HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF

CASUS CENTER FOR ADVANCED SYSTEMS UNDERSTANDING

MARE-Madeira 2025

Occurrence distributions

Using the 'ctmm' R package

Inês Silva

i.simoes-silva@hzdr.de

TECHNISCHE UNIVERSITÄT DRESDEN

CBG Max Planck Institute of Molecular Cell Biology and Genetics

UFZ HELMHOLTZ Centre for Environmental Research

Uniwersytet Wrocławski

SPONSORED BY THE

Federal Ministry of Education and Research

STAATSMINISTERIUM FÜR WISSENSCHAFT KULTUR UND TOURISMUS

Freistaat SACHSEN

Geoffrey Reynaud

Billions of animals migrate worldwide to exploit ***seasonal resources***, ***escape severe weather***, ***breed***, or to ***avoid predation***.

Which areas of a landscape contain high-priority resources (*e.g.*, **migratory corridors/stopovers**)?

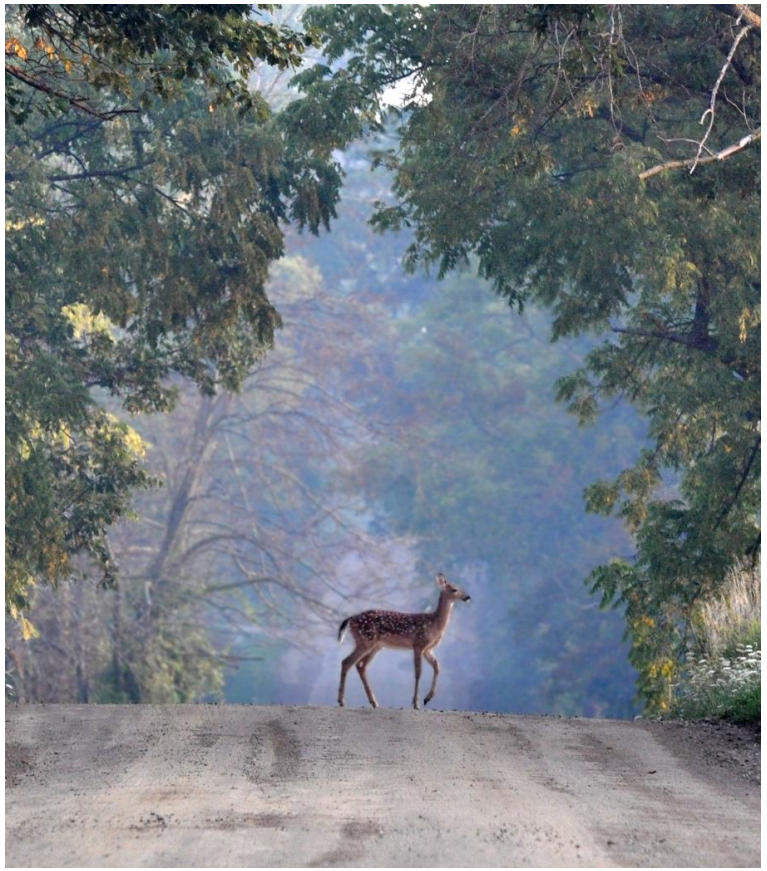
Nick Upton

Billions of animals migrate worldwide to exploit ***seasonal resources***, ***escape severe weather***, ***breed***, or to ***avoid predation***.

Which areas of a landscape contain high-priority resources (*e.g.*, **migratory corridors/stopovers**)?

How likely is it to visit a location of interest (*e.g.*, **wildlife crossing sites, wind farms**)?

Julie Falk

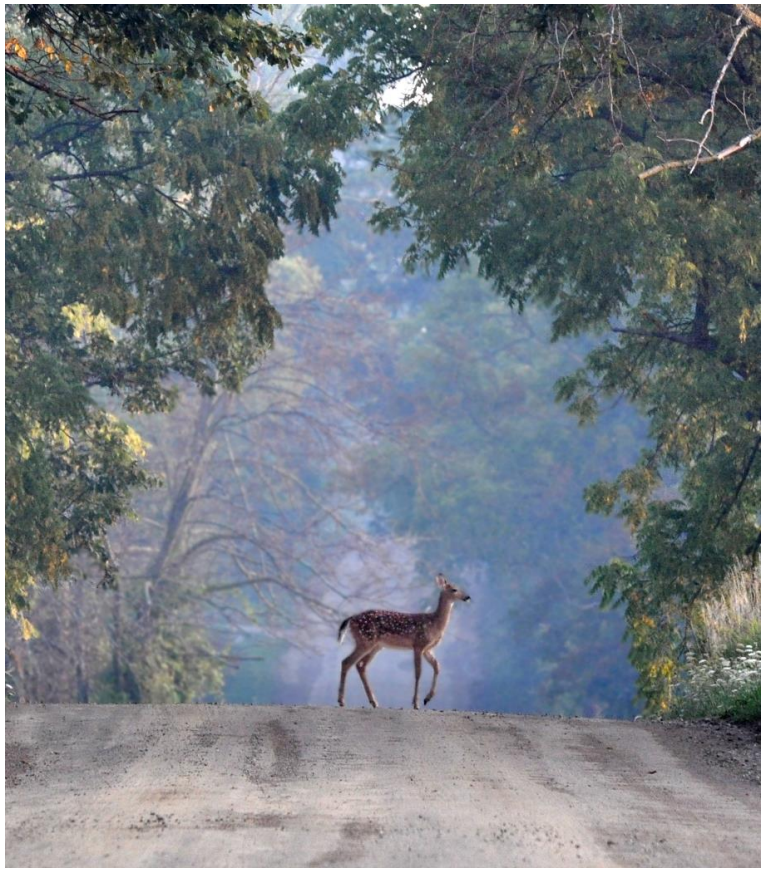


Roads have significant impacts on ecological systems, increasing the ***extinction risk*** of threatened species.

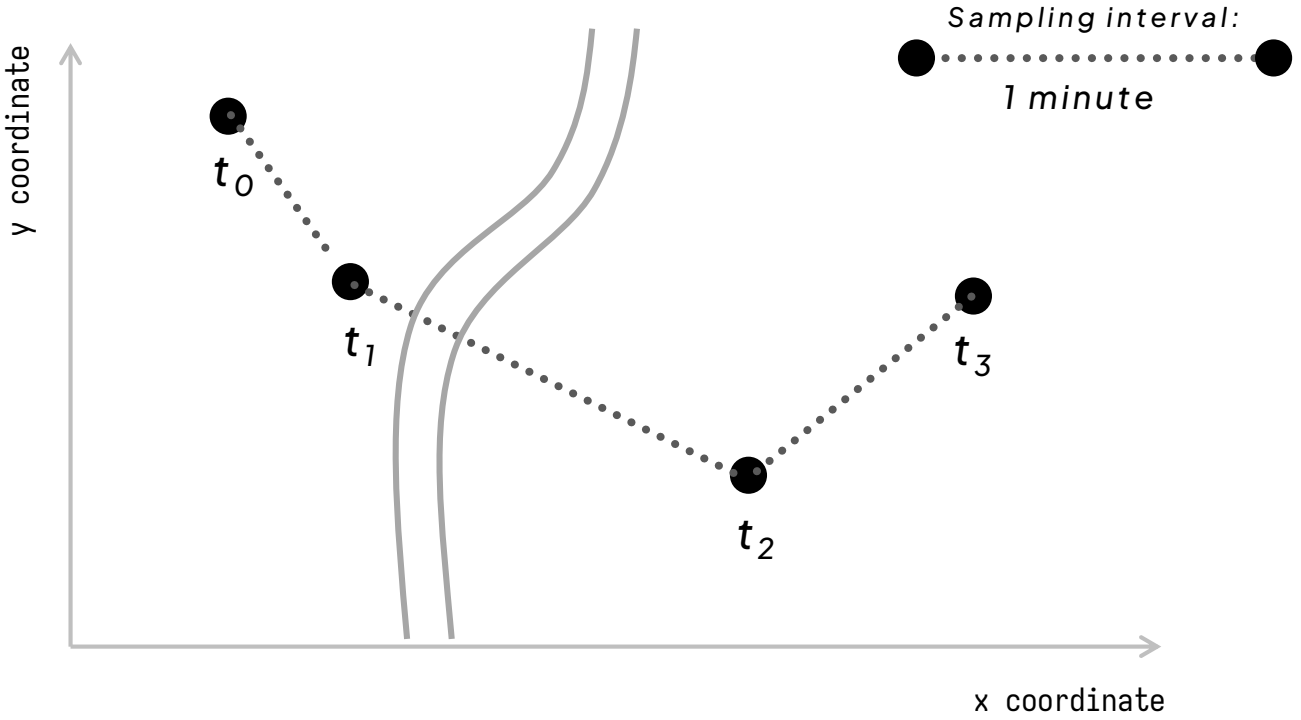
? Where did an animal cross a linear feature (*e.g.*, **road- or railways**)?

i.simoes-silva@hzdr.de

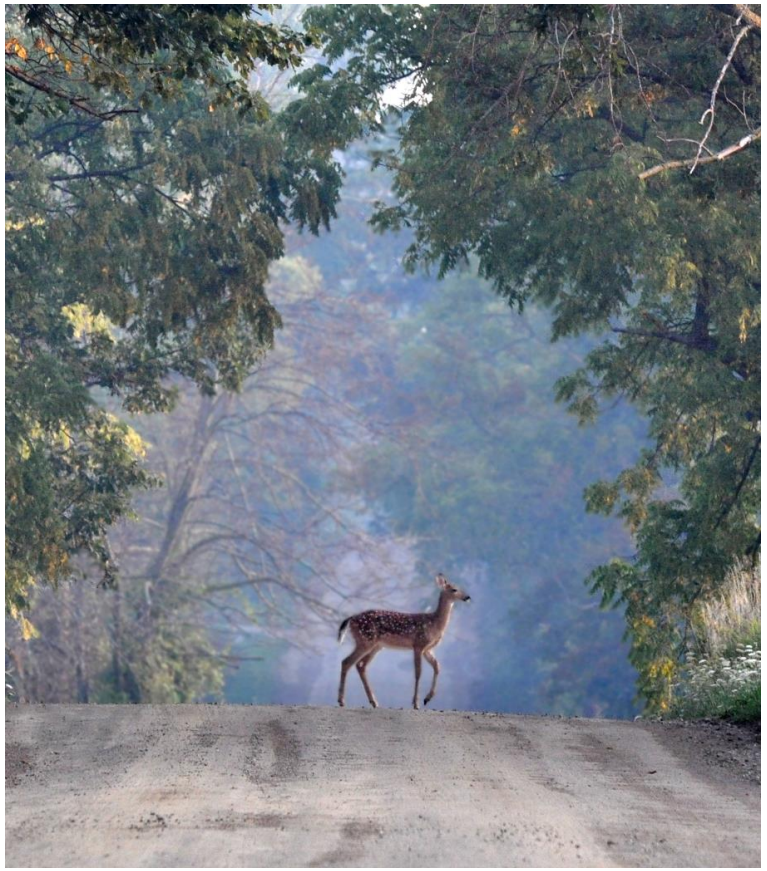
Julie Falk



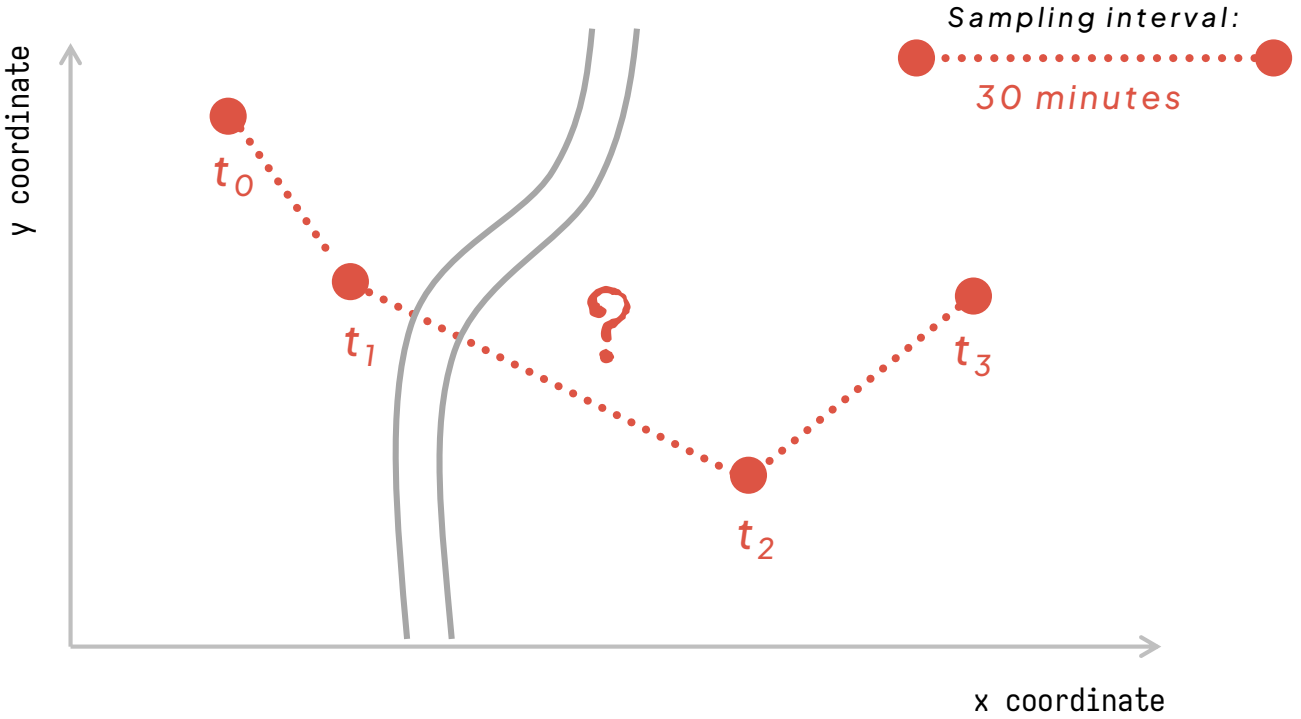
Roads have significant impacts on ecological systems, increasing the ***extinction risk*** of threatened species.



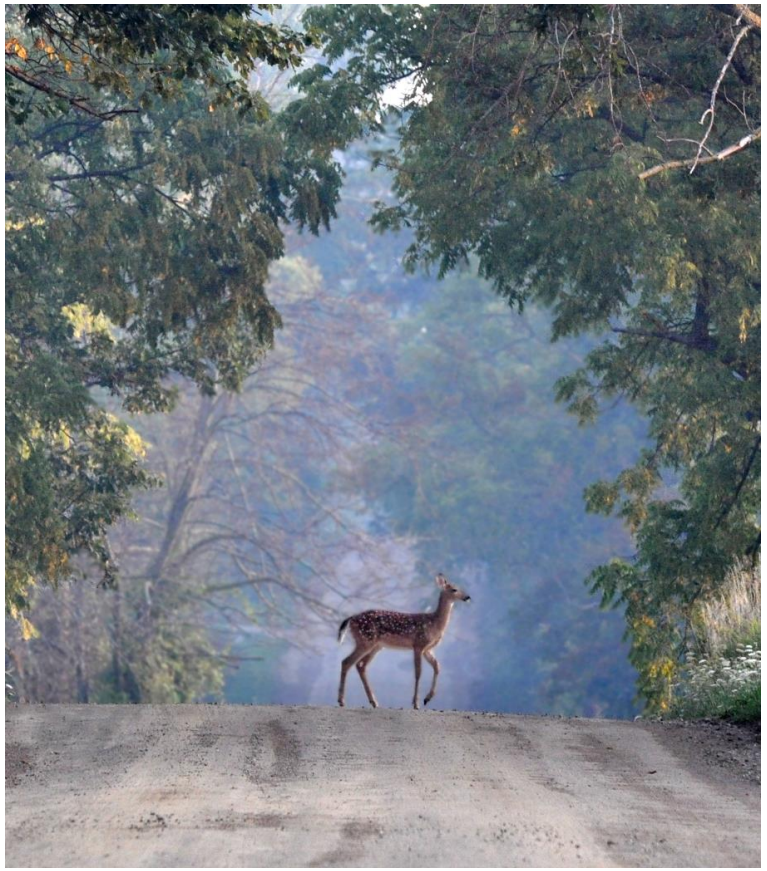
Julie Falk



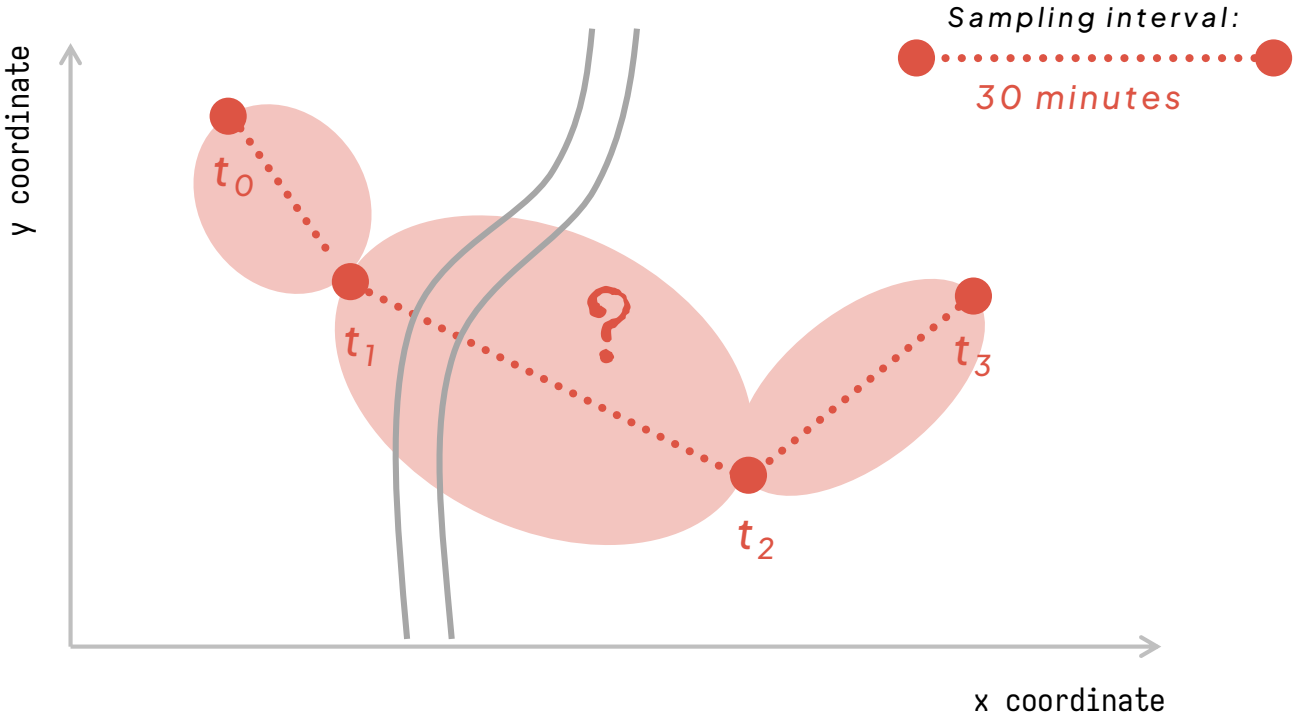
Roads have significant impacts on ecological systems, increasing the ***extinction risk*** of threatened species.



Julie Falk



Roads have significant impacts on ecological systems, increasing the ***extinction risk*** of threatened species.



i.simoes-silva@hzdr.de

Utilization distribution

represents an animal's distribution and the probability of use throughout an area

Range distribution

extrapolate space use into the future

"How much space does an animal need over the long term?"

What is an animal's home range area?
What is their the population range area?
Are protected areas sufficiently large?

≠

Occurrence distribution

interpolate between data points in the past

"Where did an animal go during a period of observation?"

Where did an animal cross a linear feature?
How likely is it to visit a location of interest?
How much time did it spend in a specific habitat?

Alston *et al.* (2022)

Range vs. occurrence distribution

Utilization distribution

represents an animal's distribution and the probability of use throughout an area

Range distribution

extrapolate space use into the future

≠

Occurrence distribution

interpolate between data points in the past

Estimates **home ranges**

Considers all realizations of the movement process that could occur.

Estimates **occurrence regions**

Pinpoints the one realization of the movement process that did occur.

Alston *et al.* (2022)

i.simoes-silva@hzdr.de

Utilization distribution

represents an animal's distribution and the probability of use throughout an area

Occurrence distribution

interpolate between data points in the past

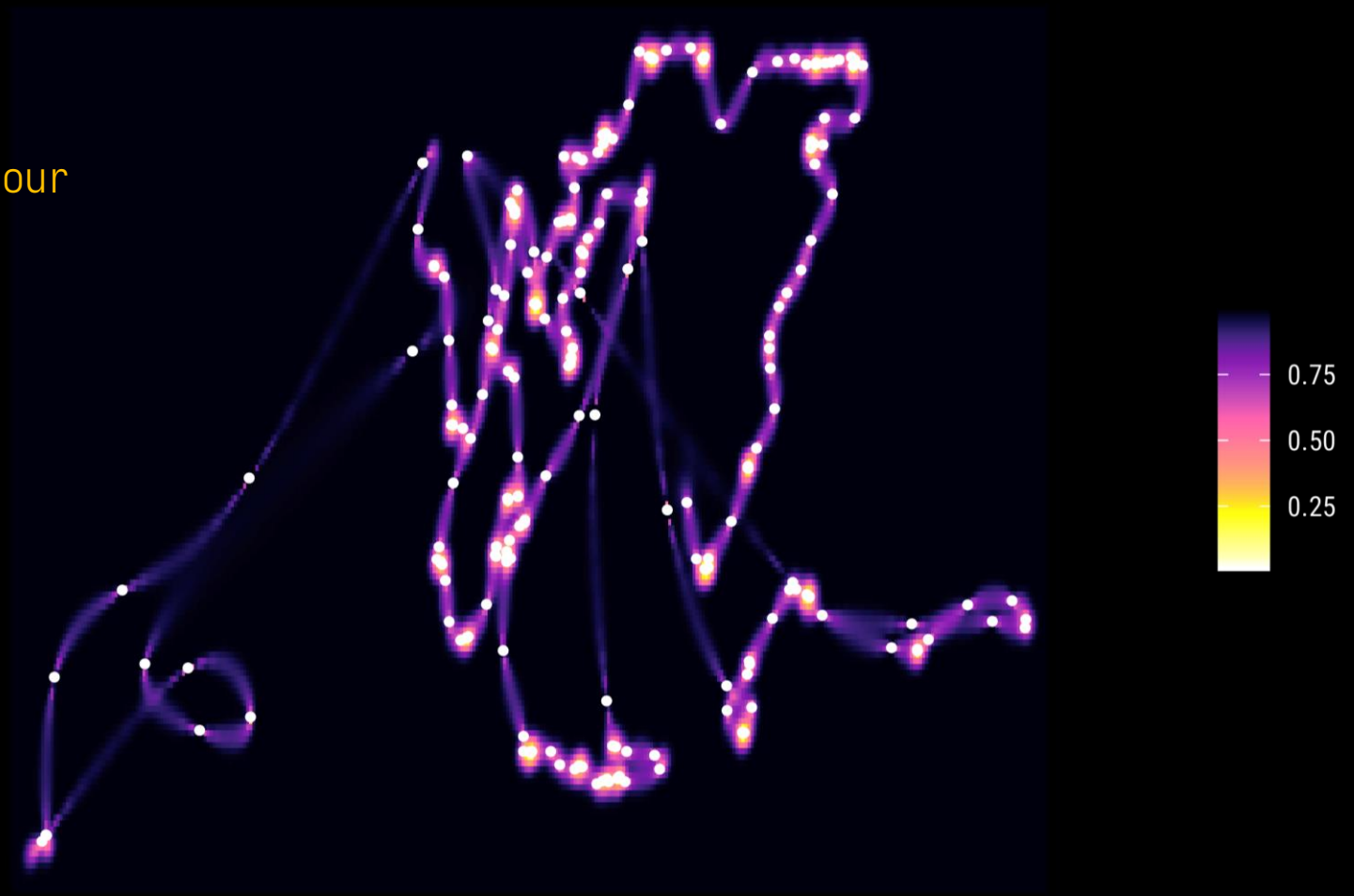
Estimates **occurrence regions**

Pinpoints the one realization of the movement process that did occur.

Alston *et al.* (2022)

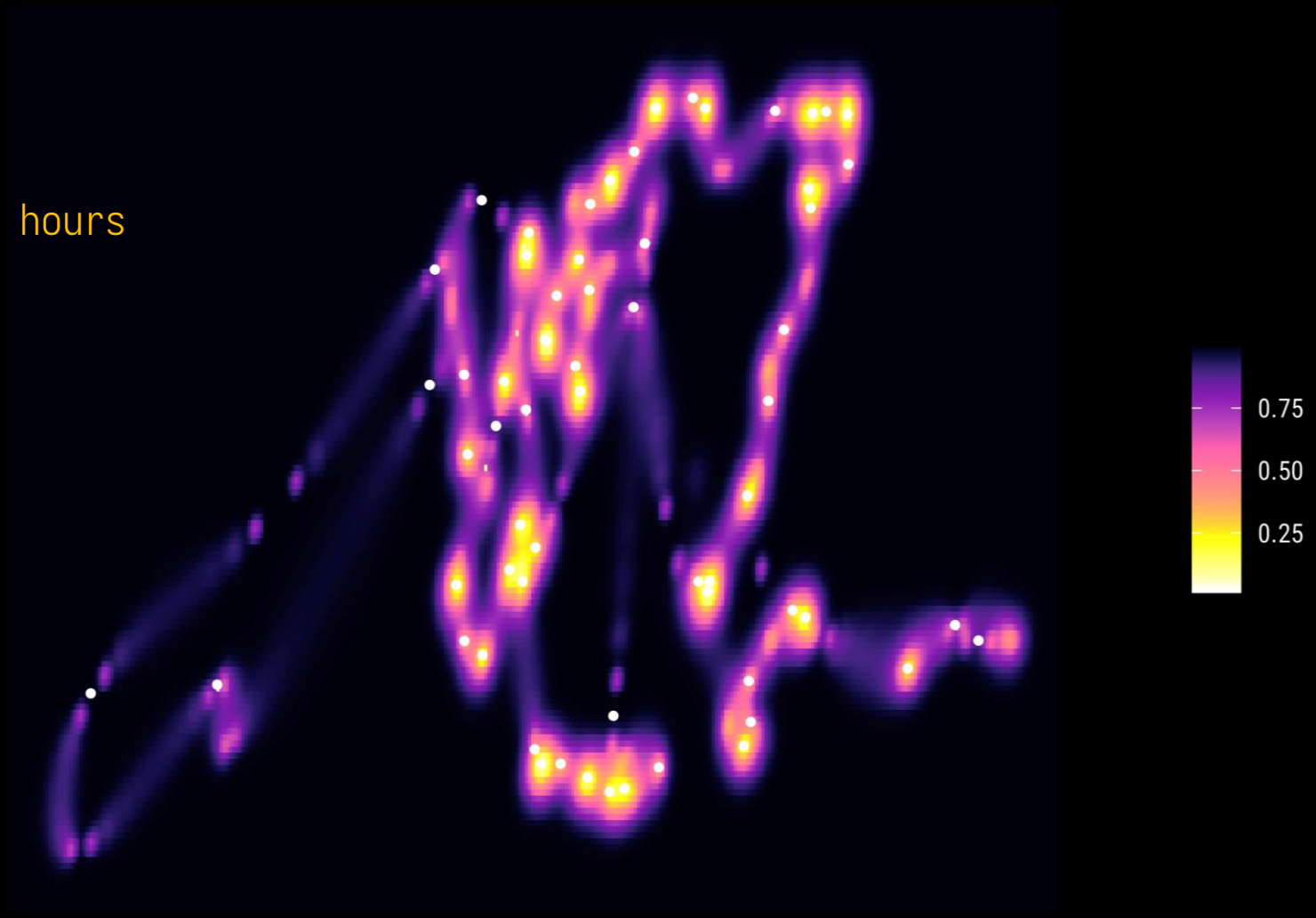
Sampling interval

$\Delta t = 1$ hour



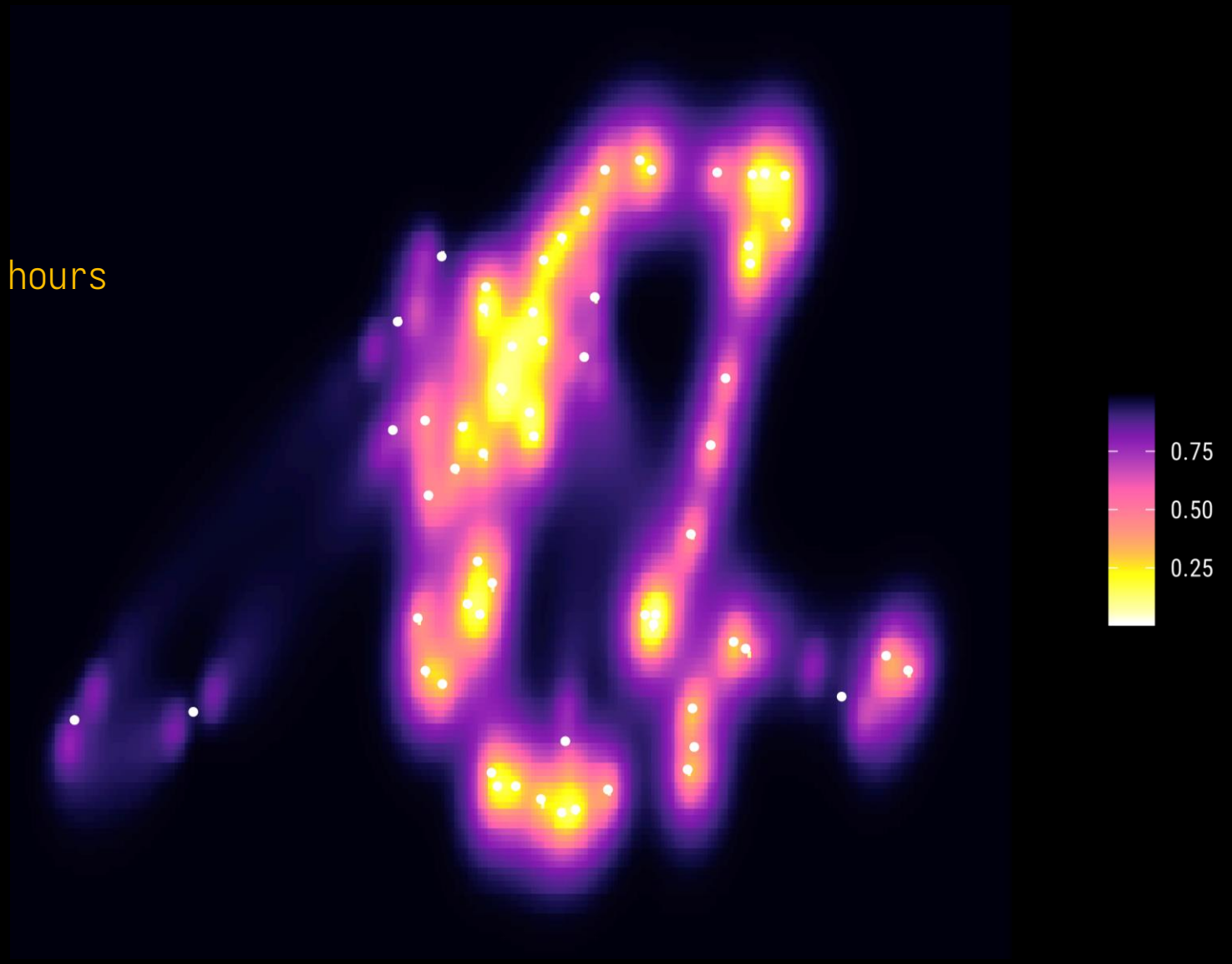
Sampling interval

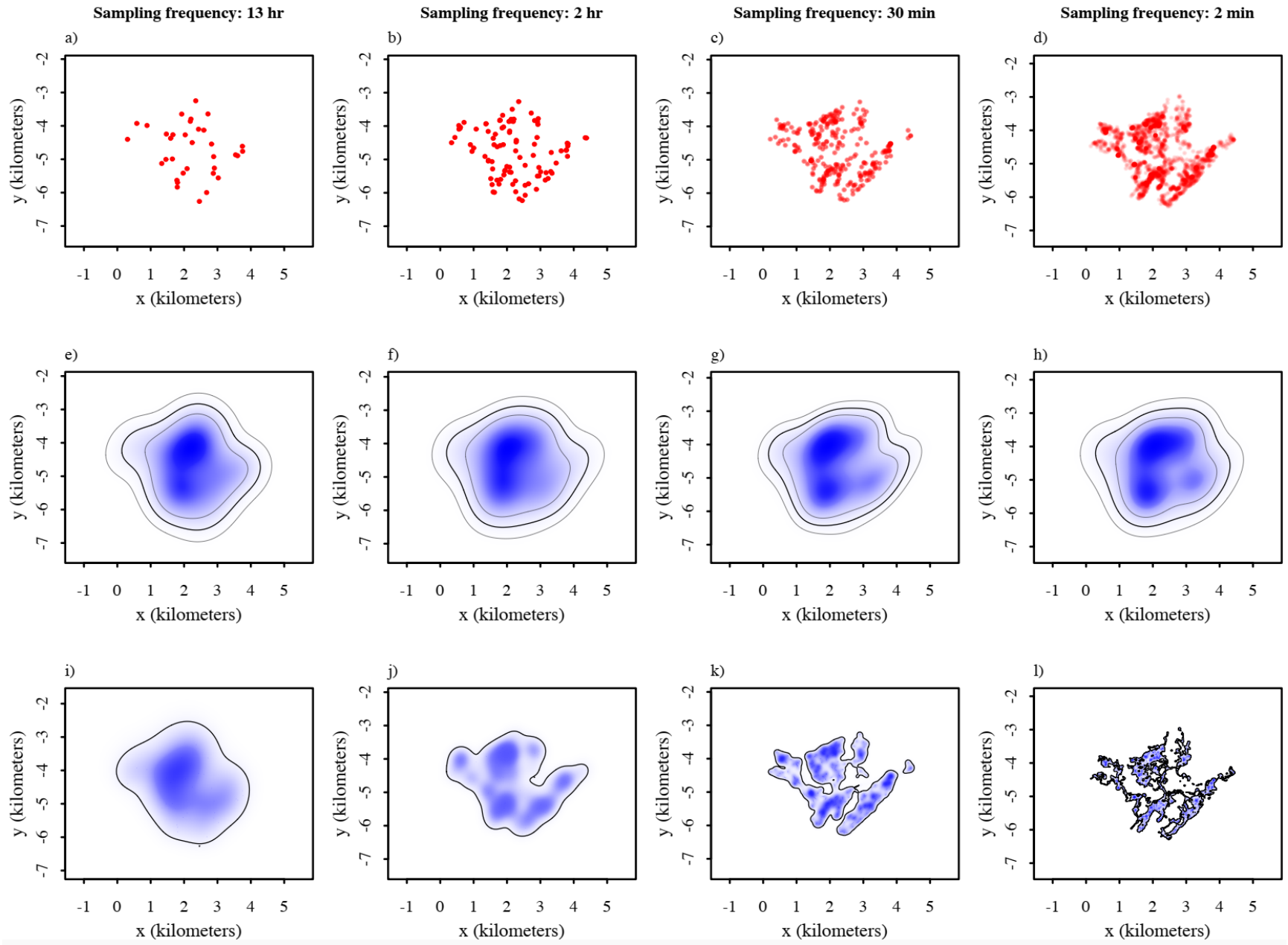
Δt = 2 hours



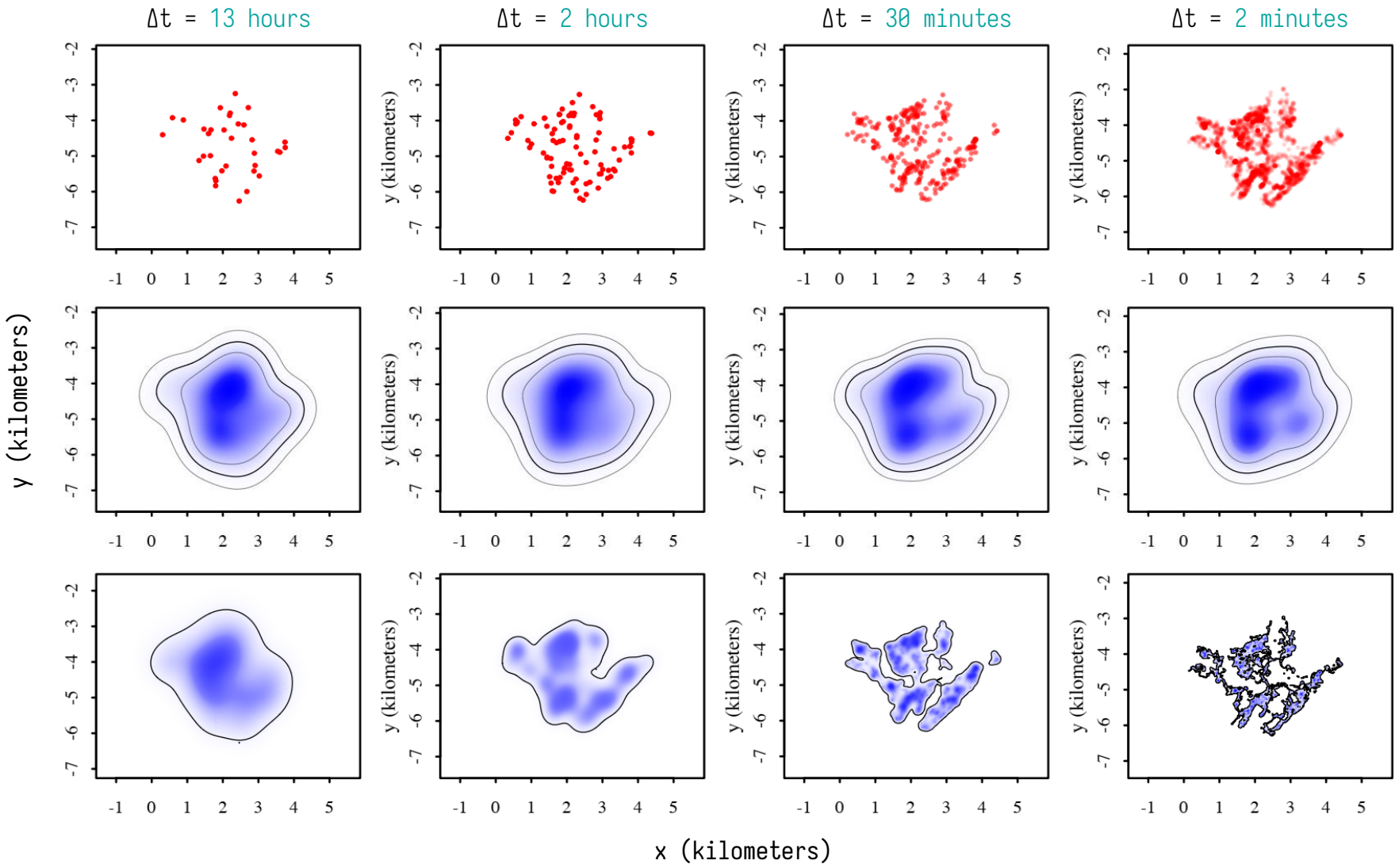
Sampling interval

$\Delta t = 4$ hours





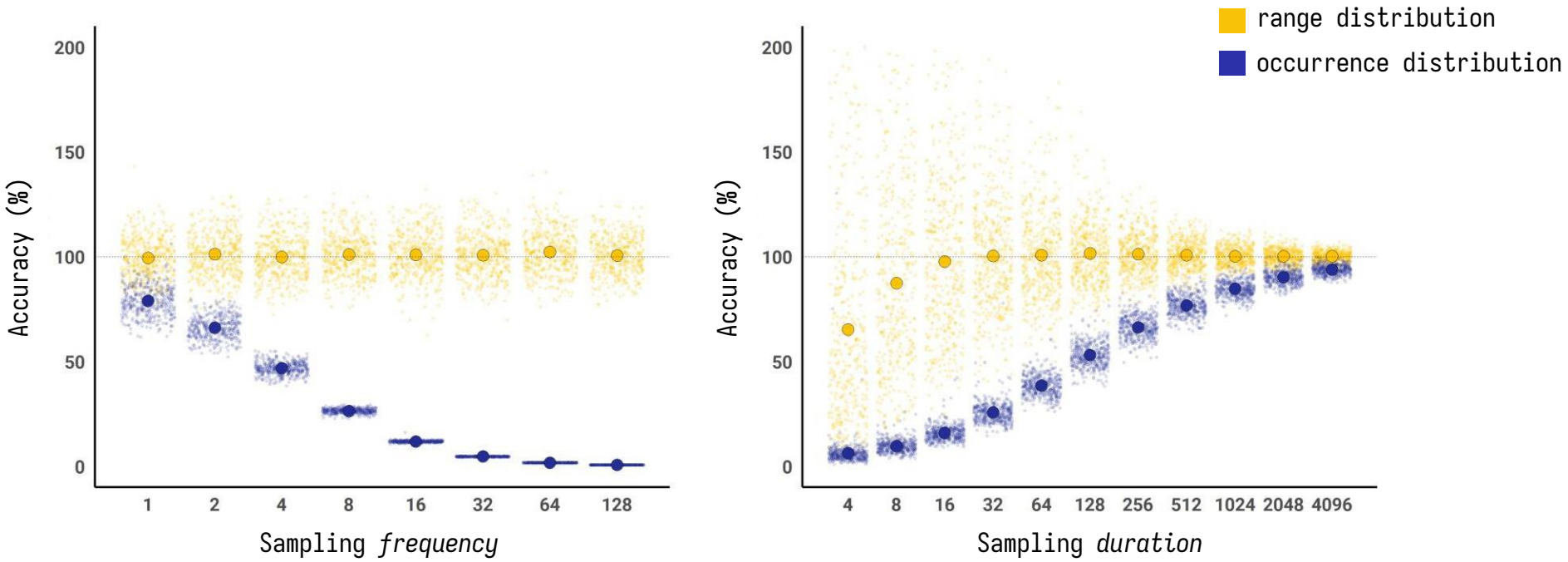
i.simoes-silva@hzdr.de



i.simoes-silva@hzdr.de

Simulated examples

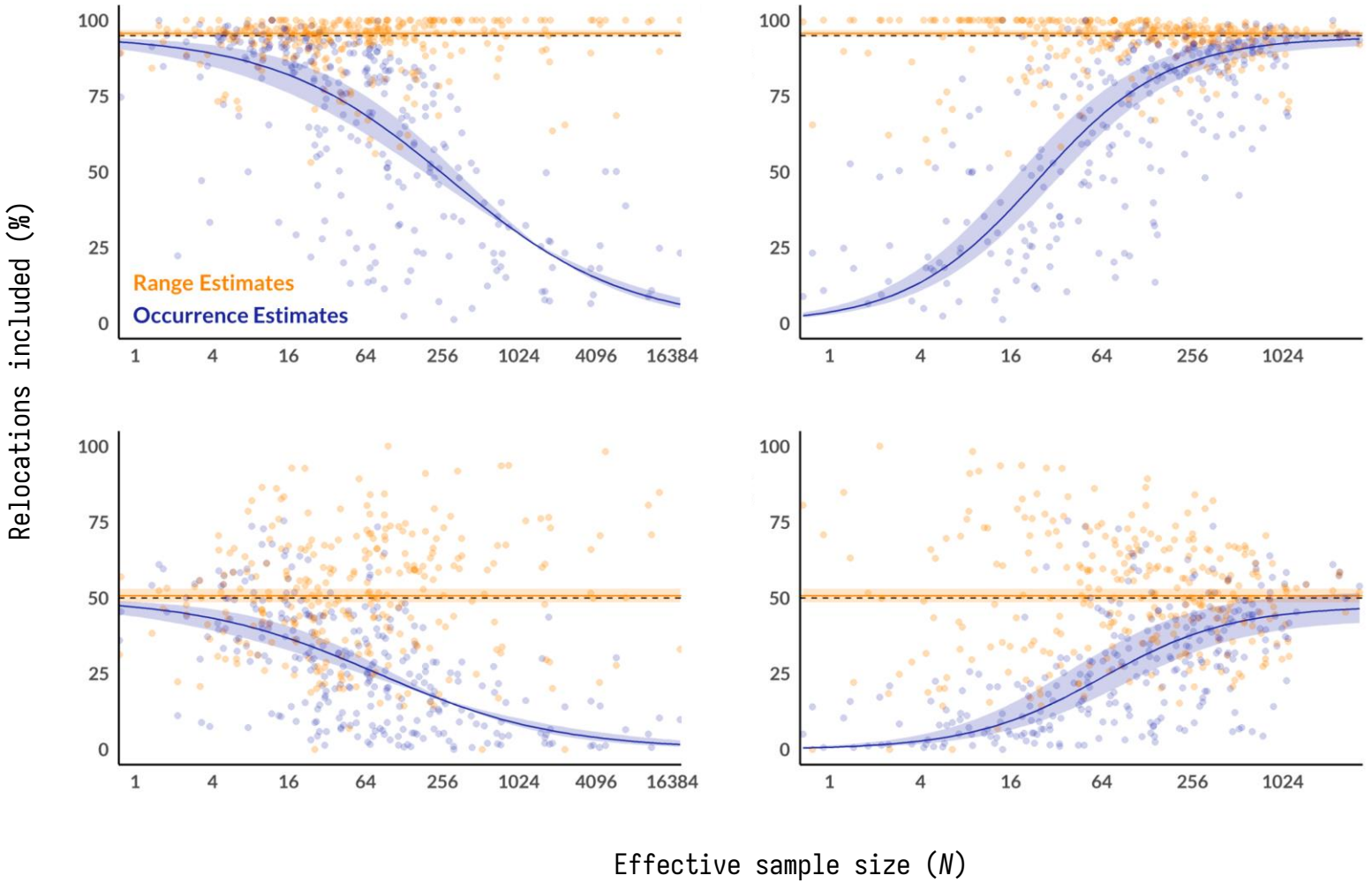
Size of occurrence estimates are a function of sampling interval, while size of range estimates are not.



i.simoes-silva@hzdr.de

Empirical examples

Holds up in real world data!



Generalized time-series **Kriging** framework:

Fleming *et al.* (2016)

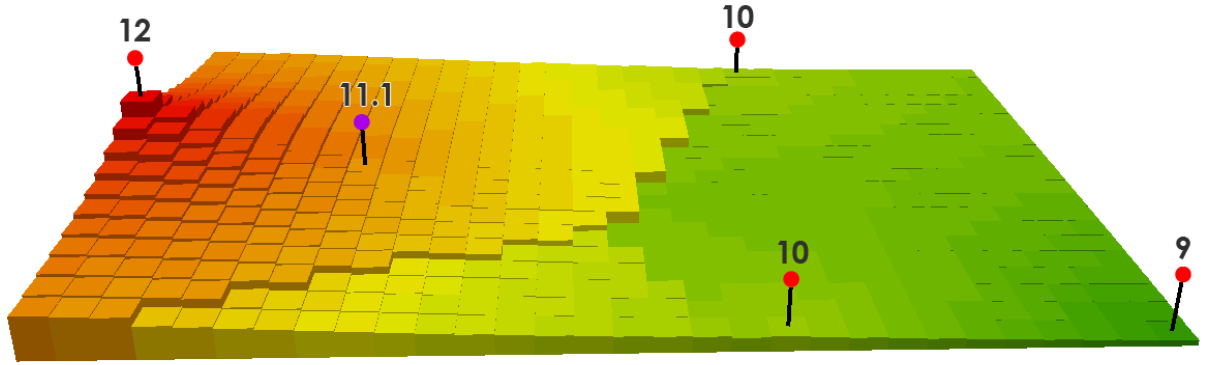
Kriging is a widely used tool in geostatistics, engineering, and computer science. It is a statistically optimal framework for ***interpolating between discrete locations***, with well-known statistical properties.

Generalized time-series **Kriging** framework:

Fleming *et al.* (2016)

Kriging is a widely used tool in geostatistics, engineering, and computer science. It is a statistically optimal framework for ***interpolating between discrete locations***, with well-known statistical properties.

Fig. spatially interpolated temperature from weather stations.

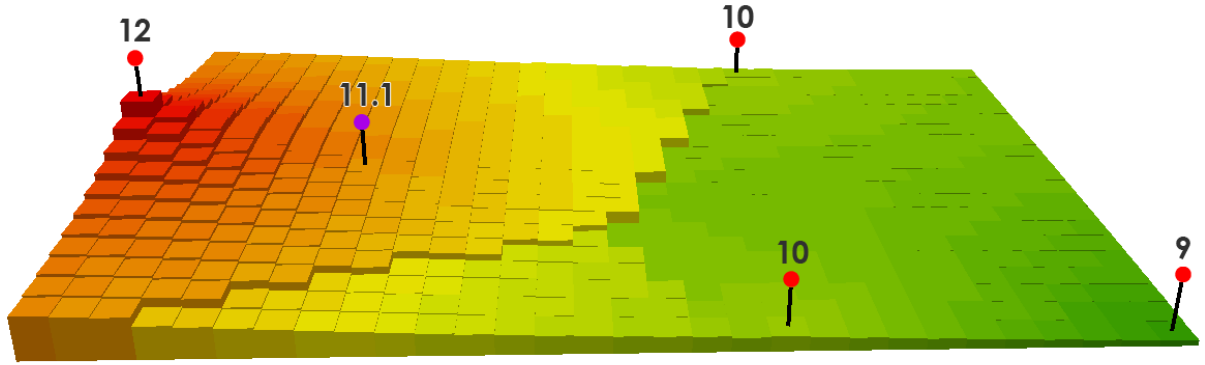


Generalized time-series **Kriging** framework:

Fleming *et al.* (2016)

Kriging is a widely used tool in geostatistics, engineering, and computer science. It is a statistically optimal framework for ***interpolating between discrete locations***, with well-known statistical properties.

Fig. spatially interpolated temperature from weather stations.



Encompasses both **Brownian Bridge Movement Model** (**BBMM**; Horne *et al.* 2007) and **Correlated Random Walk** library (**CRAWL**; Johnson *et al.* 2008).

Generalized time-series **Kriging** framework:

Fleming *et al.* (2016)

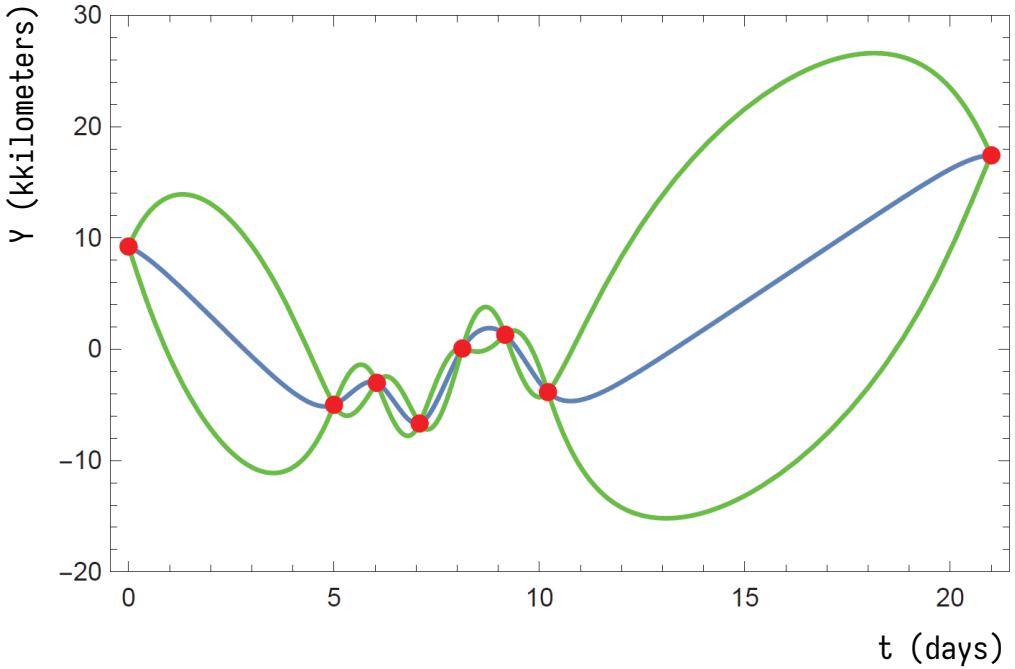


Fig. Time series of Mongolia Gazelle locations (red), with Krige interpolated locations (blue) and 95% contour intervals (green).

Not only does ***Kriging*** provide an optimal prediction surface, but it also delivers a measure of confidence of how likely that prediction will be true.

Generalized time-series **Kriging** framework:

Fleming *et al.* (2016)

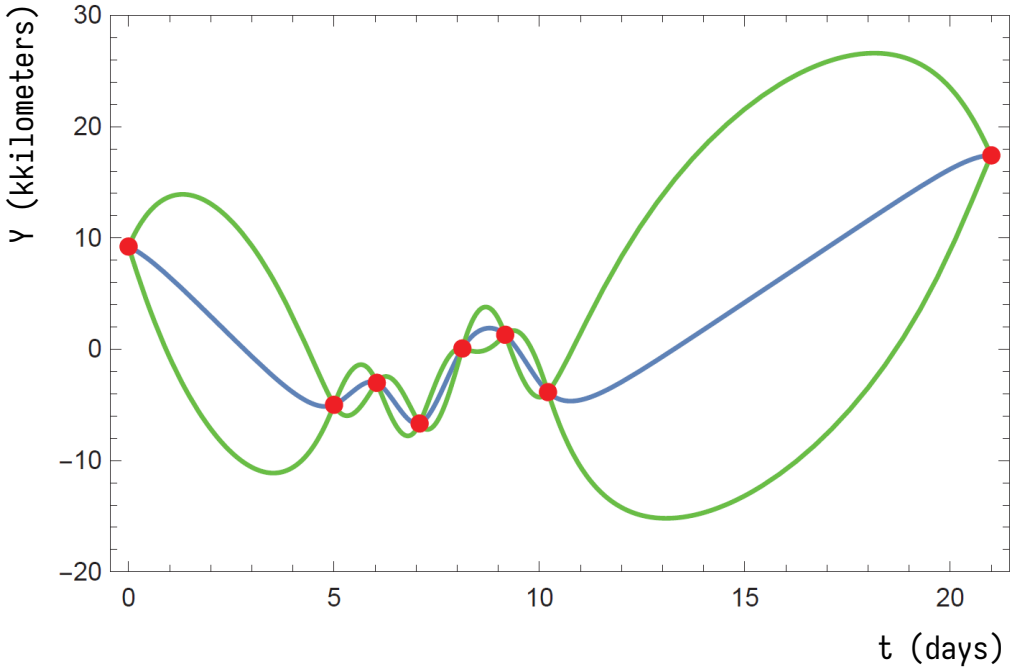


Fig. Time series of Mongolia Gazelle locations (red), with Krige interpolated locations (blue) and 95% contour intervals (green).

Not only does ***Kriging*** provide an optimal prediction surface, but it also delivers a measure of confidence of how likely that prediction will be true.

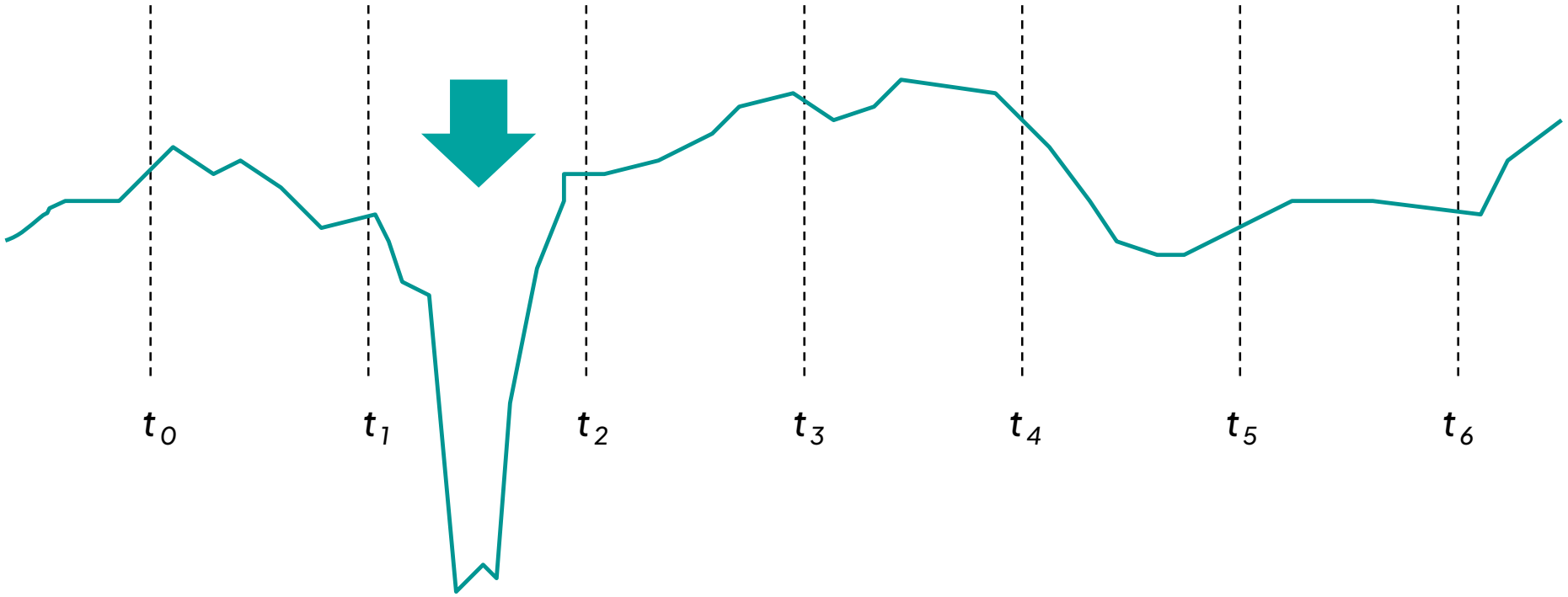
Two step process:

1. ***Select a movement model,***
   (describing an animal's movements)

2. ***Solve for an animal's location at time t,***
   (conditional upon the data and the fitted model)

An occurrence region is sampling-dependent.

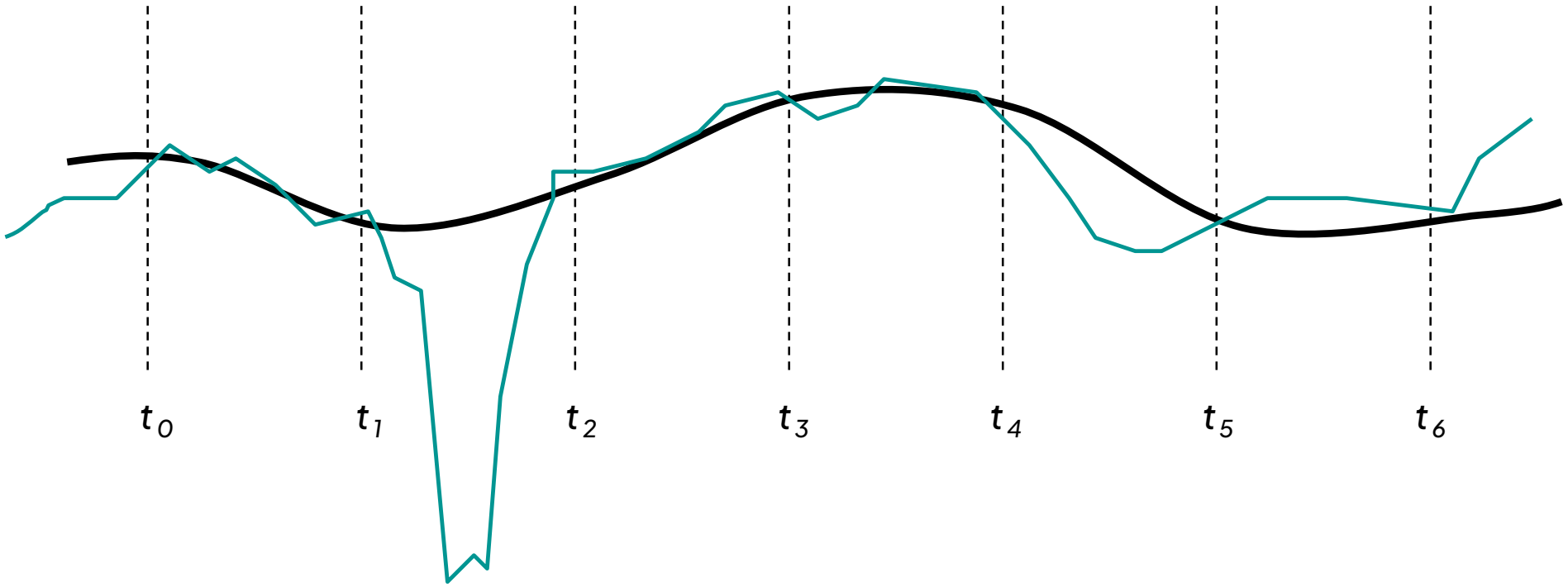
If each dashed line represented a sample point (in 1-D), this spacing would miss a major local source of variation.



i.simoes-silva@hzdr.de

An occurrence region is sampling-dependent.

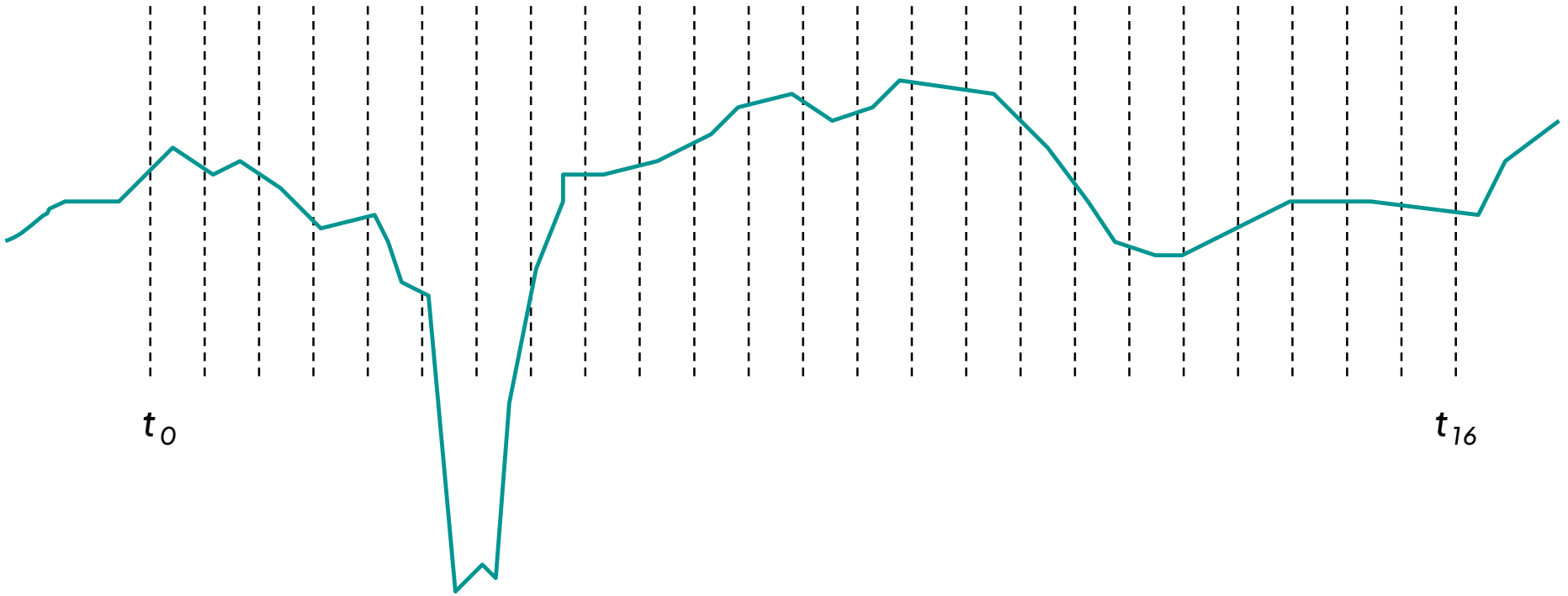
Our interpolated surface (represented in 1-D by the black line) would look like this.



Estimating occurrence region

An occurrence region is sampling-dependent.

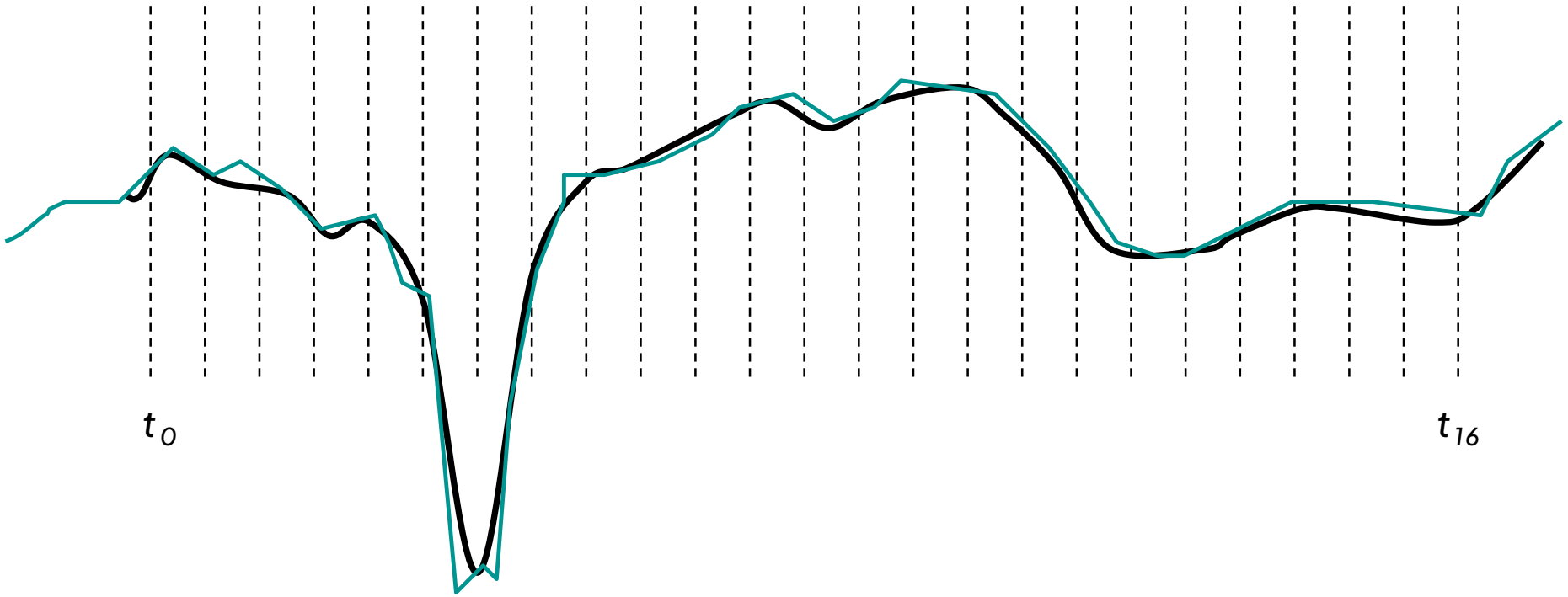
Only by increasing the sampling frequency, would we pick up that local variation.



i.simoes-silva@hzdr.de

An occurrence region is sampling-dependent.

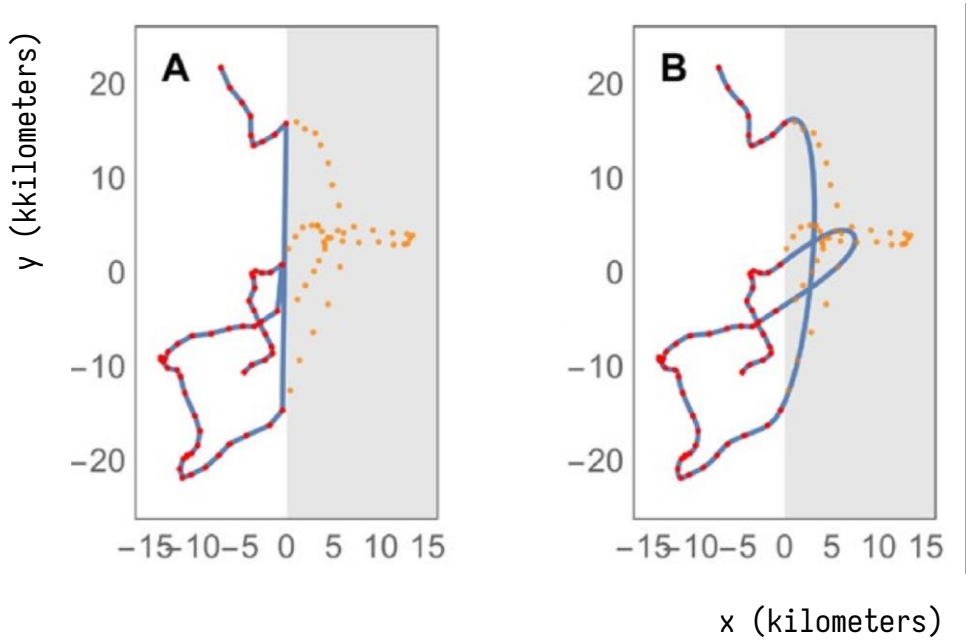
Here our interpolated surface is much closer to reality at the local level, but we pay for this in the form of higher data gathering cost.



Now that we know how to interpolate, we can:

- Fill in missing gaps,
- Project beyond the sampling period,
- Identify areas of potential use,

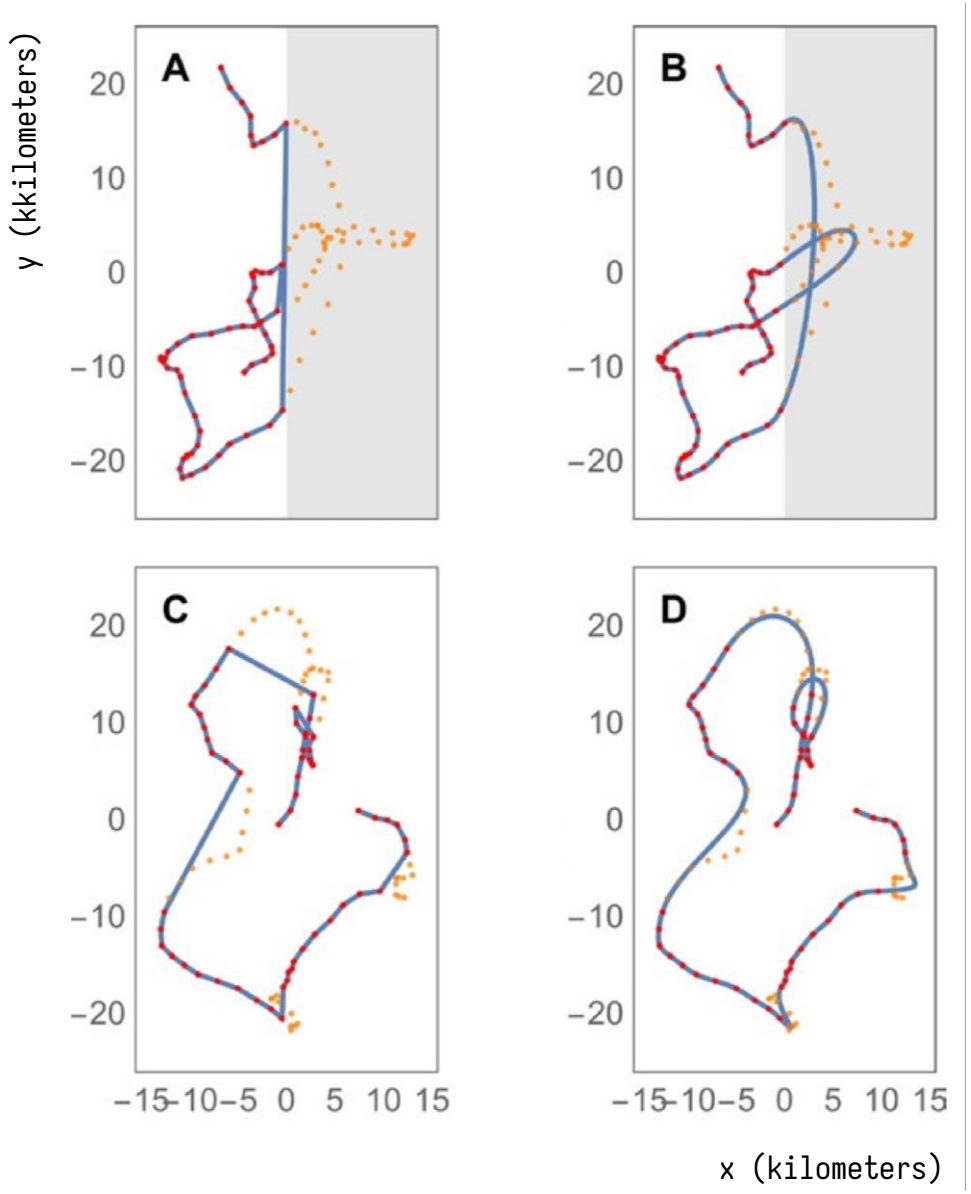
  (*e.g.*, related to human-wildlife conflict).



Now that we know how to interpolate, we can:

- Fill in missing gaps,
- Project beyond the sampling period,
- Identify areas of potential use,

  (*e.g.*, related to human-wildlife conflict).



Now that we know how to interpolate, we can:

- Fill in missing gaps,
- Project beyond the sampling period,
- Identify areas of potential use,
  (*e.g.*, related to human-wildlife conflict).

Can be very ***memory-intensive***! (on large data sets, consider looping through each animal individually).