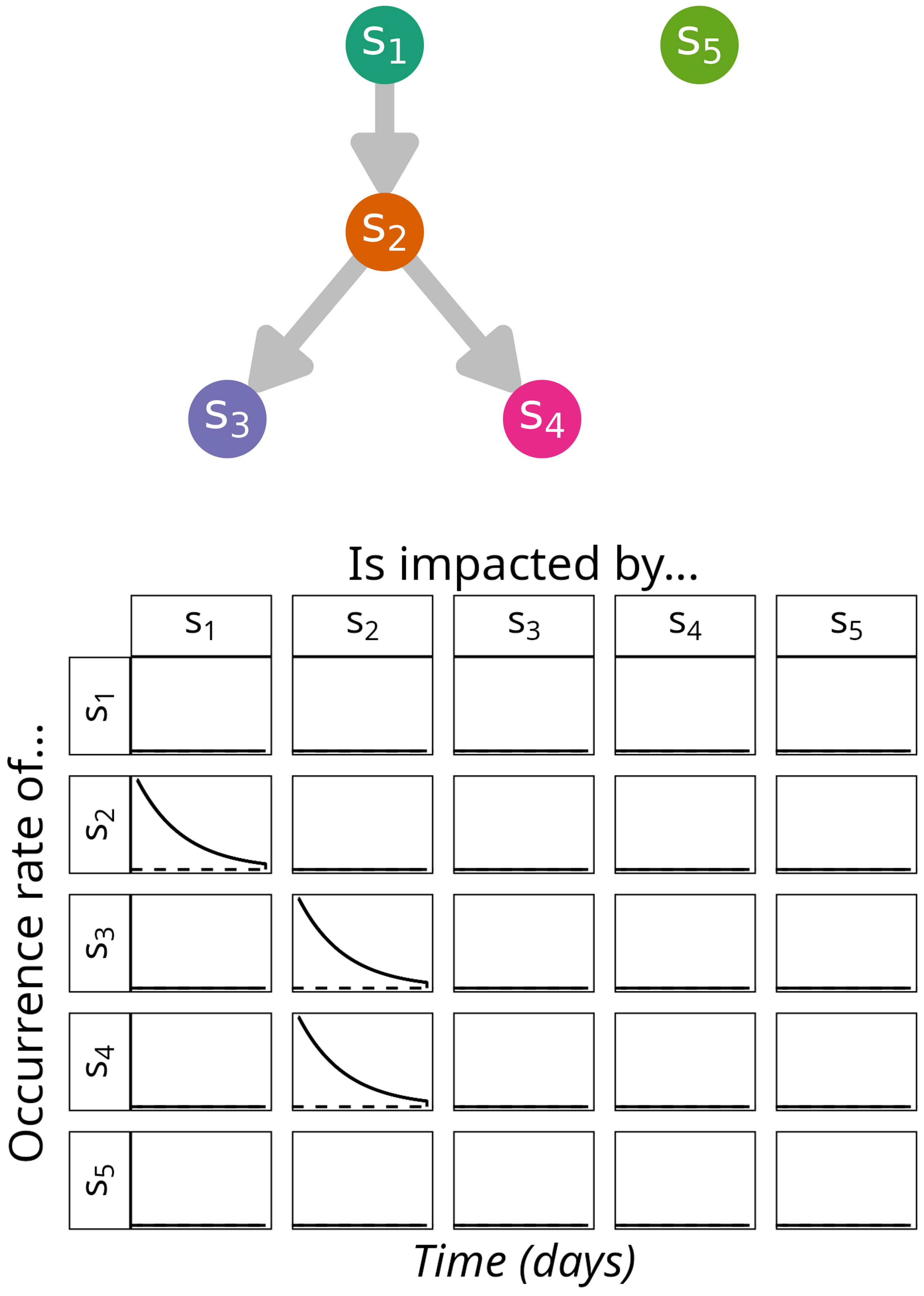
different interaction strengths





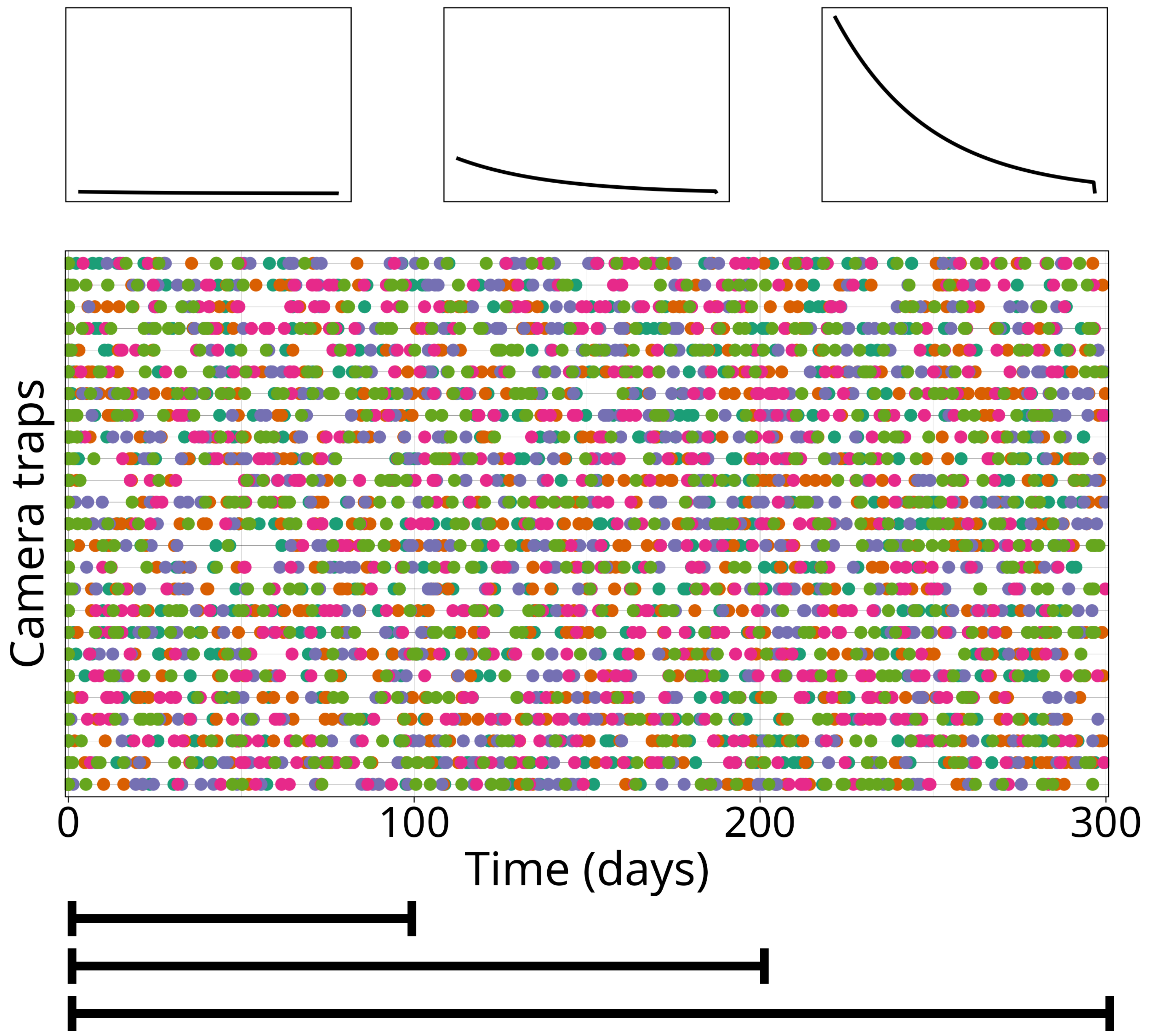
Material and methods

Simulation



simulation

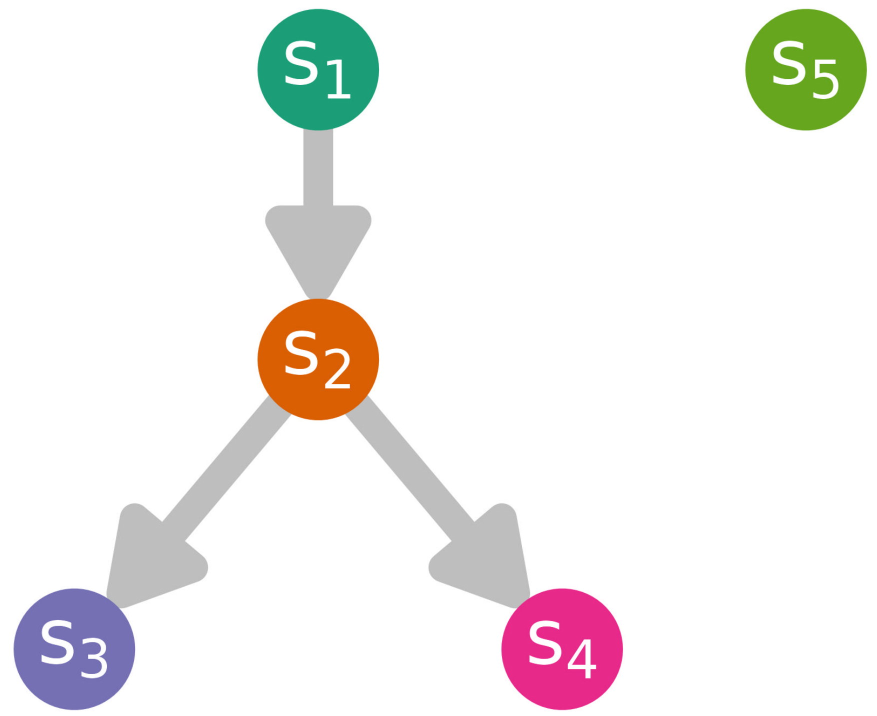
different interaction strengths

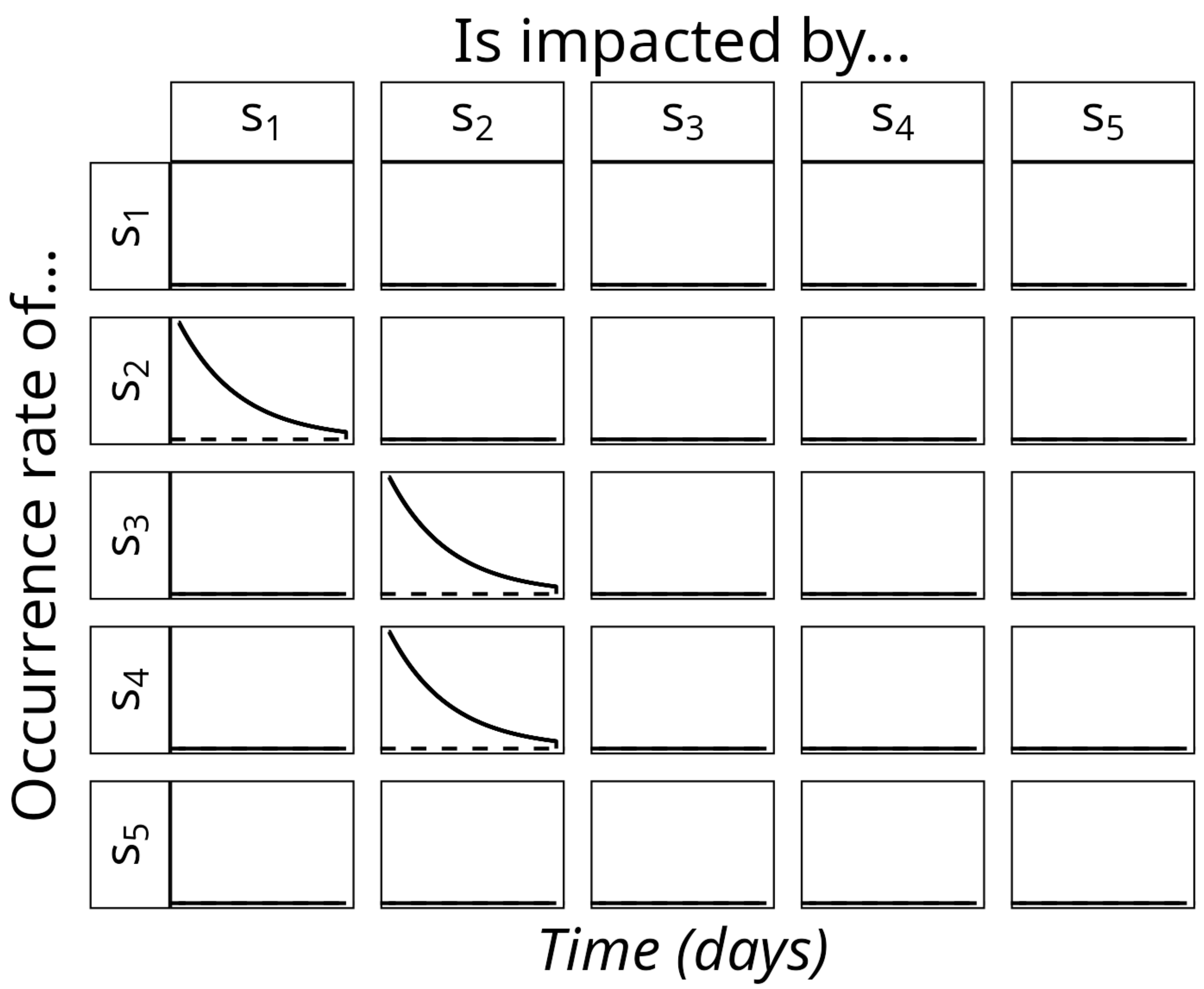


different data lengths

Material and methods

Simulation

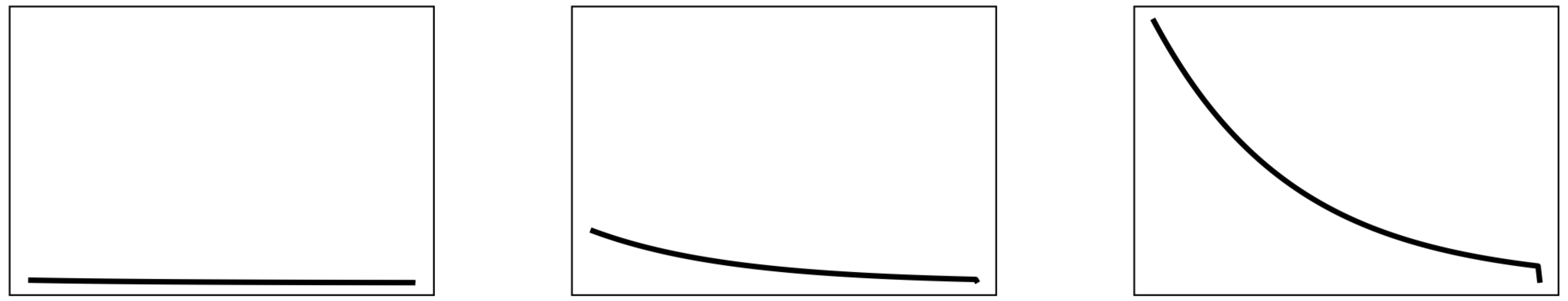


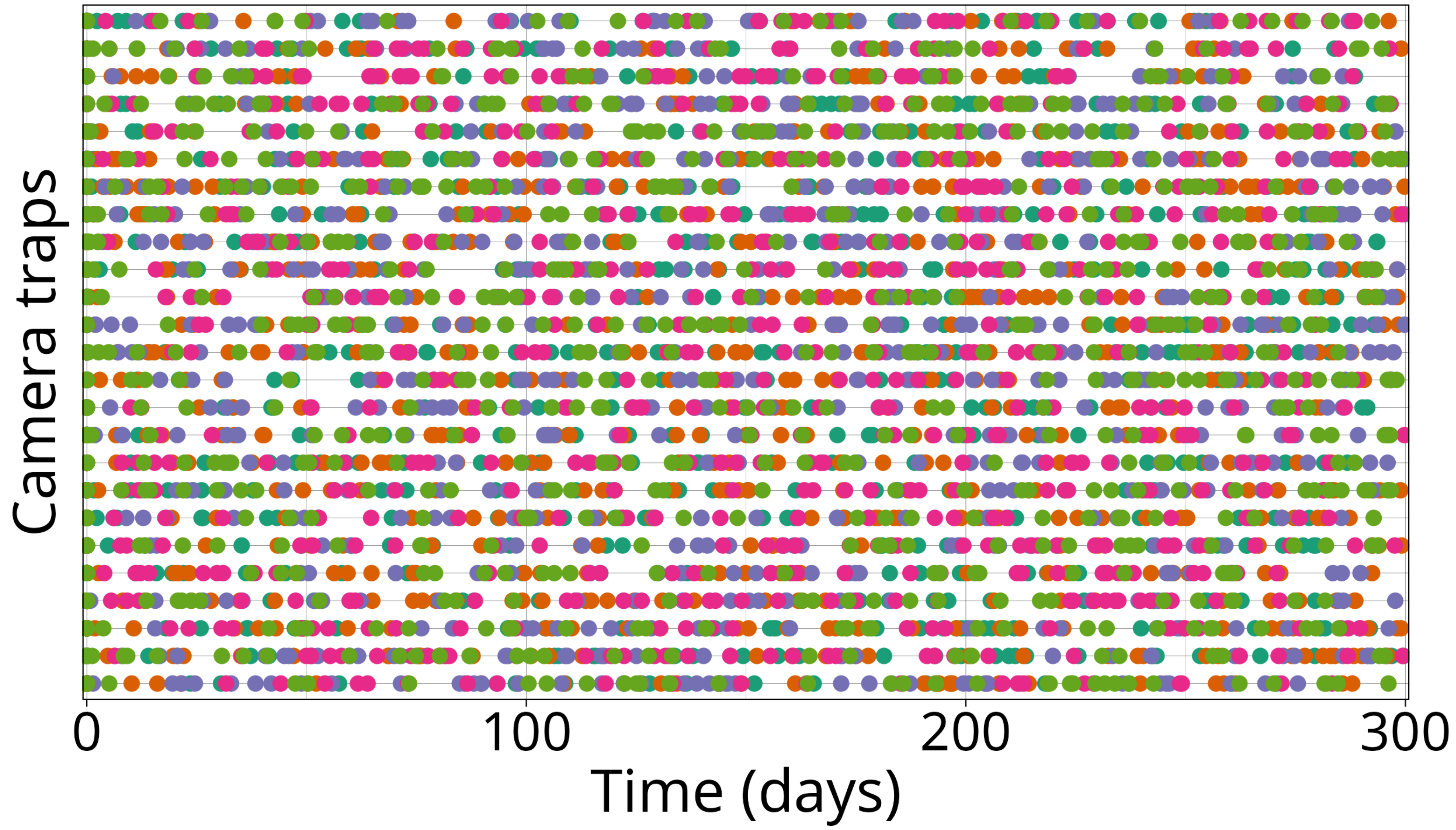


simulation

inference

different interaction strengths

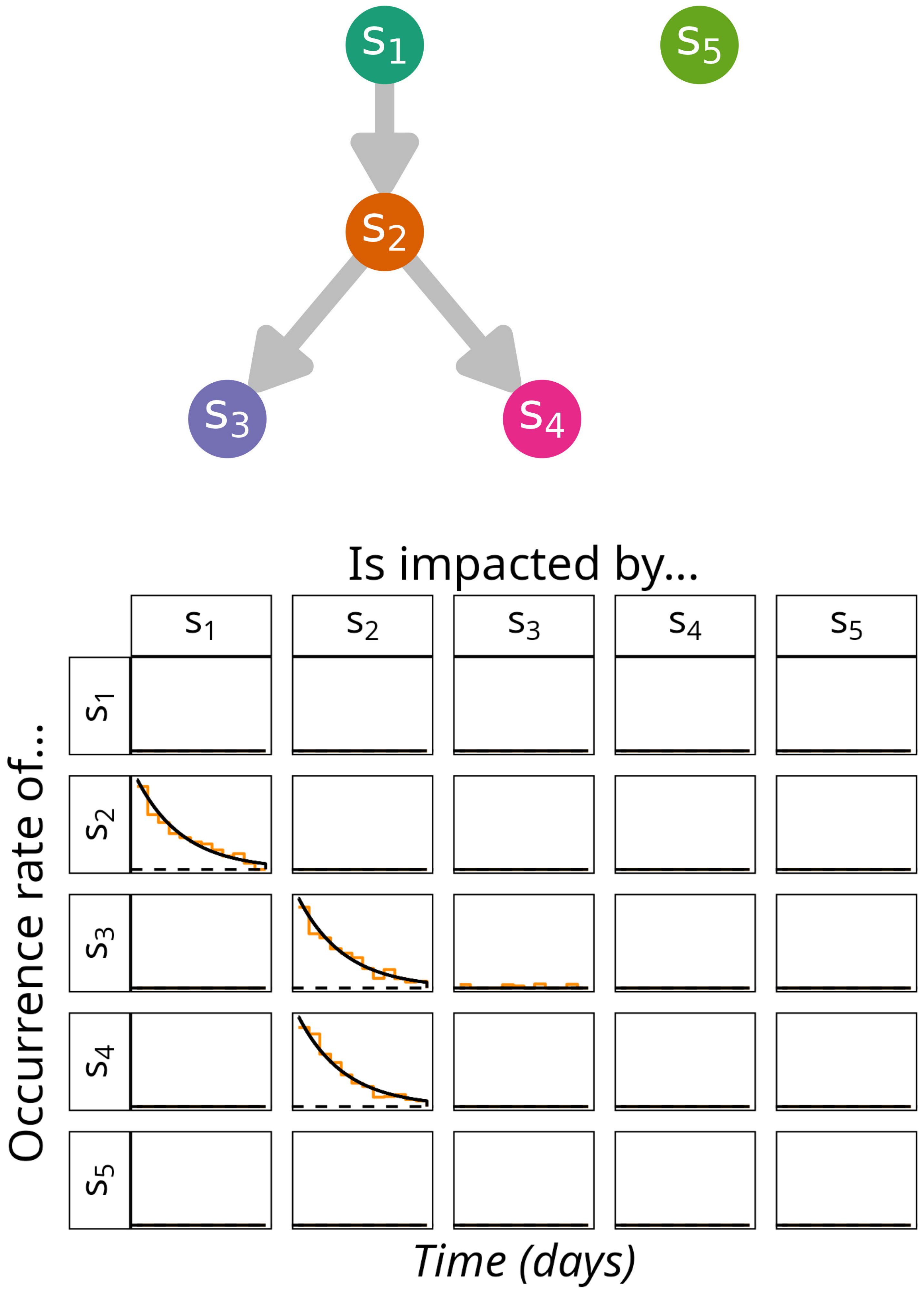




different data lengths

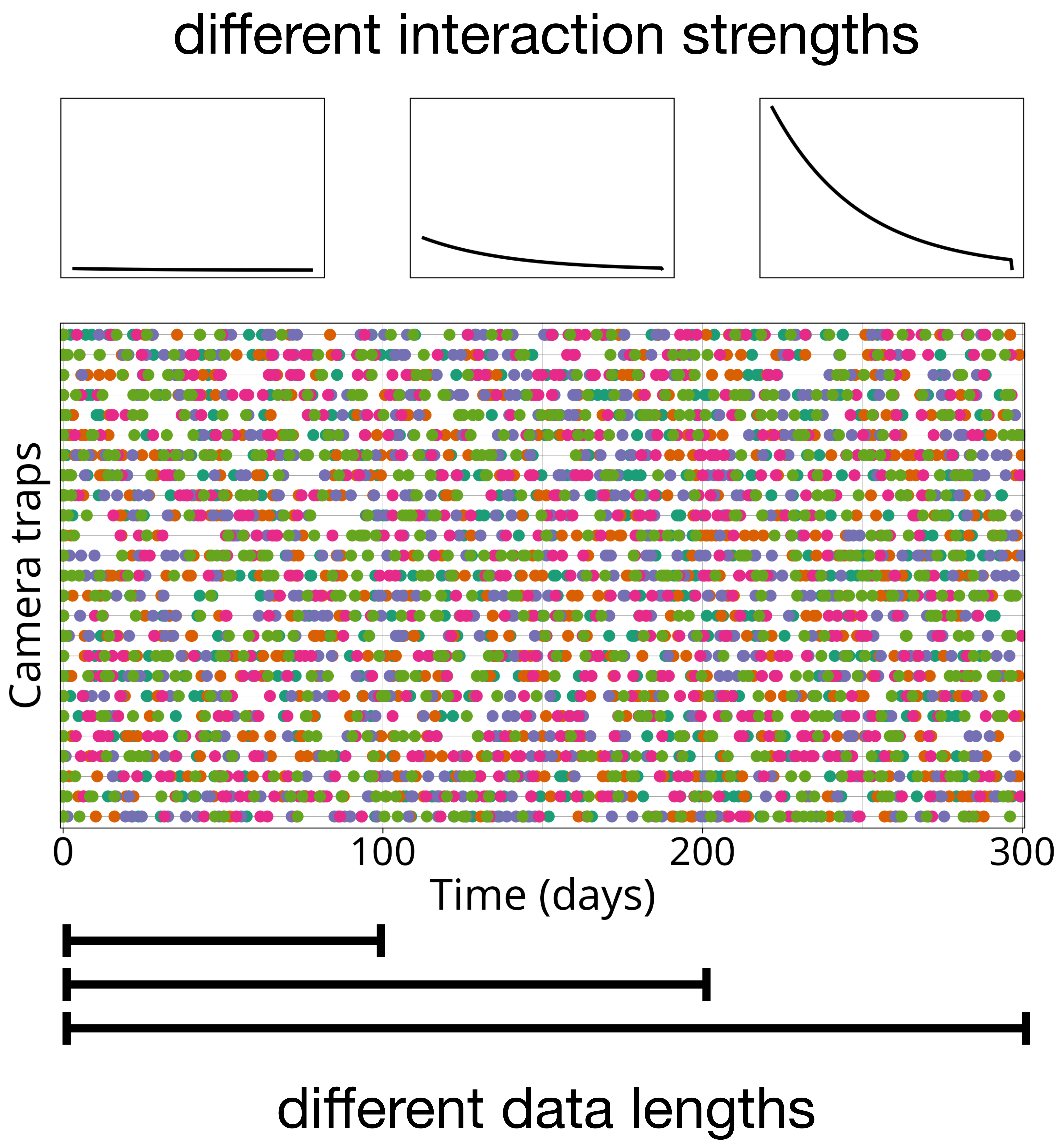
Material and methods

Simulation



simulation

inference



Results & discussion

Modified from Figure 4 from Nicvert et al. 2024

Results & discussion

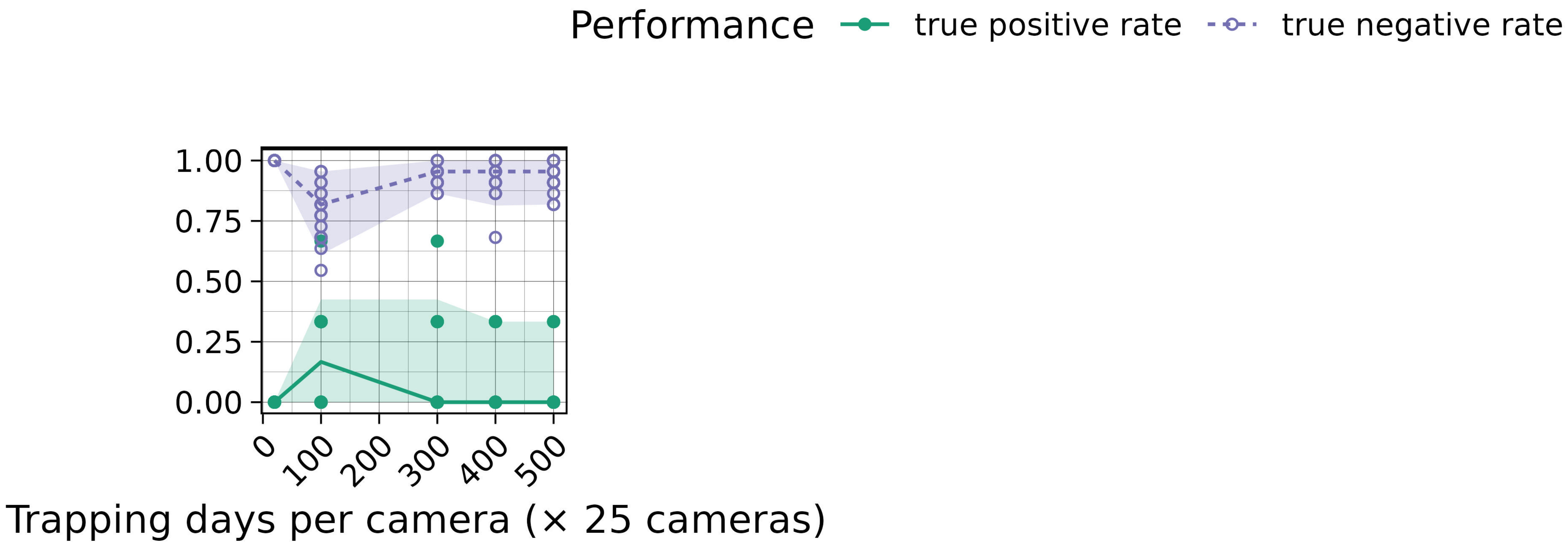
Evaluate the inference

Performance — true positive rate - - true negative rate

Modified from Figure 4 from Nicvert et al. 2024

Results & discussion

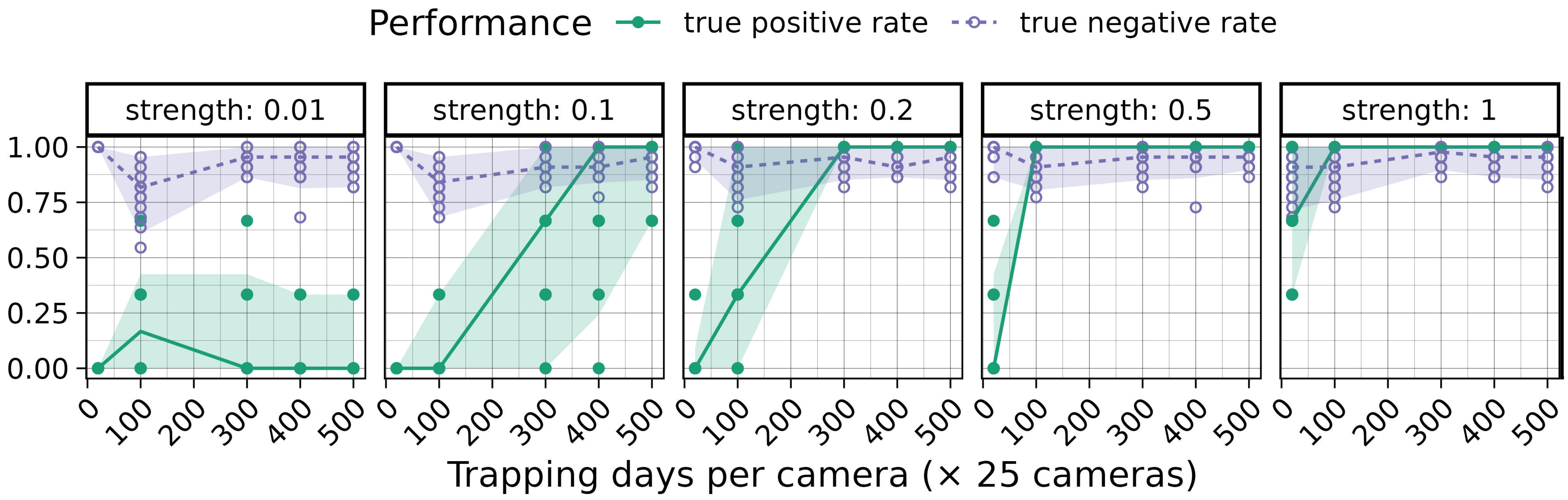
Evaluate the inference



Modified from Figure 4 from Nicvert et al. 2024

Results & discussion

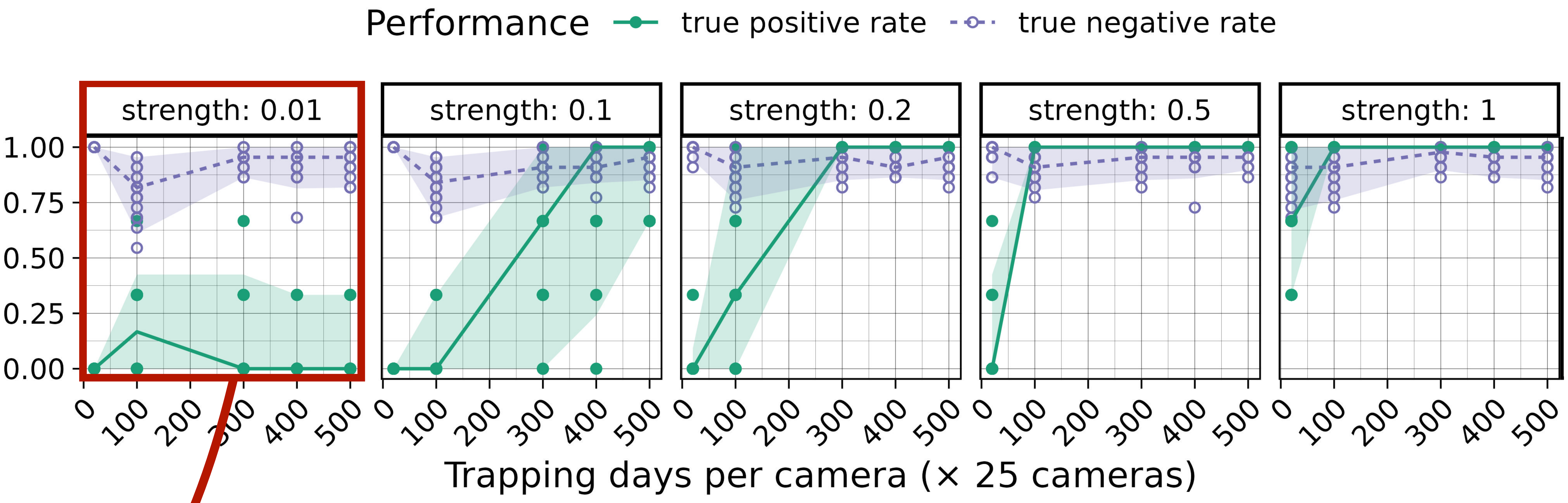
Evaluate the inference



Modified from Figure 4 from Nicvert et al. 2024

Results & discussion

Evaluate the inference

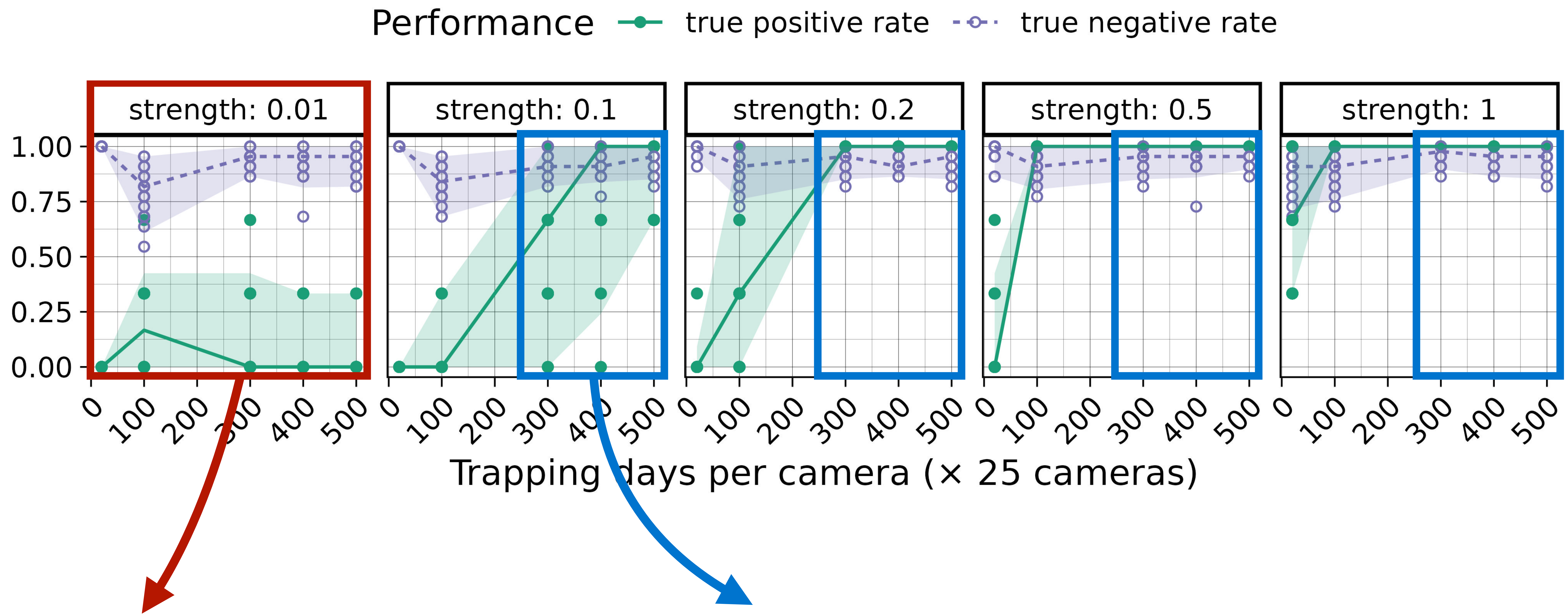


Poor performance with weak interactions

Modified from Figure 4 from Nicvert et al. 2024

Results & discussion

Evaluate the inference



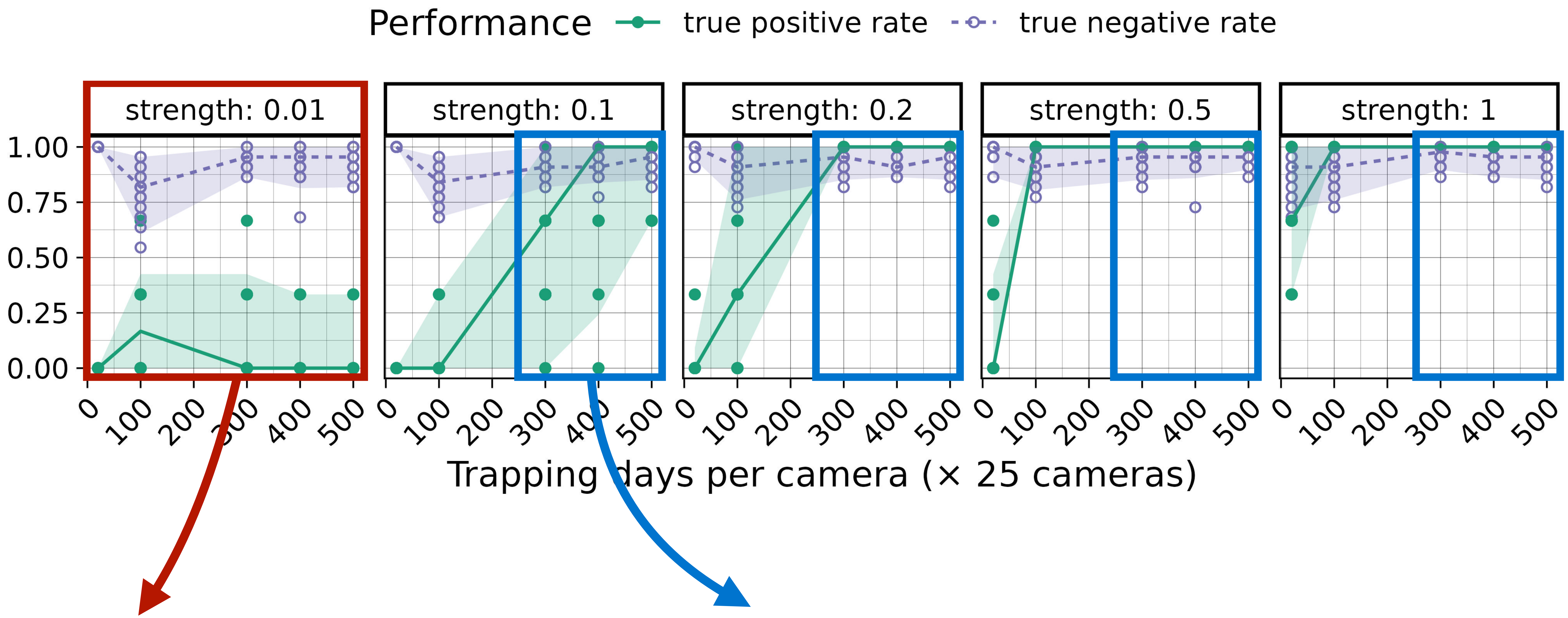
Poor performance with weak interactions

Good performance when there are enough data

Modified from Figure 4 from Nicvert et al. 2024

Results & discussion

Evaluate the inference



Poor performance with weak interactions

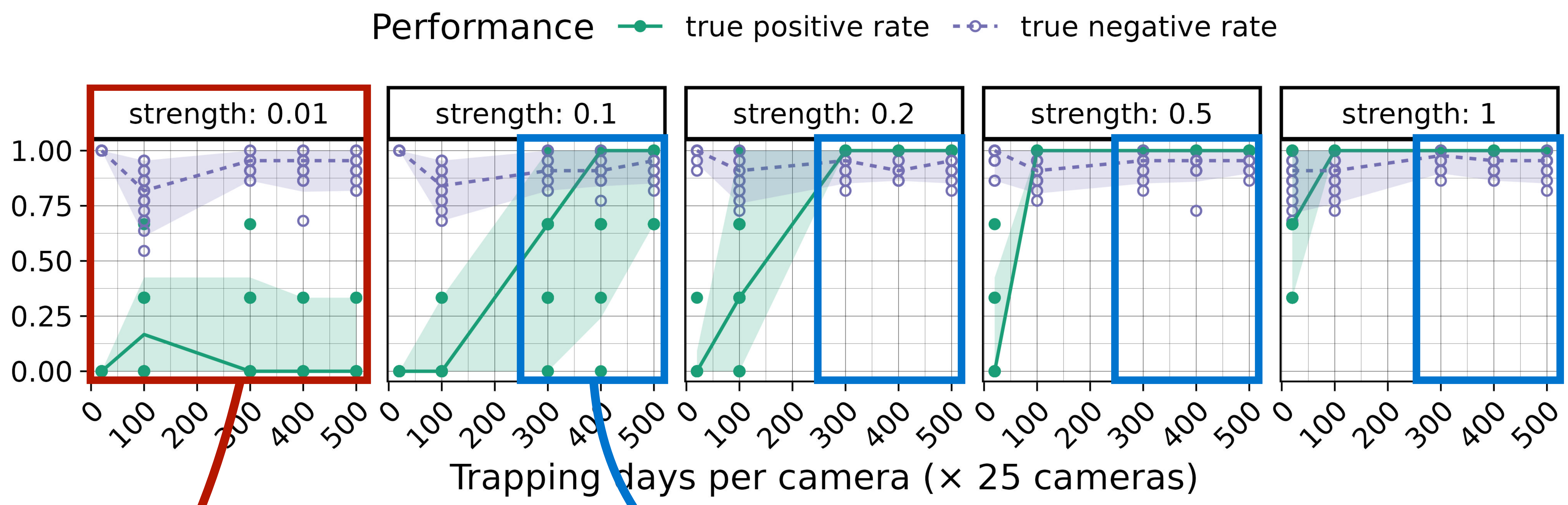
Good performance when there are enough data

→ a lot of data needed

Modified from Figure 4 from Nicvert et al. 2024

Results & discussion

Evaluate the inference



Poor performance with weak interactions

Good performance when there are enough data

→ a lot of data needed

→ typical interaction strength?

Modified from Figure 4 from Nicvert et al. 2024

Results & discussion
Data analysis

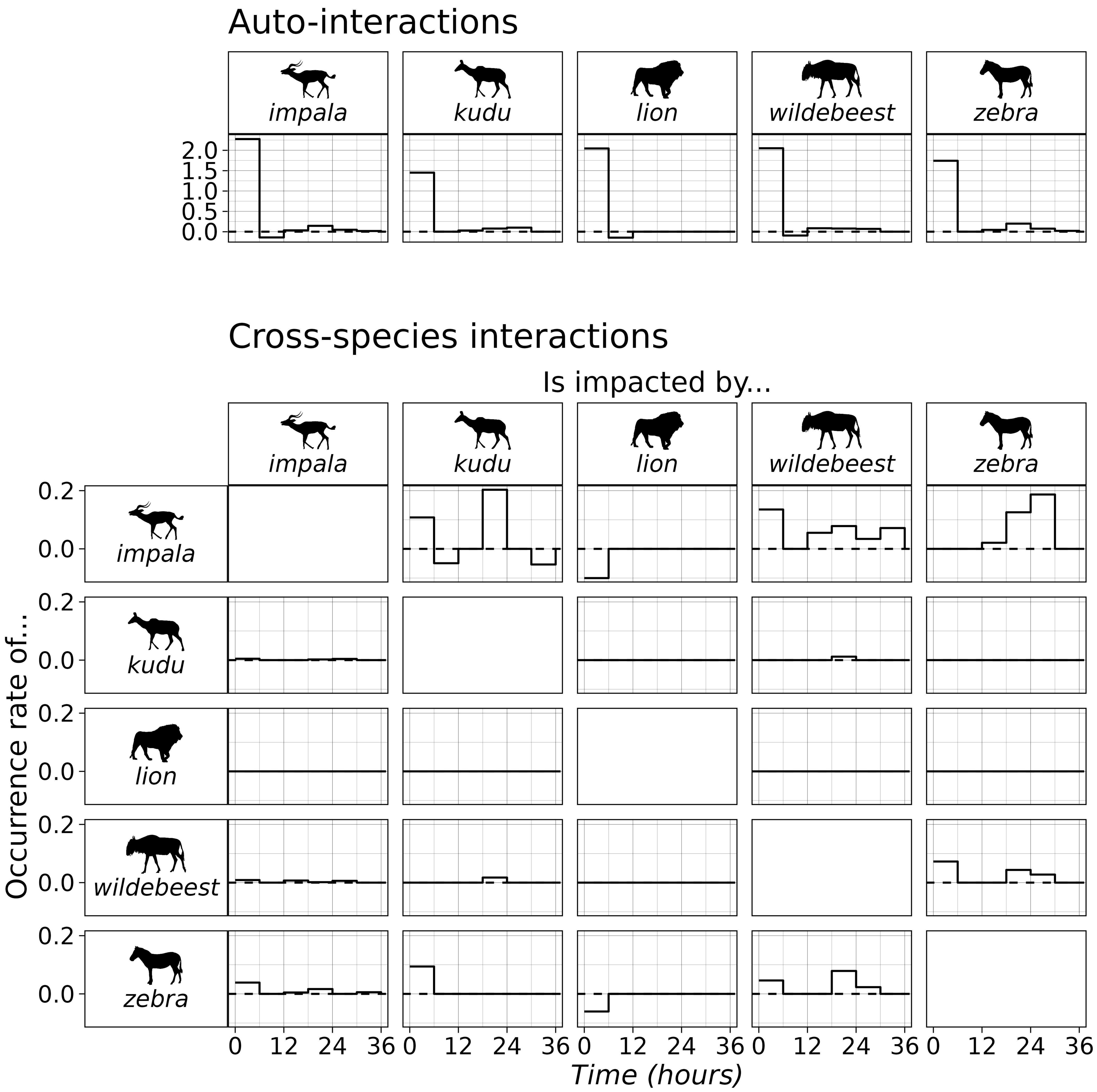


Figure 5 from Nicvert et al. 2024

Results & discussion

Data analysis

Parametrization

36 hours

6 hours bins

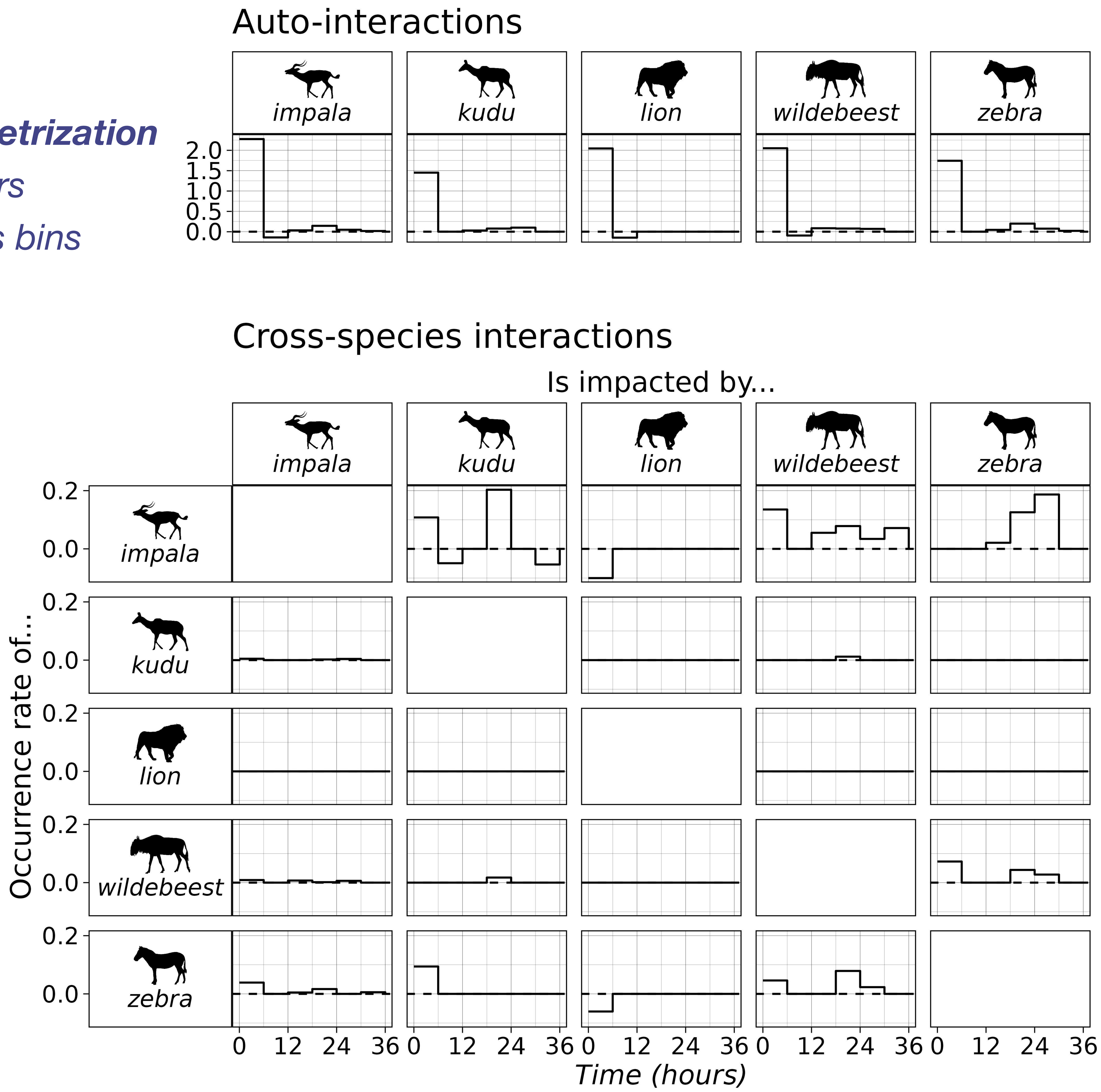


Figure 5 from Nicvert et al. 2024

Results & discussion

Data analysis

Parametrization

36 hours

6 hours bins

Strong auto-attractions

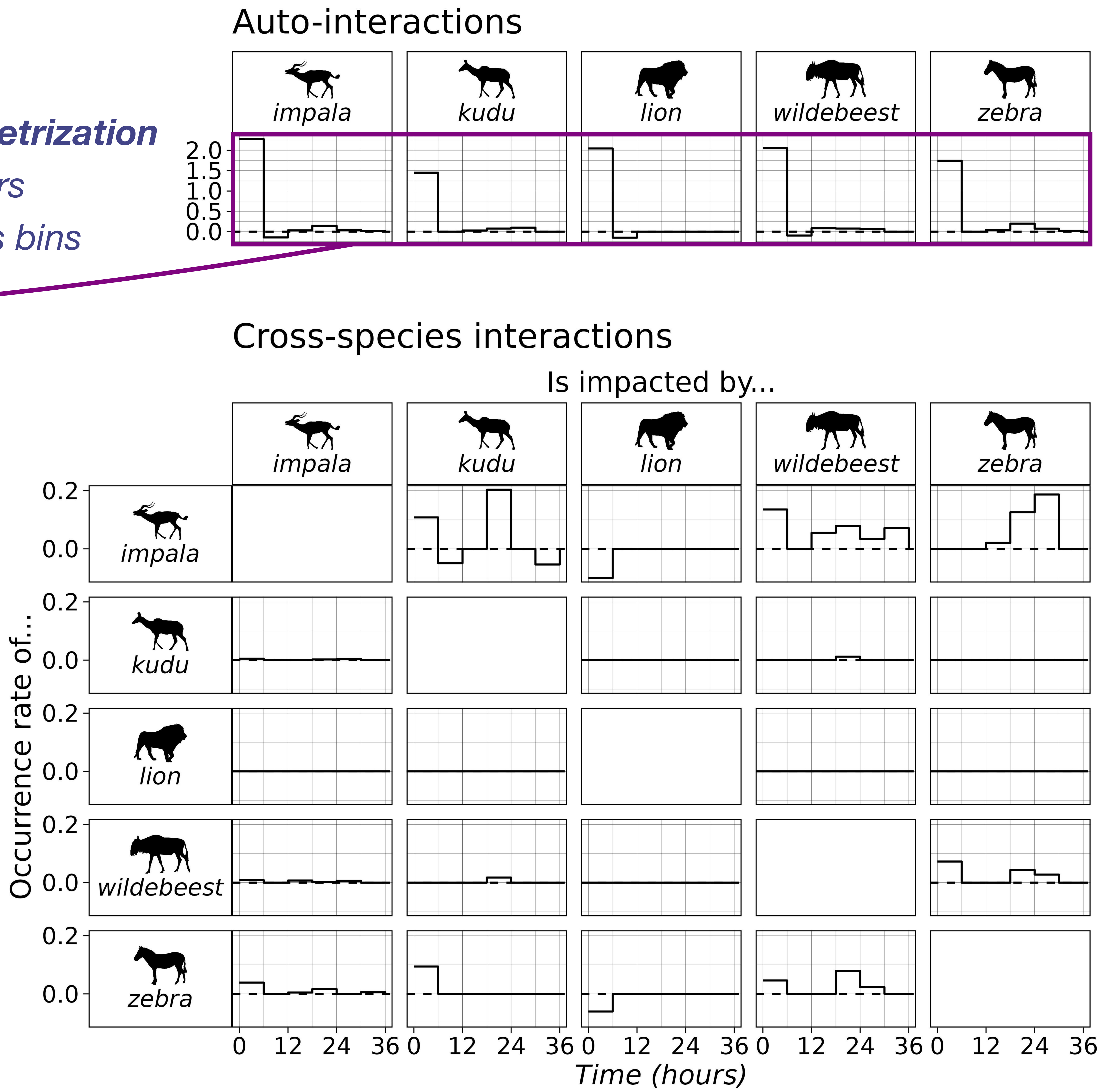


Figure 5 from Nicvert et al. 2024

Results & discussion
Data analysis

Parametrization

36 hours

6 hours bins

Strong auto-attractions

Impala attracted by other herbivores

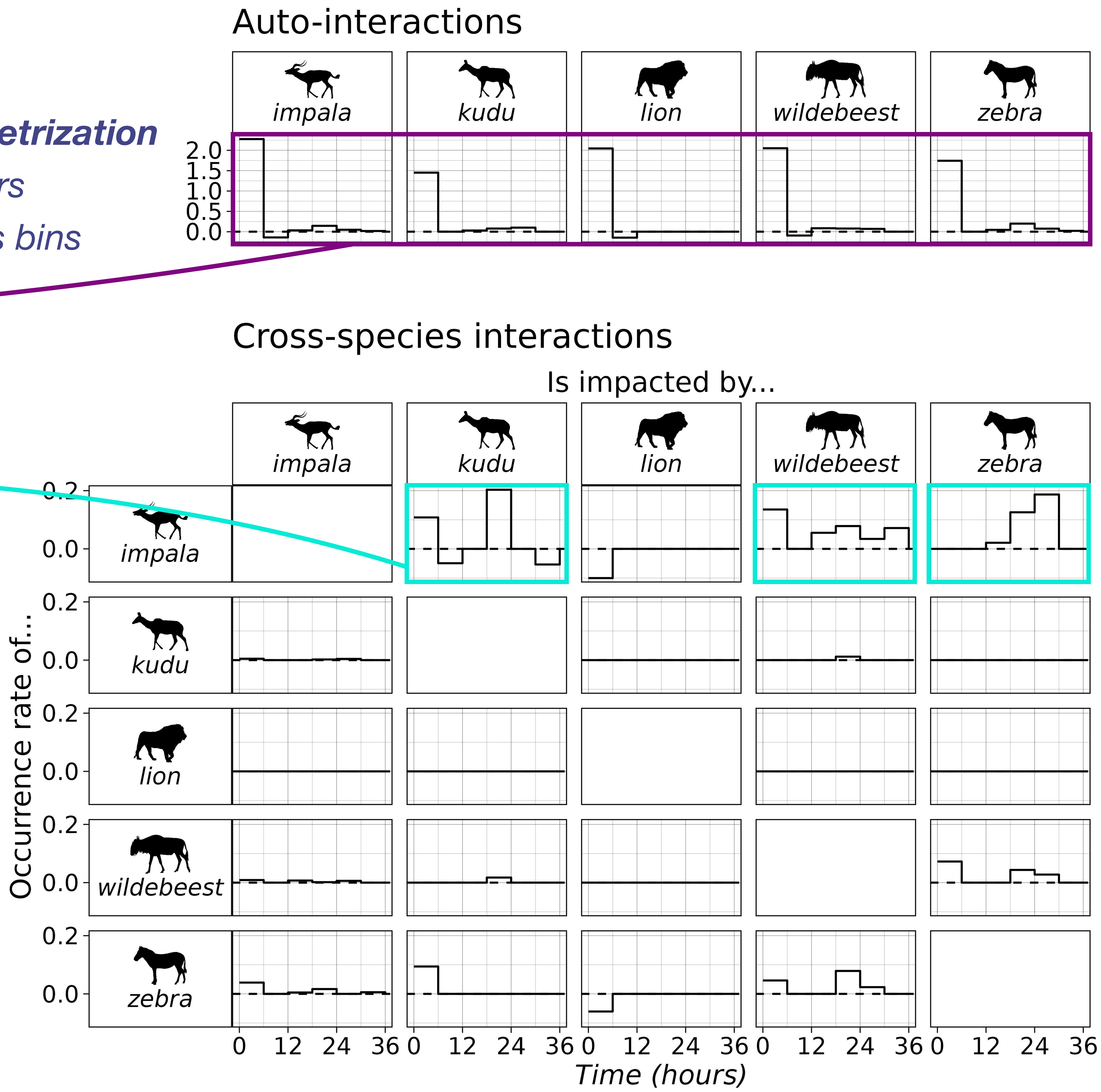


Figure 5 from Nicvert et al. 2024

Results & discussion

Data analysis

Parametrization

36 hours

6 hours bins

Strong auto-attractions

Impala attracted by other herbivores

Zebra attracted by other herbivores

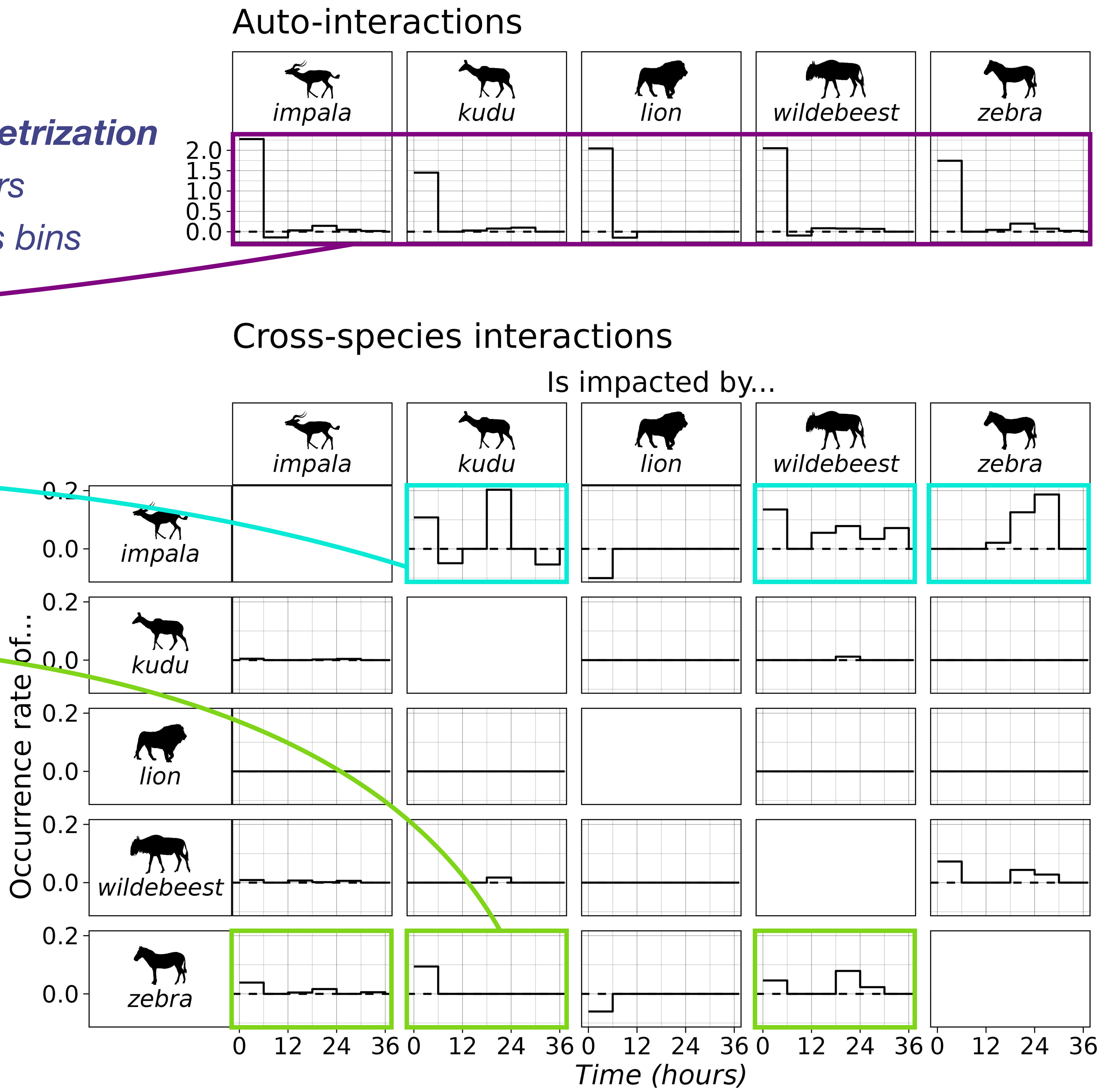


Figure 5 from Nicvert et al. 2024

Results & discussion

Data analysis

Parametrization

36 hours

6 hours bins

Strong auto-attractions

Impala attracted by other herbivores

Zebra attracted by other herbivores

Wildebeest attracted by zebra

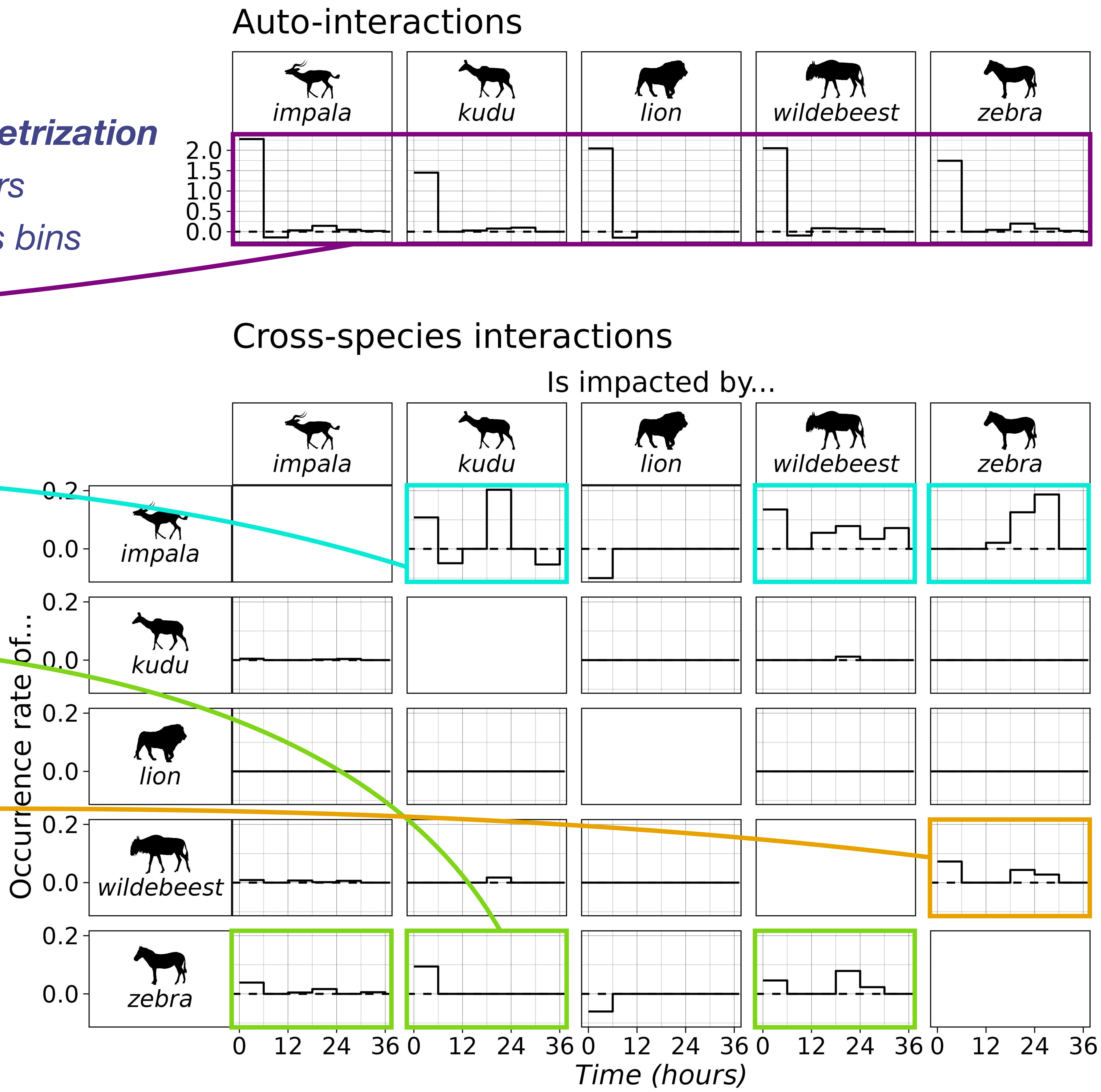
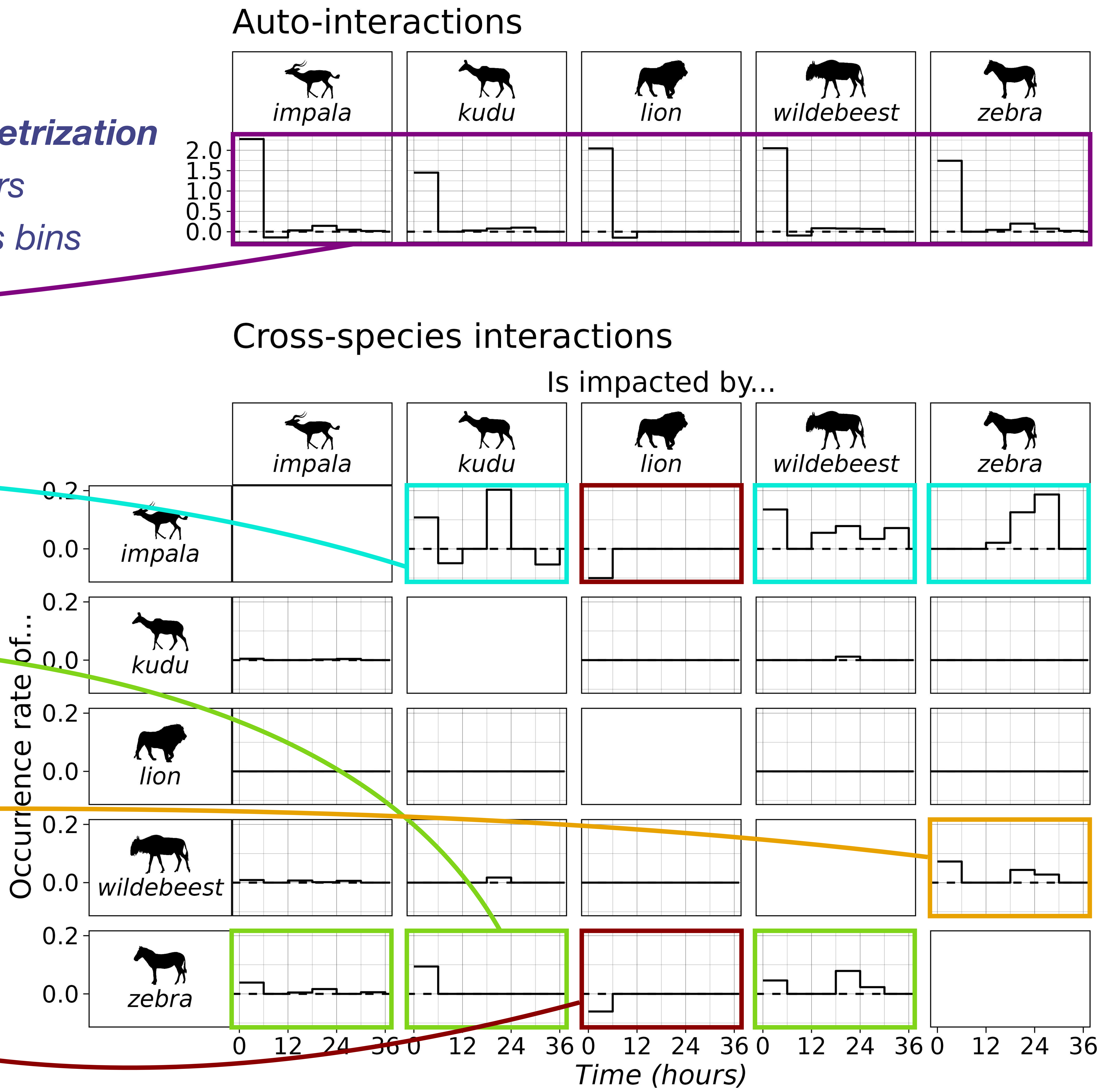


Figure 5 from Nicvert et al. 2024

Results & discussion
Data analysis

Parametrization
36 hours
6 hours bins



Strong auto-attractions

Impala attracted by other herbivores

Zebra attracted by other herbivores

Wildebeest attracted by zebra

Impala and zebra avoiding lion

Figure 5 from Nicvert et al. 2024

Results & discussion

Interpretation

Results & discussion

Interpretation

Auto-attractions → Social behaviors

Group of impalas © Snaphot Safari

Results & discussion
Interpretation

Auto-attractions → Social behaviors

Herbivore-herbivore attractions → Mixed-species groups

Beaudrot et al. 2020

Impalas and zebras *© Snaphot Safari*

Results & discussion

Interpretation

Auto-attractions → Social behaviors

Herbivore-herbivore attractions →

Mixed-species groups

Beaudrot et al. 2020

Grazing succession

Bell 1971, Anderson et al. 2024

Impalas and zebras *© Snaphot Safari*

Results & discussion
Interpretation

Auto-attractions → Social behaviors

Herbivore-herbivore attractions →

Mixed-species groups
Beaudrot et al. 2020

Grazing succession
Bell 1971, Anderson et al. 2024

Lion avoidance → Anti-predation strategy
Valeix et al. 2009

Impala fleeing from lions *© Gavin St Leger*

Results & discussion

Interpretation

Auto-attractions → Social behaviors

Herbivore-herbivore attractions → Mixed-species groups

Beaudrot et al. 2020

Grazing succession

Bell 1971, Anderson et al. 2024

Lion avoidance → Anti-predation strategy

Valeix et al. 2009

Confounding factors

- Spatial variables

Icons: Freepik from Flaticon

Results & discussion

Interpretation

Auto-attractions → Social behaviors

Herbivore-herbivore attractions → Mixed-species groups
Beaudrot et al. 2020
Grazing succession
Bell 1971, Anderson et al. 2024

Lion avoidance → Anti-predation strategy
Valeix et al. 2009

Confounding factors

- Spatial variables
- Circadian rhythms

Icons: Freepik from Flaticon

Results & discussion

Conclusion & perspectives

distributions → interactions

ECOLOGY LETTERS

Ideas and Perspectives

Co-occurrence is not evidence of ecological interactions

F. Guillaume Blanchet, Kevin Cazelles, Dominique Gravel

Results & discussion

Conclusion & perspectives

distributions → interactions

ECOLOGY LETTERS

Ideas and Perspectives

~~Co-occurrence~~ is not evidence of ecological interactions yet
Temporal delay

F. Guillaume Blanchet, Kevin Cazelles, Dominique Gravel

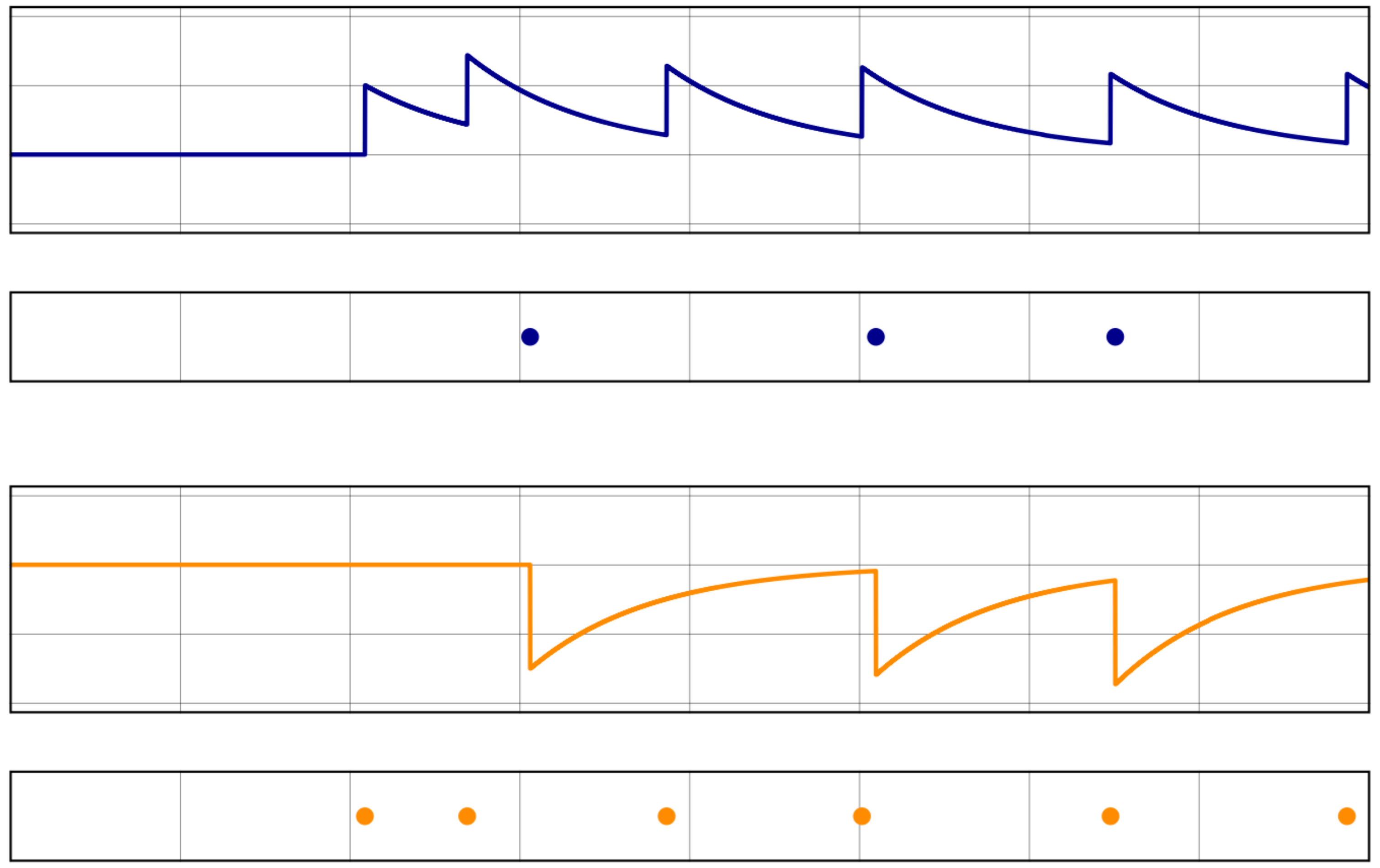
Results & discussion

Conclusion & perspectives

Point processes to analyze camera trap data *Schliep et al. 2018, Kellner et al. 2022, Ferry et al. 2024*

Steenbok *© Snapshot Safari*

~



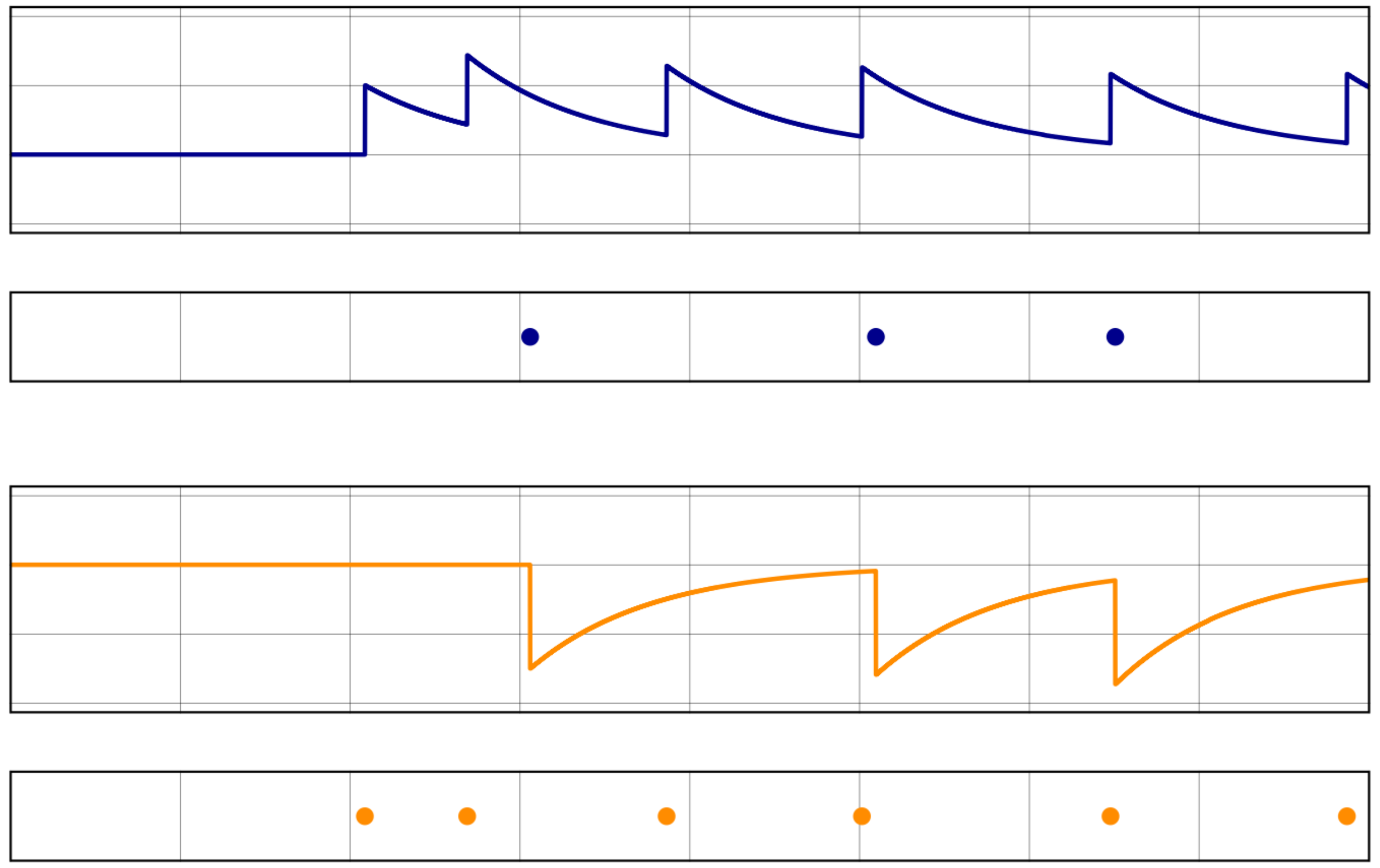
Conclusion & perspectives

Point processes to analyze camera trap data *Schliep et al. 2018, Kellner et al. 2022, Ferry et al. 2024*

- multi-species approach

Steenbok *© Snapshot Safari*

~



Results & discussion

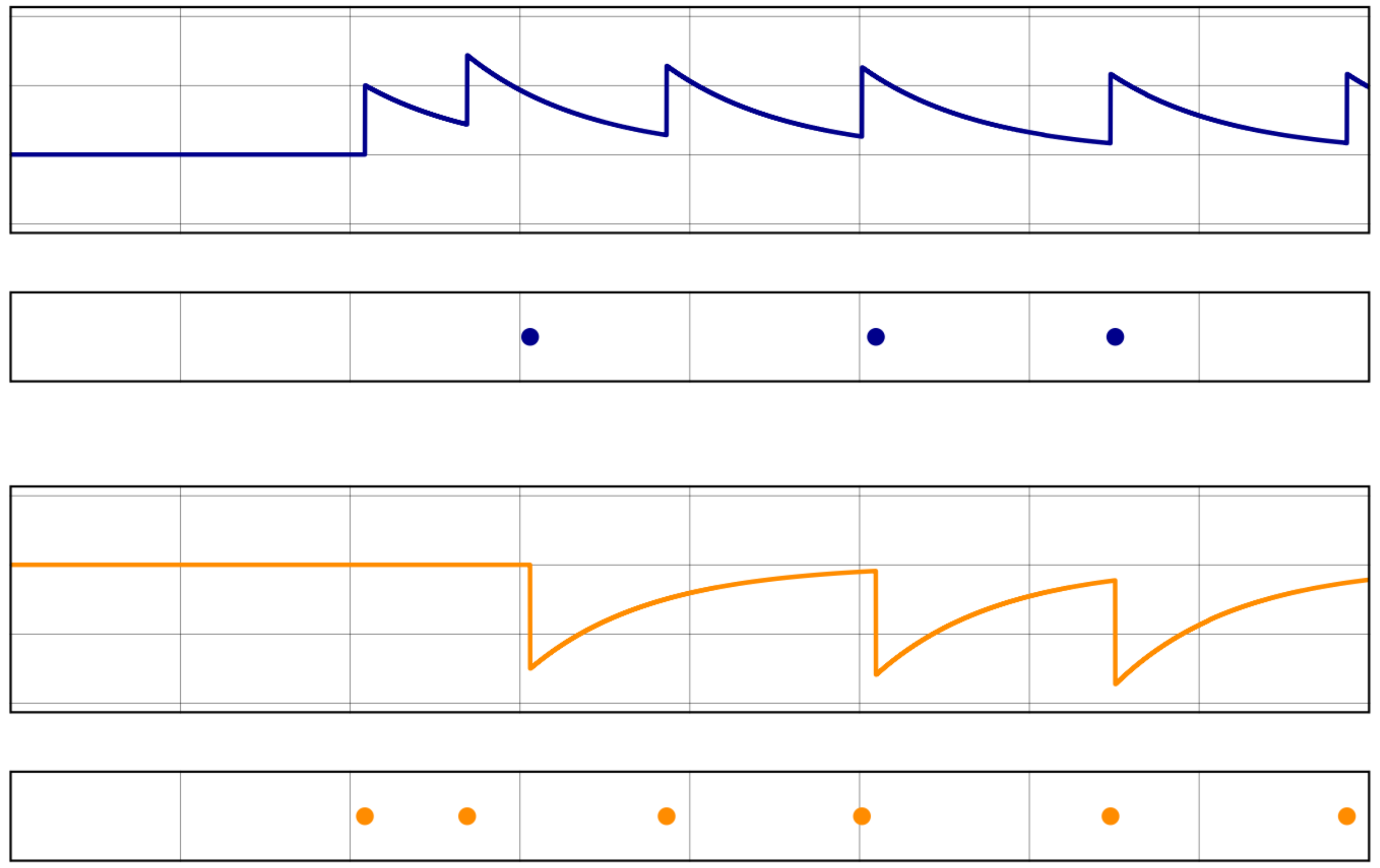
Conclusion & perspectives

Point processes to analyze camera trap data *Schliep et al. 2018, Kellner et al. 2022, Ferry et al. 2024*

- multi-species approach
- directed interactions

Steenbok *© Snapshot Safari*

~



Results & discussion

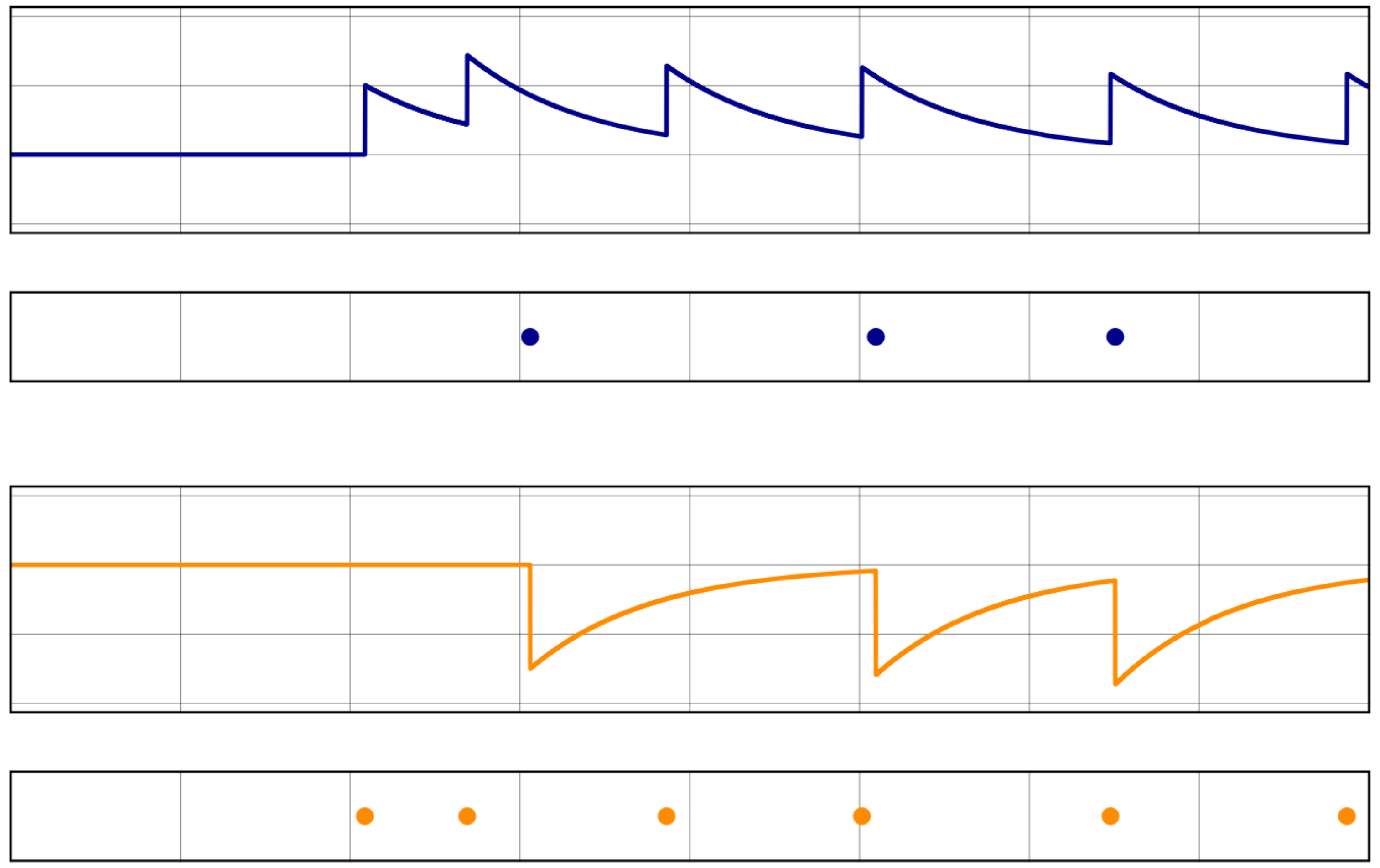
Conclusion & perspectives

Point processes to analyze camera trap data *Schliep et al. 2018, Kellner et al. 2022, Ferry et al. 2024*

- multi-species approach
- directed interactions
- temporal evolution of interaction strength

Steenbok *© Snapshot Safari*

~



Results & discussion

Conclusion & perspectives

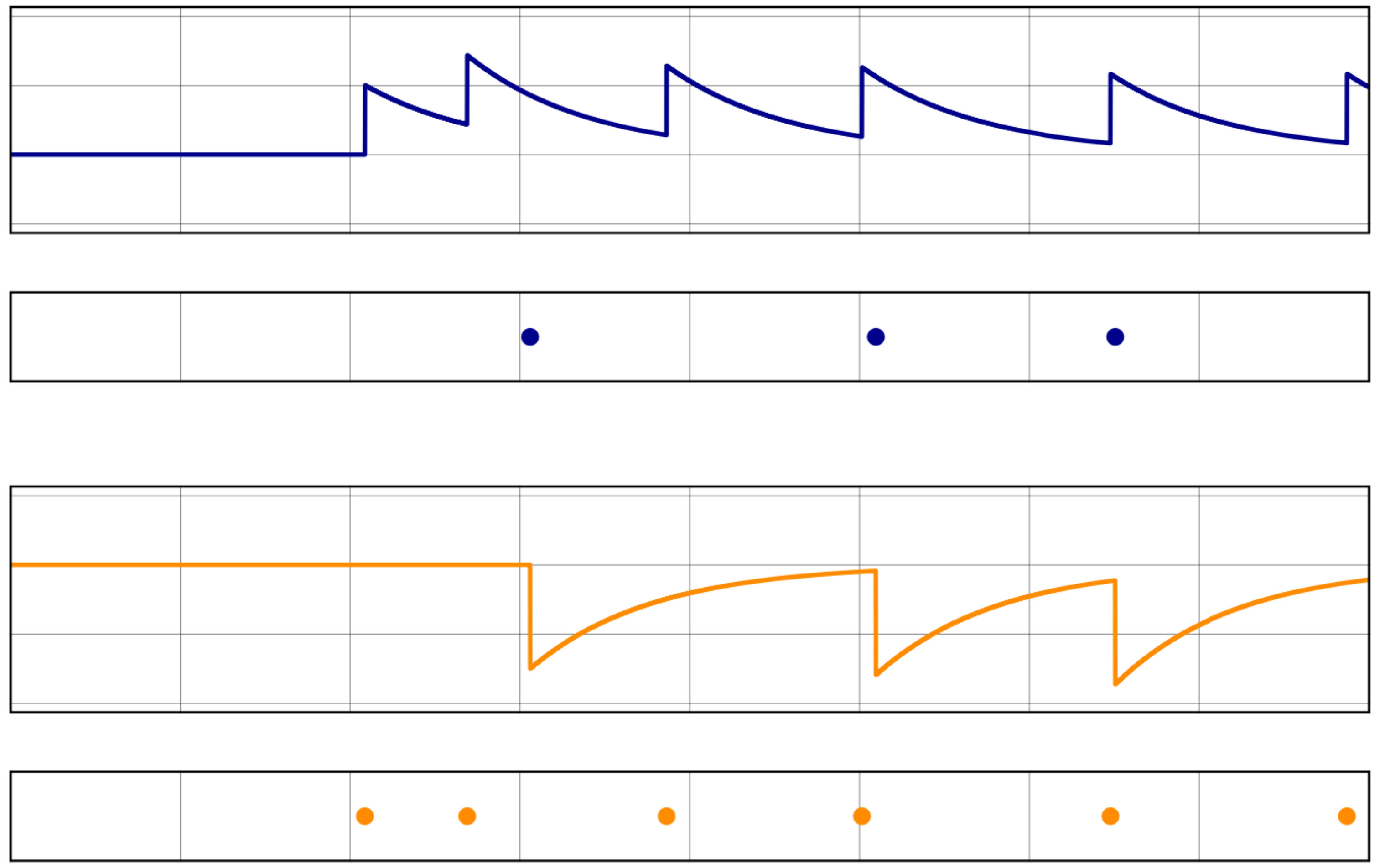
Point processes to analyze camera trap data *Schliep et al. 2018, Kellner et al. 2022, Ferry et al. 2024*

- multi-species approach
- directed interactions
- temporal evolution of interaction strength

Steenbok *© Snapshot Safari*

~

Perspectives



Results & discussion

Conclusion & perspectives

Point processes to analyze camera trap data *Schliep et al. 2018, Kellner et al. 2022, Ferry et al. 2024*

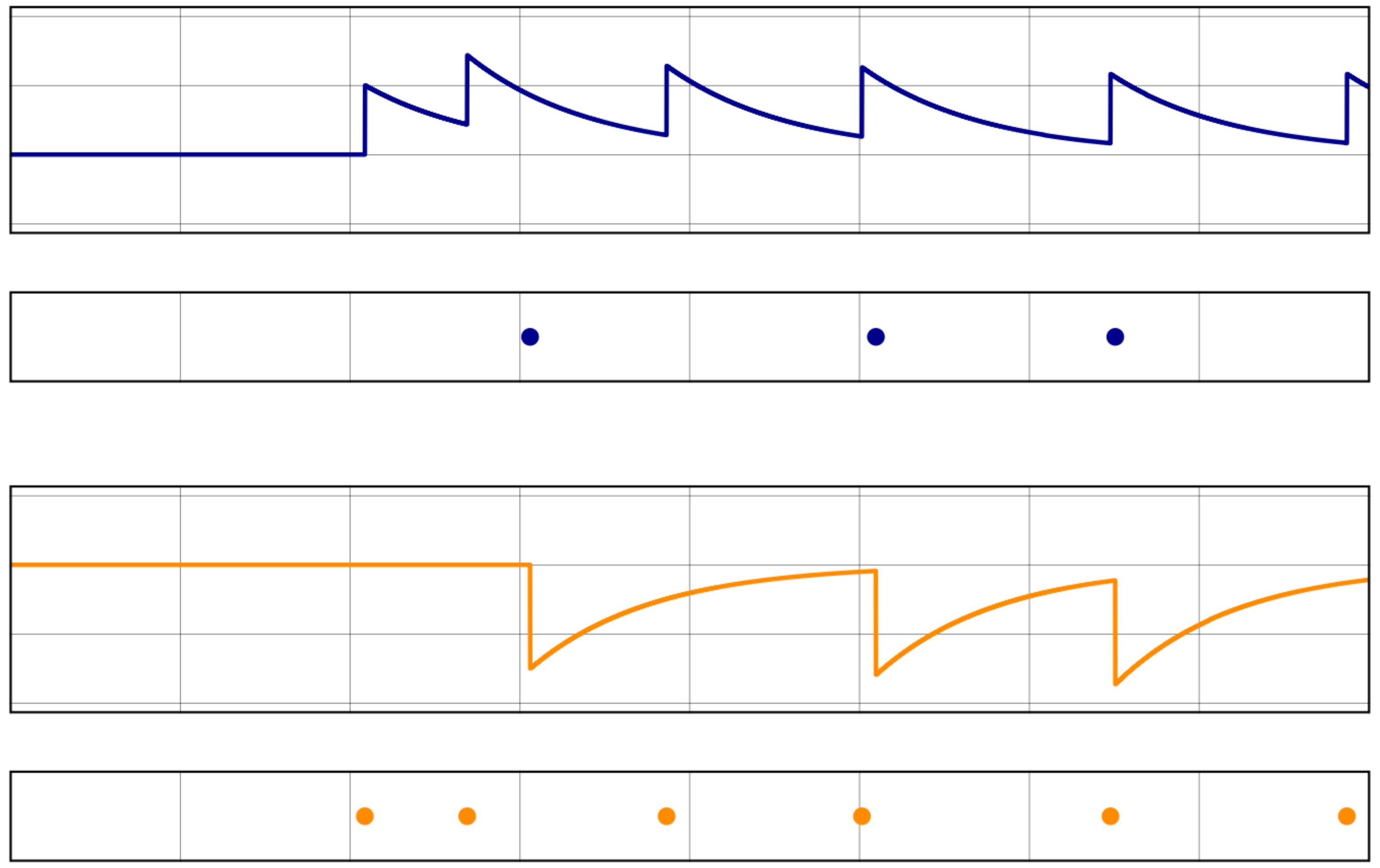
- multi-species approach
- directed interactions
- temporal evolution of interaction strength

Perspectives

- improve model (covariates)

Steenbok *© Snapshot Safari*

~



Conclusion & perspectives

Point processes to analyze camera trap data *Schliep et al. 2018, Kellner et al. 2022, Ferry et al. 2024*

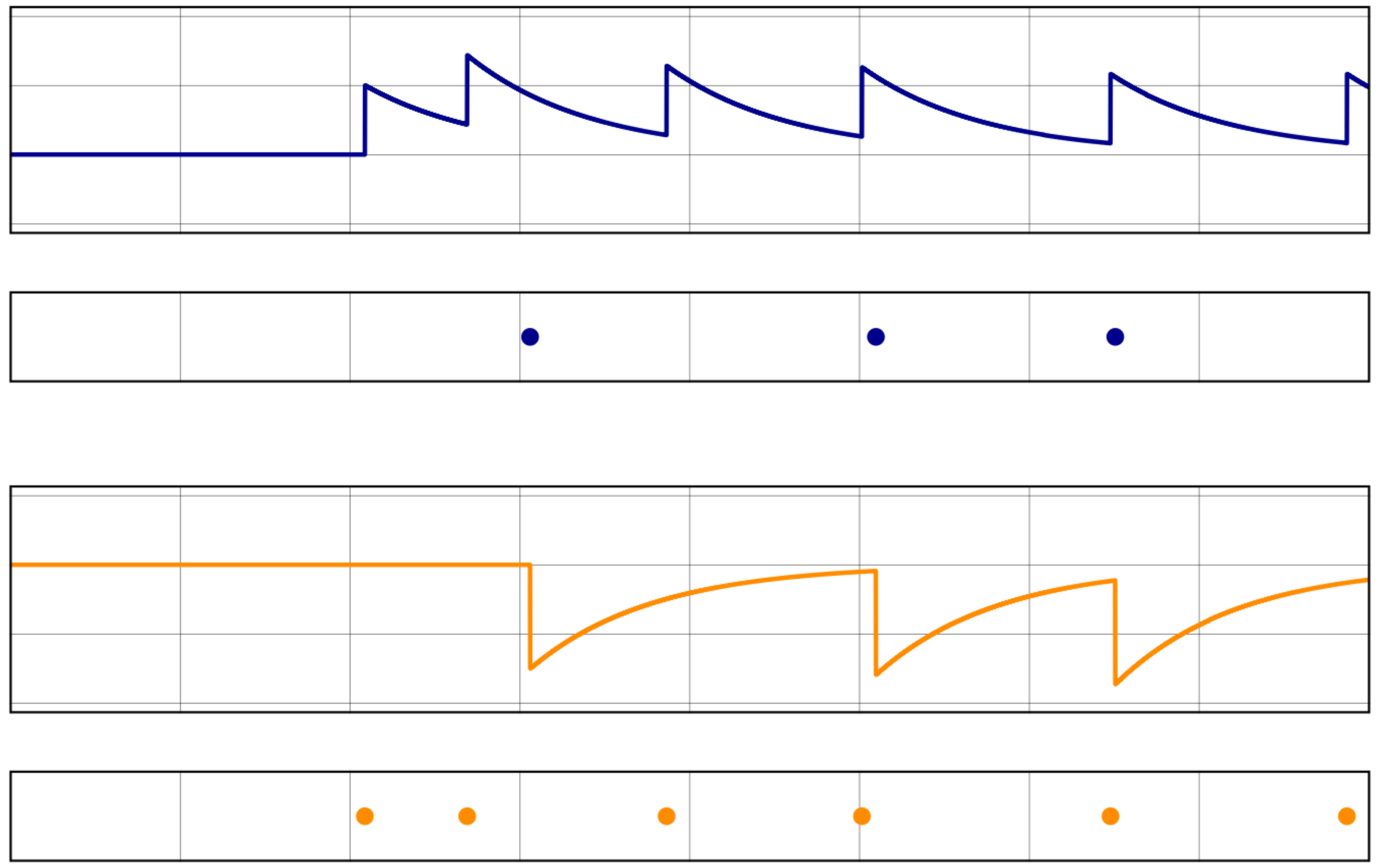
- multi-species approach
- directed interactions
- temporal evolution of interaction strength

Perspectives

- improve model (covariates)
- controlled experiments → check hypotheses

Steenbok *© Snapshot Safari*

~



Thank you!

© Own drawings

@lisanicvert.bsky.social
Lisa Nicvert

References

Nicvert, L. (2024). Statistical methods and software tools to analyze and infer ecological networks and process multi-species data. Universite Claude Bernard Lyon 1. https://theses.hal.science/tel-04751639

Nicvert, L., Donnet, S., Keith, M., Peel, M., Somers, M. J., Swanepoel, L. H., Venter, J., Fritz, H., & Dray, S. (2024). Using the multivariate Hawkes process to study interactions between multiple species from camera trap data. *Ecology*, *105*(4), e4237. https://doi.org/10.1002/ecy.4237

Diamond, J. M. (1975). Assembly of species communities. In M. L. Cody & J. M. Diamond, *Ecology and evolution of communities* (pp. 342–444). Harvard Univ. Press.

Connor, E. F., & Simberloff, D. (1979). The Assembly of Species Communities: Chance or Competition? *Ecology*, *60*(6), 1132–1140. https://doi.org/10.2307/1936961

Connor, E. F., Collins, M. D., & Simberloff, D. (2013). The checkered history of checkerboard distributions. *Ecology*, *94*(11), 2403–2414. https://doi.org/10.1890/12-1471.1

Diamond, J., Pimm, S. L., & Sanderson, J. G. (2015). The checkered history of checkerboard distributions: Comment. *Ecology*, *96*(12), 3386–3388. https://doi.org/10.1890/14-1848.1

Blanchet, F. G., Cazelles, K., & Gravel, D. (2020). Co-occurrence is not evidence of ecological interactions. *Ecology Letters*, *23*(7), 1050–1063. https://doi.org/10.1111/ele.13525

Harmsen, B. J., Foster, R. J., Silver, S. C., Ostro, L. E. T., & Doncaster, C. P. (2009). Spatial and Temporal Interactions of Sympatric Jaguars (Panthera onca) and Pumas (Puma concolor) in a Neotropical Forest. Journal of Mammalogy, 90(3), 612–620. https://doi.org/10.1644/08-MAMM-A-140R.1

Parsons, A. W., Bland, C., Forrester, T., Baker-Whatton, M. C., Schuttler, S. G., McShea, W. J., Costello, R., & Kays, R. (2016). The ecological impact of humans and dogs on wildlife in protected areas in eastern North America. Biological Conservation, 203, 75–88. https://doi.org/10.1016/j.biocon.2016.09.001

Murphy, A., Diefenbach, D. R., Ternent, M., Lovallo, M., & Miller, D. (2021). Threading the needle: How humans influence predator–prey spatiotemporal interactions in a multiple-predator system. Journal of Animal Ecology, 90(10), 2377–2390. https://doi.org/10.1111/1365-2656.13548

Cusack, J. J., Dickman, A. J., Kalyahe, M., Rowcliffe, J. M., Carbone, C., MacDonald, D. W., & Coulson, T. (2017). Revealing kleptoparasitic and predatory tendencies in an African mammal community using camera traps: A comparison of spatiotemporal approaches. Oikos, 126(6), 812–822. https://doi.org/10.1111/oik.03403

Karanth, K. U., Srivathsa, A., Vasudev, D., Puri, M., Parameshwaran, R., & Kumar, N. S. (2017). Spatio-temporal interactions facilitate large carnivore sympatry across a resource gradient. Proceedings of the Royal Society B: Biological Sciences, 284(1848), 20161860. https://doi.org/10.1098/rspb.2016.1860

References

Schliep, E. M., Gelfand, A. E., Clark, J. S., & Kays, R. (2018). Joint Temporal Point Pattern Models for Proximate Species Occurrence in a Fixed Area Using Camera Trap Data. *Journal of Agricultural, Biological and Environmental Statistics*, *23*(3), 334–357. https://doi.org/10.1007/s13253-018-0327-8

Kellner, K. F., Parsons, A. W., Kays, R., Millspaugh, J. J., & Rota, C. T. (2022). A Two-Species Occupancy Model with a Continuous-Time Detection Process Reveals Spatial and Temporal Interactions. *Journal of Agricultural, Biological and Environmental Statistics*, *27*(2), 321–338. https://doi.org/10.1007/s13253-021-00482-y

Ferry, N., Dupont, P., Bender, A., & Heurich, M. (2024). Introducing recurrent event analyses to assess species interactions based on camera-trap data: A comparison with time-to-first-event approaches. *Methods in Ecology and Evolution*, *15*(7). https://doi.org/10.1111/2041-210X.14338

Pardo, L. E., Bombaci, S. P., Huebner, S., Somers, M. J., Fritz, H., Downs, C., Guthmann, A., Hetem, R. S., Keith, M., le Roux, A., Mgqatsa, N., Packer, C., Palmer, M. S., Parker, D. M., Peel, M., Slotow, R., Strauss, W. M., Swanepoel, L., Tambling, C., … Venter, J. A. (2021). Snapshot Safari: A large-scale collaborative to monitor Africa's remarkable biodiversity. *South African Journal of Science*, *117*(1/2), 1–4. https://doi.org/10.17159/sajs.2021/8134

Hawkes, A. G. (1971). Spectra of some self-exciting and mutually exciting point processes. *Biometrika*, *58*(1), 83–90. https://doi.org/10.1093/biomet/58.1.83

Lambert, R. C., Tuleau-Malot, C., Bessaih, T., Rivoirard, V., Bouret, Y., Leresche, N., & Reynaud-Bouret, P. (2018). Reconstructing the functional connectivity of multiple spike trains using Hawkes models. *Journal of Neuroscience Methods*, *297*, 9–21. https://doi.org/10.1016/j.jneumeth.2017.12.026

Albert, M., Bouret, Y., Chevallier, J., Fromont, M., Grammont, F., Laloe, T., Mascart, C., Reynaud-Bouret, P., Rouis, A., Scarella, G., & Tuleau-Malot, C. (2021). *UnitEvents: Unitary Events Method with Delayed Coincidence Count (MTGAUE or Permutation Method) and Bernstein Lasso method for Hawkes processes* (Version 0.0.8). https://sourcesup.renater.fr/frs/?group_id=3267

Beaudrot, L., Palmer, M. S., Anderson, T. M., & Packer, C. (2020). Mixed-species groups of Serengeti grazers: A test of the stress gradient hypothesis. *Ecology*, *101*(11), e03163. https://doi.org/10.1002/ecy.3163

Bell, R. H. (1971). A grazing ecosystem in the Serengeti. *Scientific American*, *225*(1), 86–93.

Anderson, T. M., Hepler, S. A., Holdo, R. M., Donaldson, J. E., Erhardt, R. J., Hopcraft, J. G. C., Hutchinson, M. C., Huebner, S. E., Morrison, T. A., Muday, J., Munuo, I. N., Palmer, M. S., Pansu, J., Pringle, R. M., Sketch, R., & Packer, C. (2024). Interplay of competition and facilitation in grazing succession by migrant Serengeti herbivores. *Science*, *383*(6684), 782–788. https://doi.org/10.1126/science.adg0744

Valeix, M., Fritz, H., Loveridge, A. J., Davidson, Z., Hunt, J. E., Murindagomo, F., & Macdonald, D. W. (2009). Does the risk of encountering lions influence African herbivore behaviour at waterholes? *Behavioral Ecology and Sociobiology*, *63*(10), 1483–1494. https://doi.org/10.1007/s00265-009-0760-3