

MARE-Madeira 2025

Occurrence distributions

Using the 'ctmm' R package



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📷 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

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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

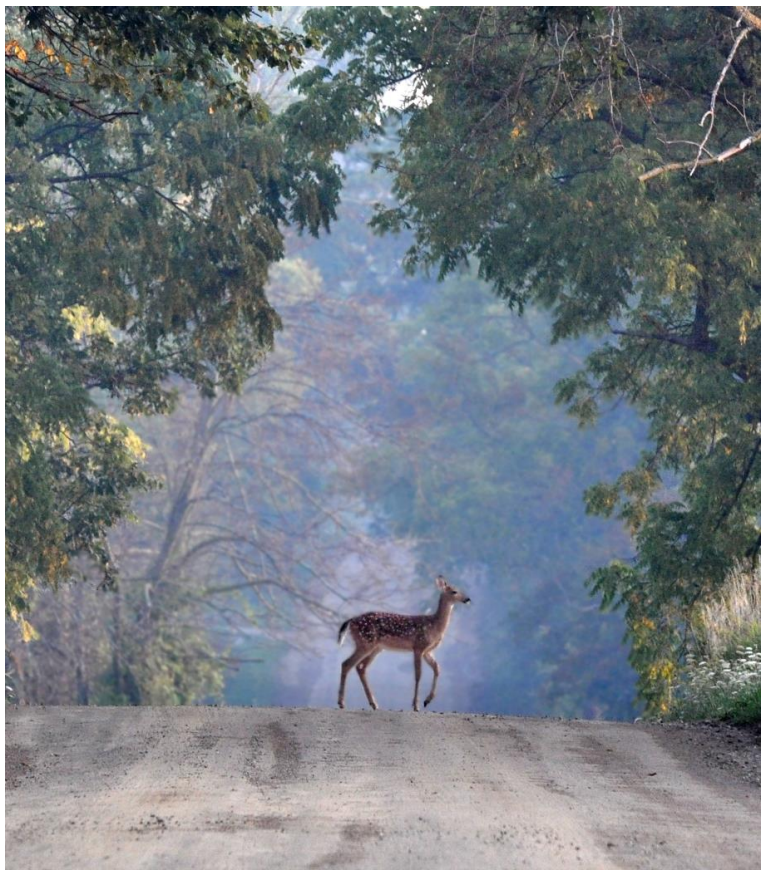


Roads have significant impacts on ecological systems, increasing the **extinction risk** of threatened species.

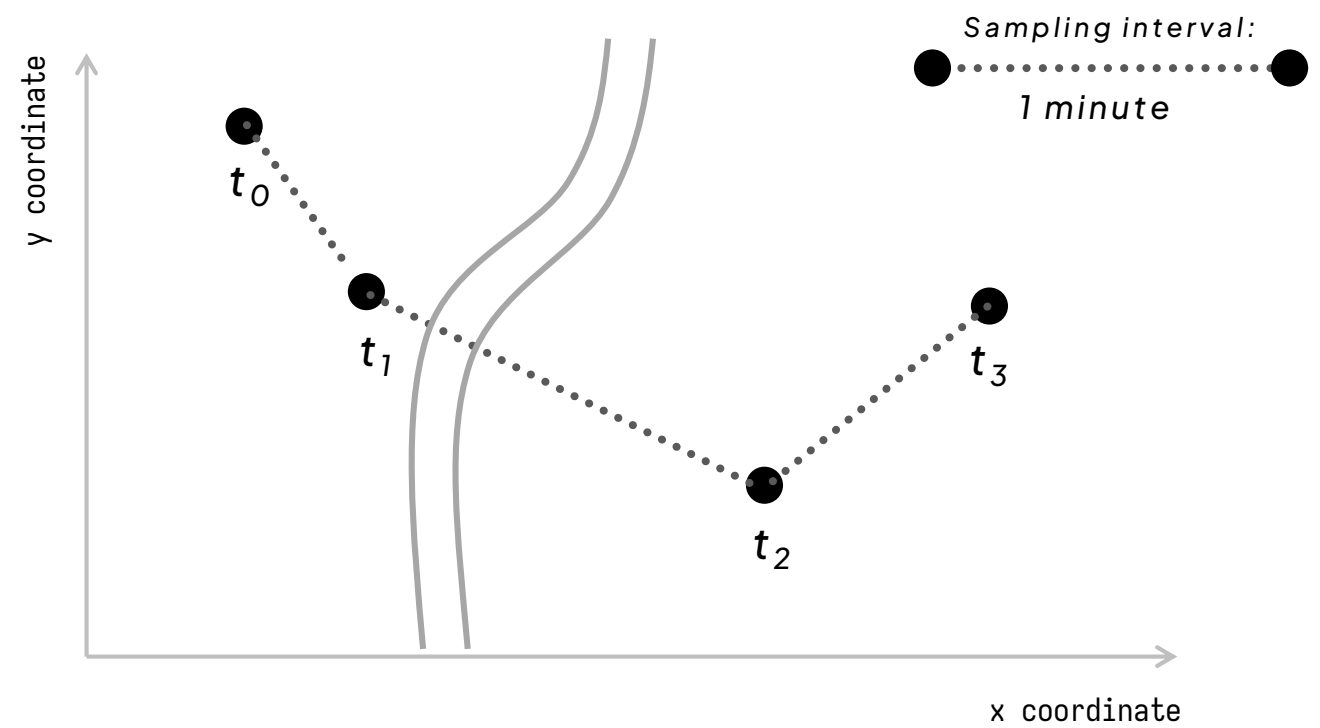


Where did an animal cross a linear feature (e.g., road- or railways)?

 Julie Falk



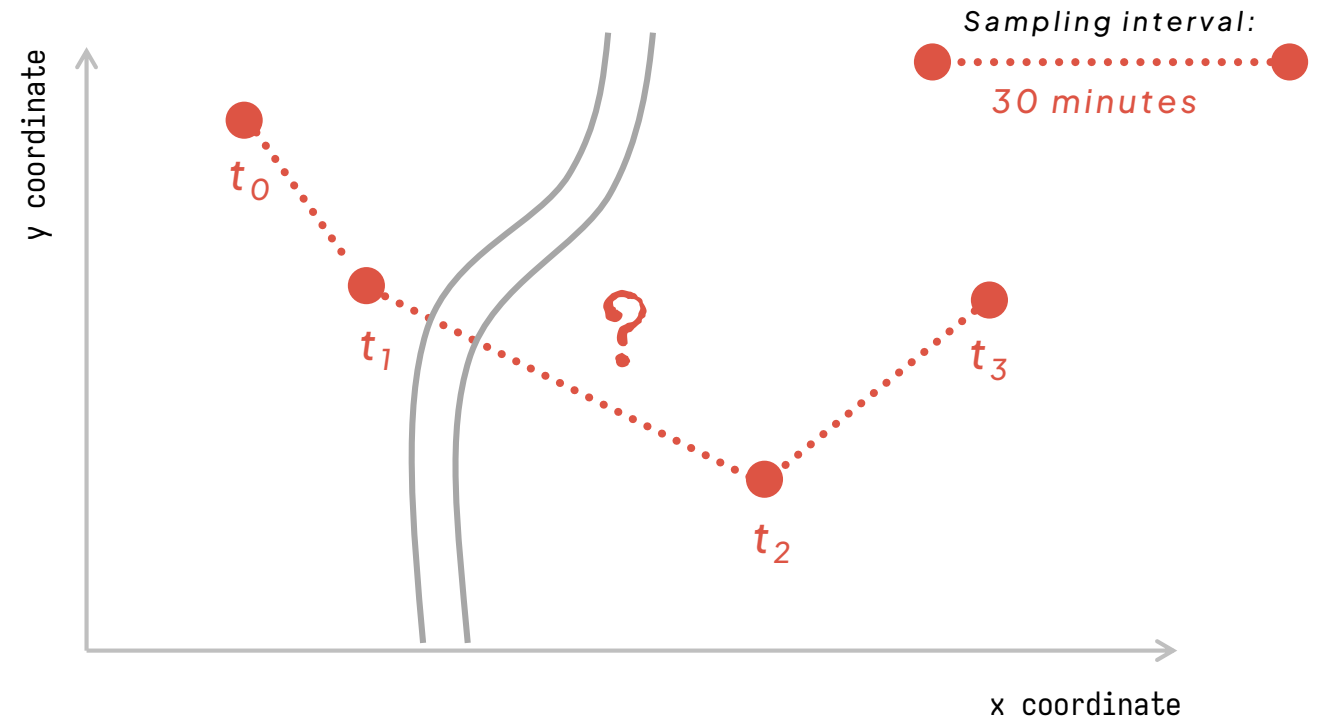
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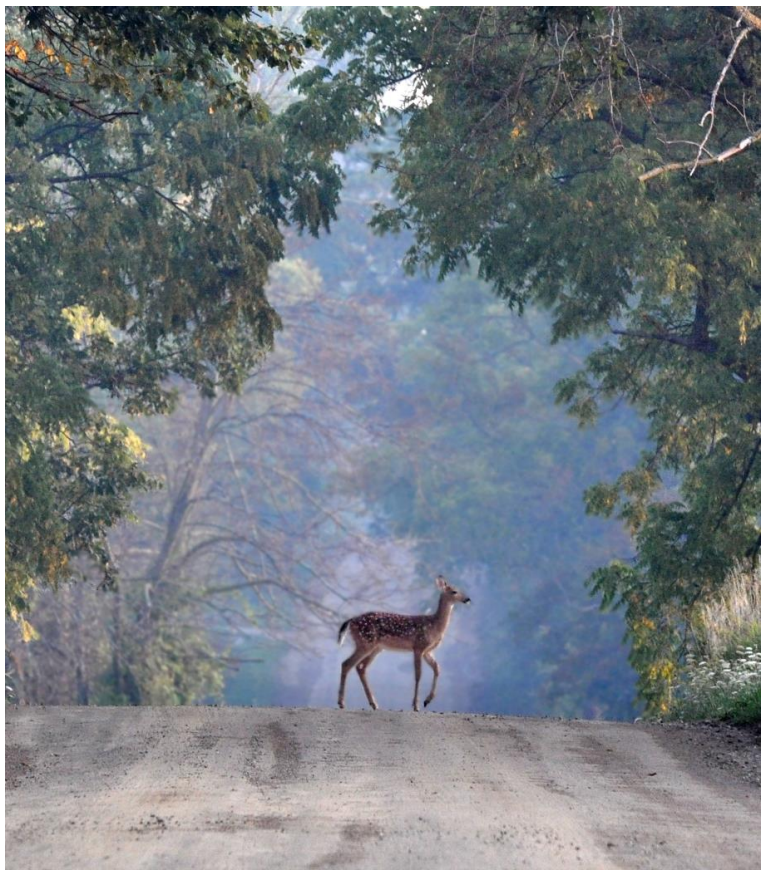
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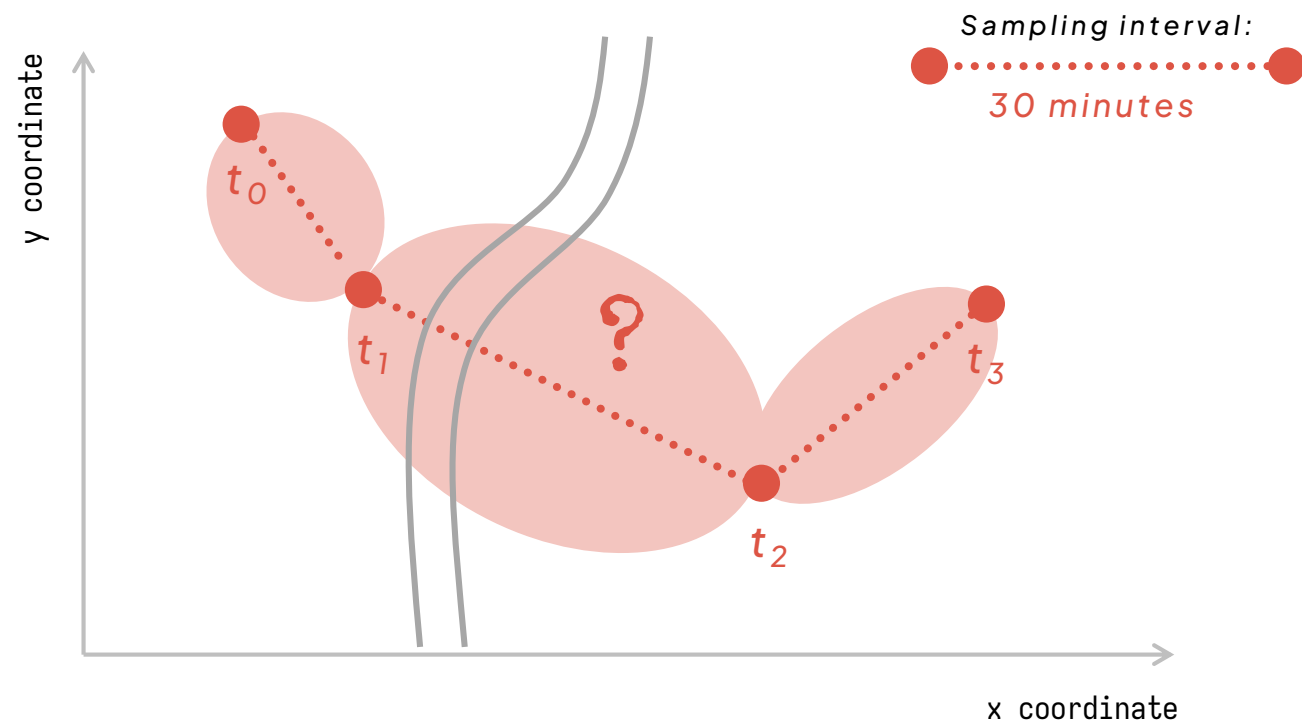
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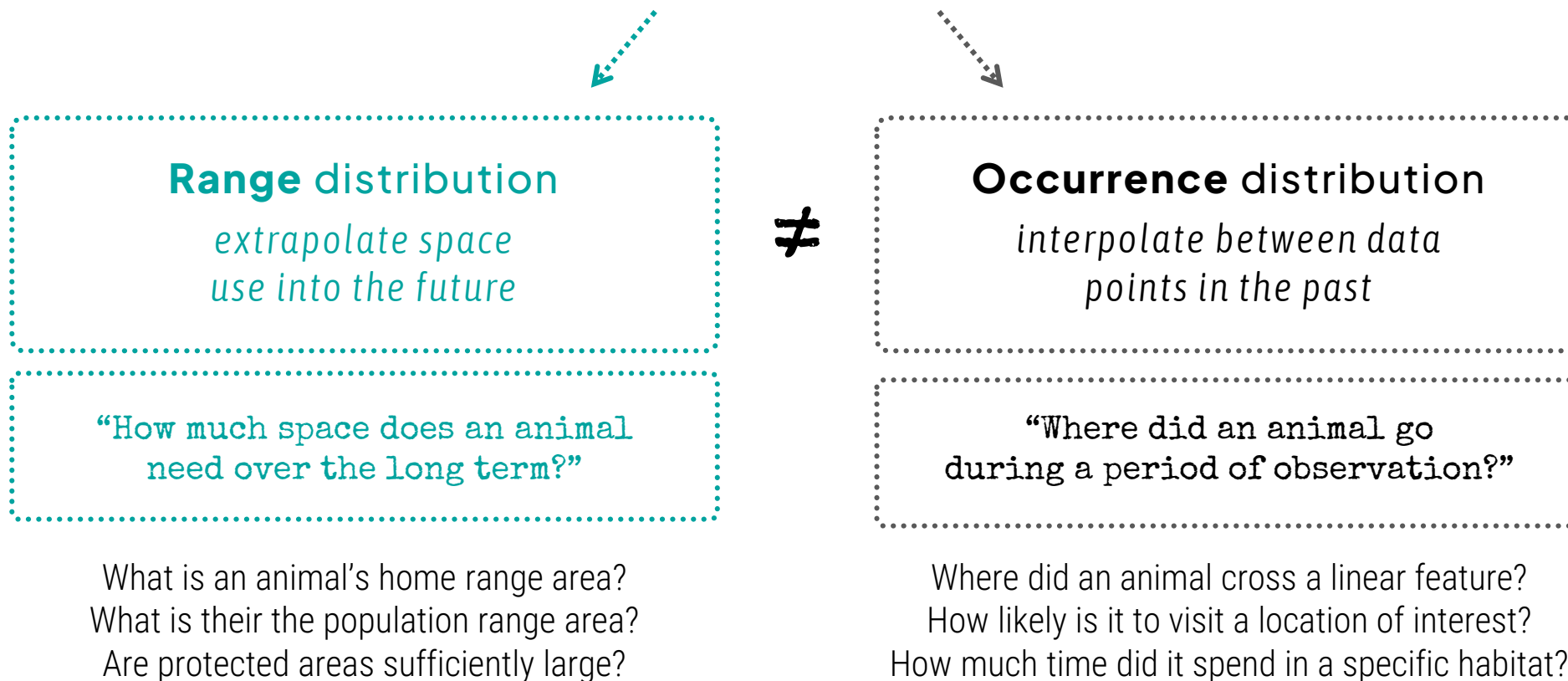


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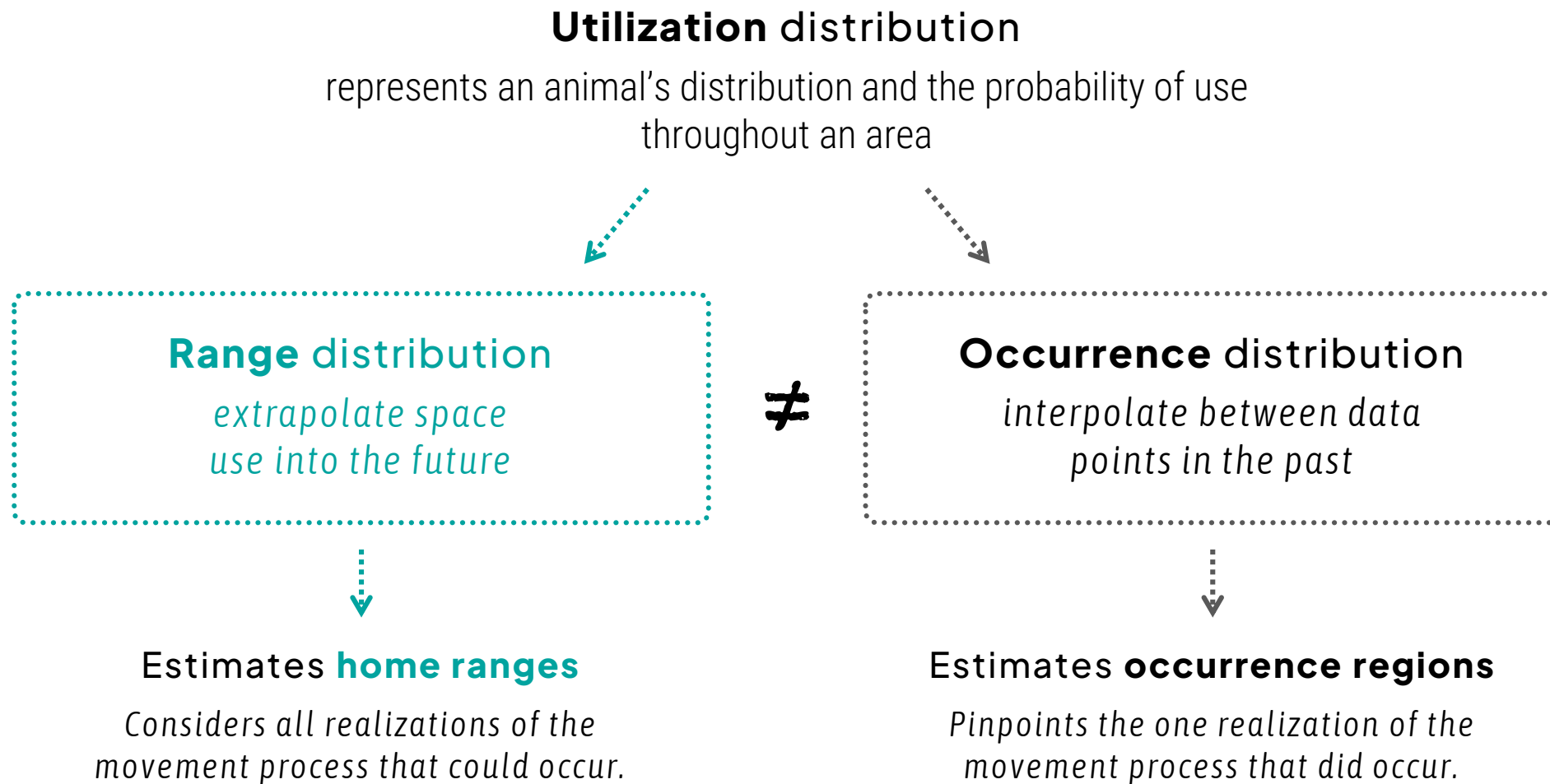


Utilization distribution

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



 **Alston et al. (2022)**



Utilization distribution

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Occurrence distribution

interpolate between data points in the past

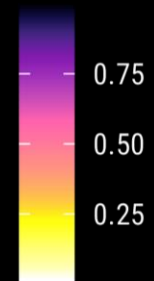


Estimates **occurrence regions**

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

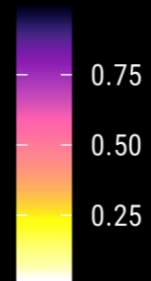
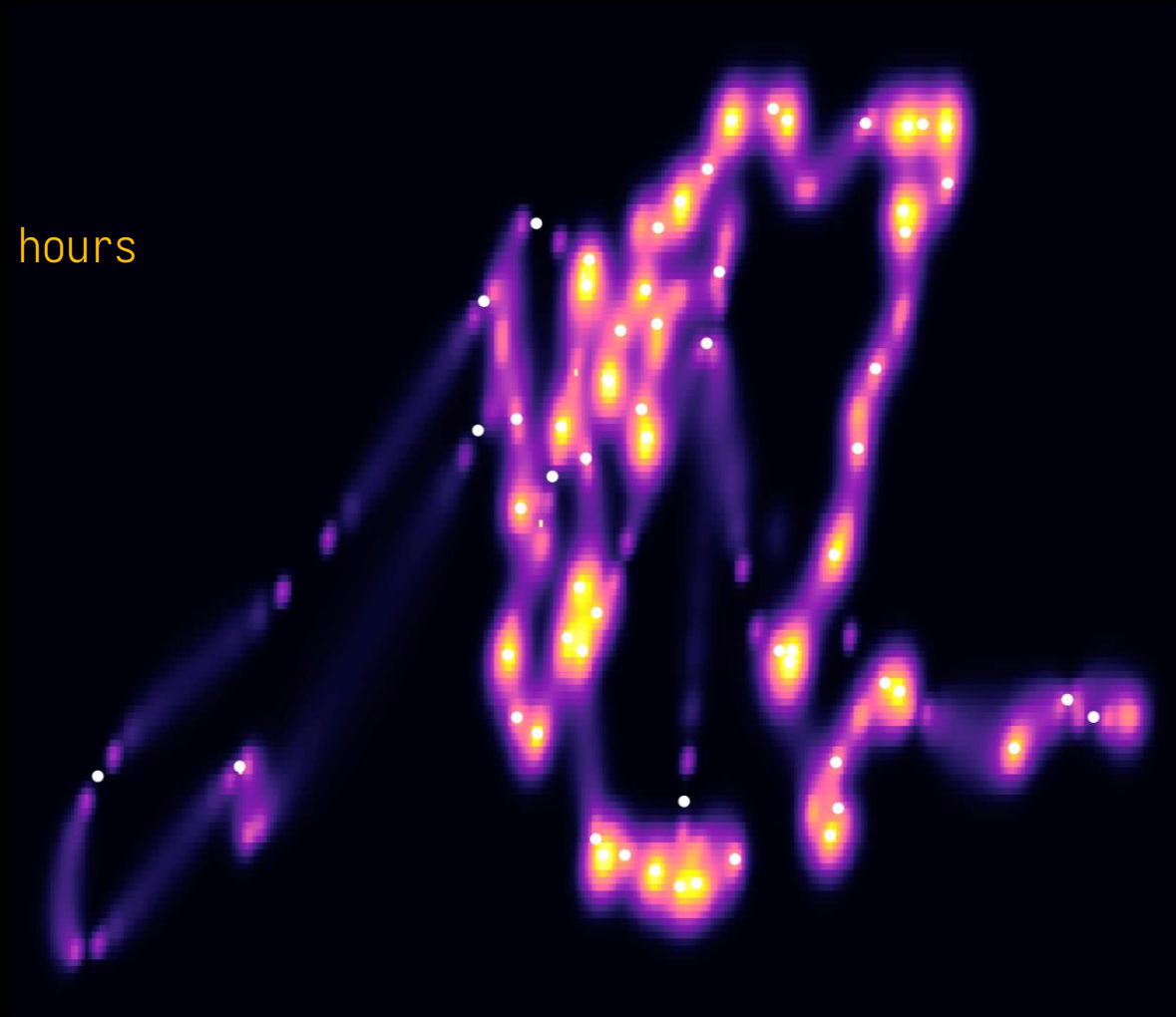
..... Sampling interval

$\Delta t = 1$ hour



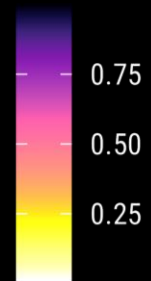
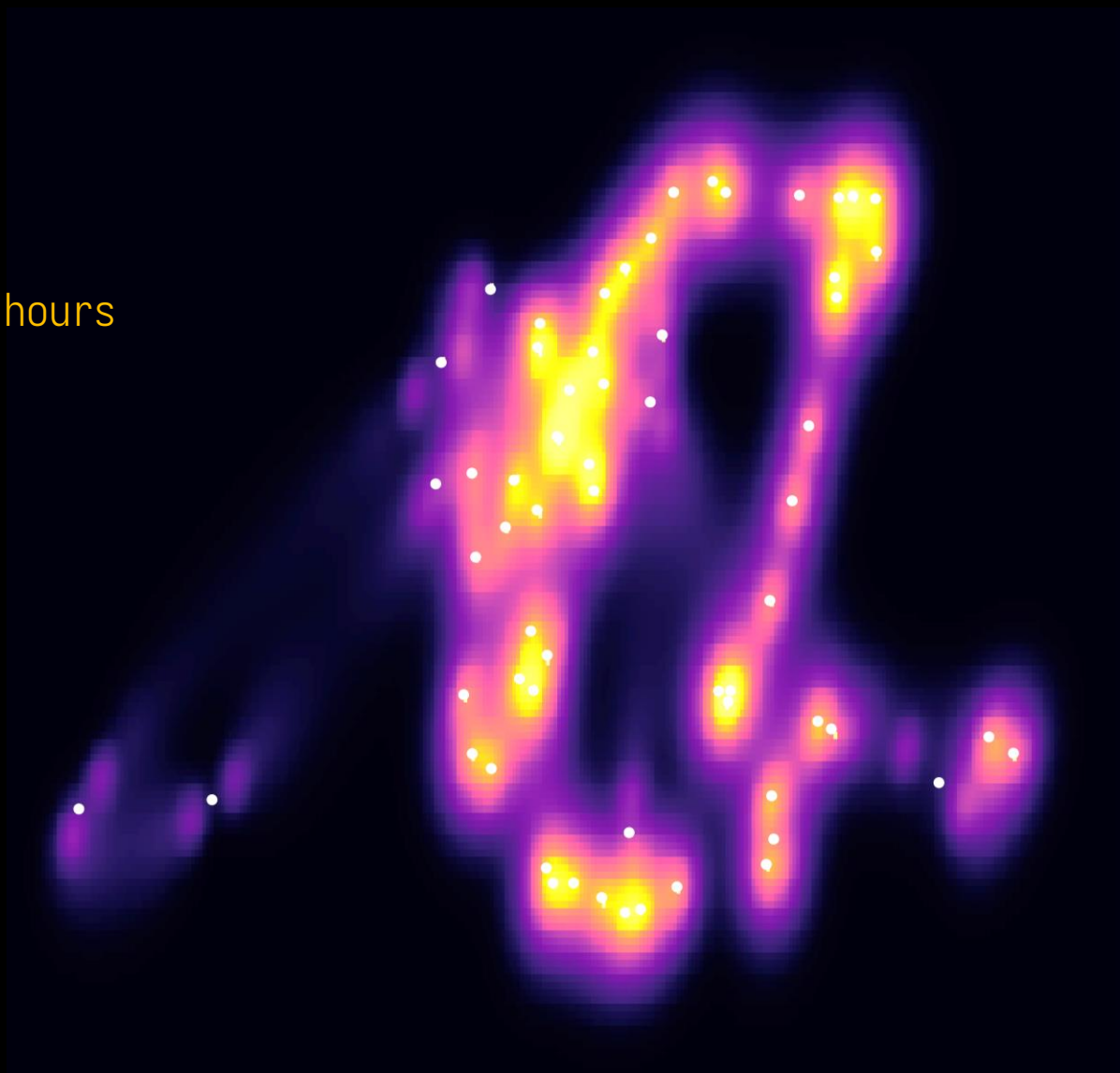
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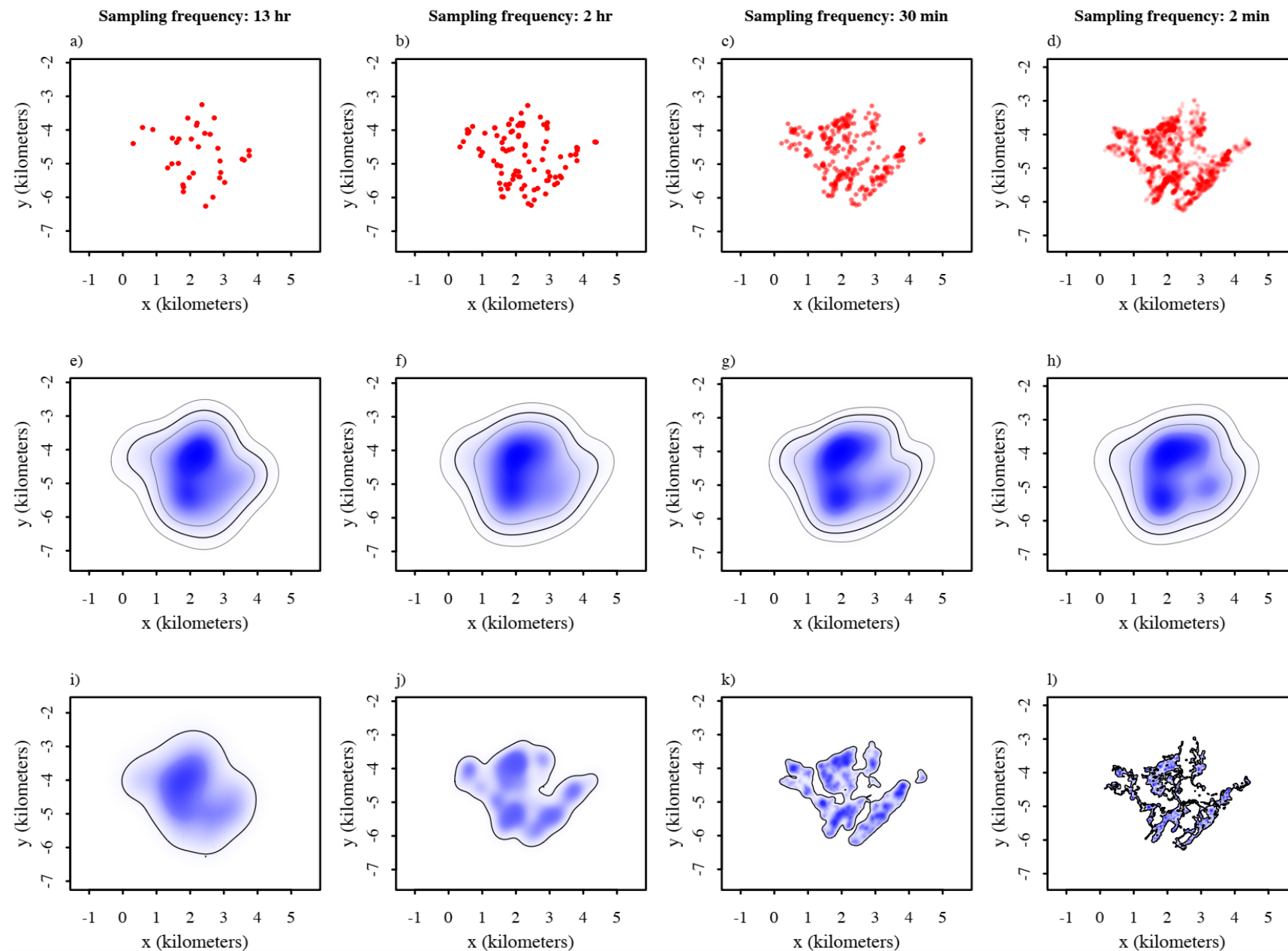
$\Delta t = 2$ hours

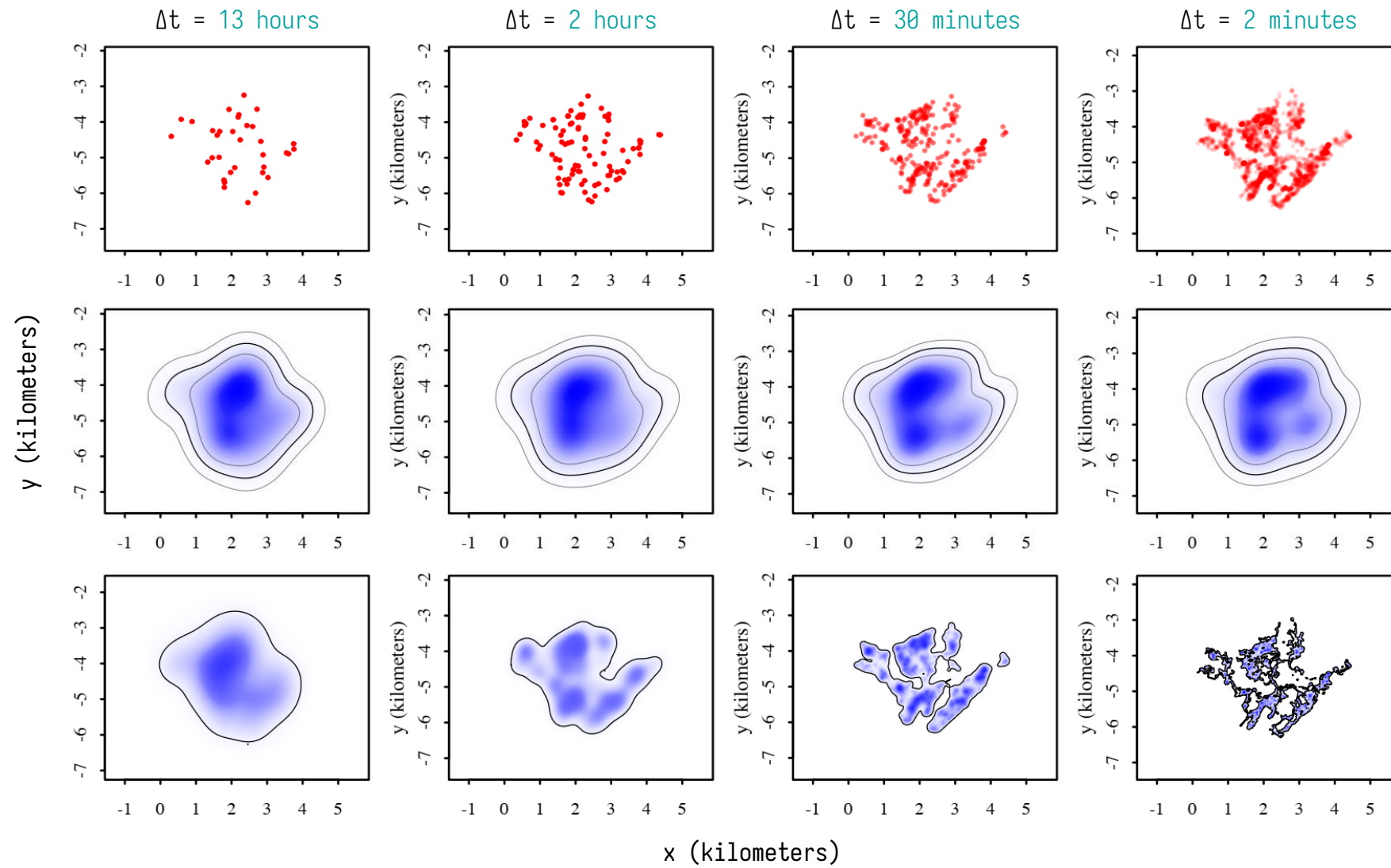


..... Sampling interval

$\Delta t = 4$ hours



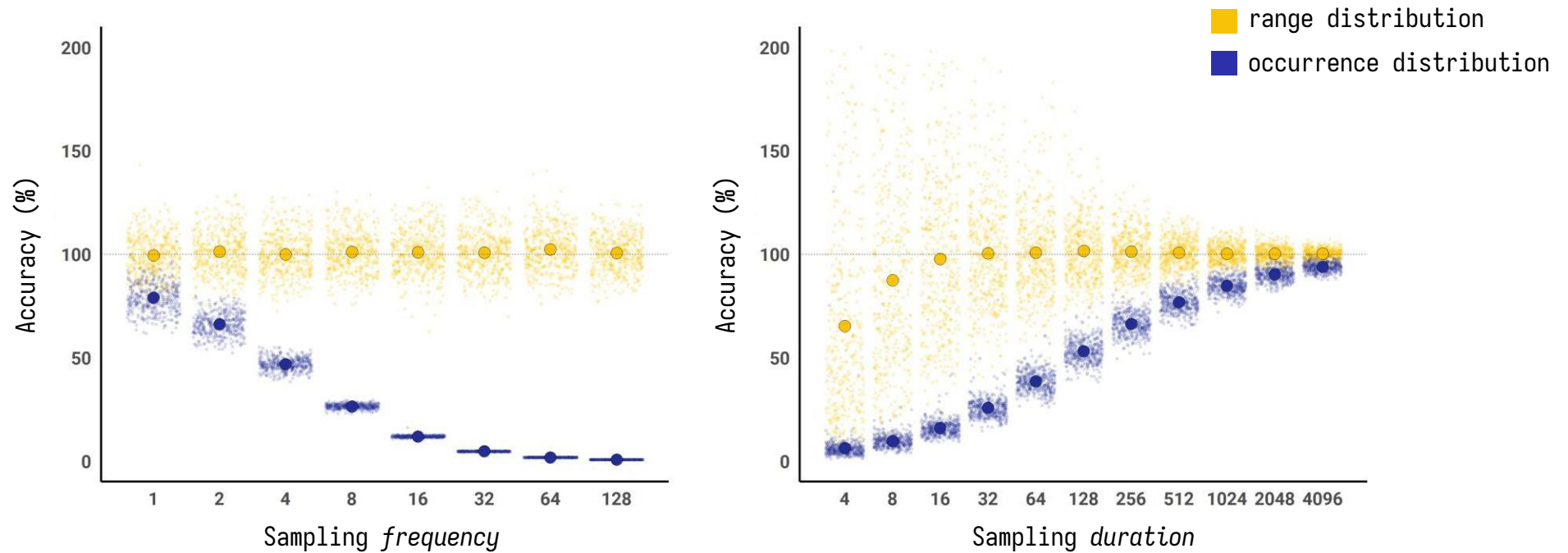






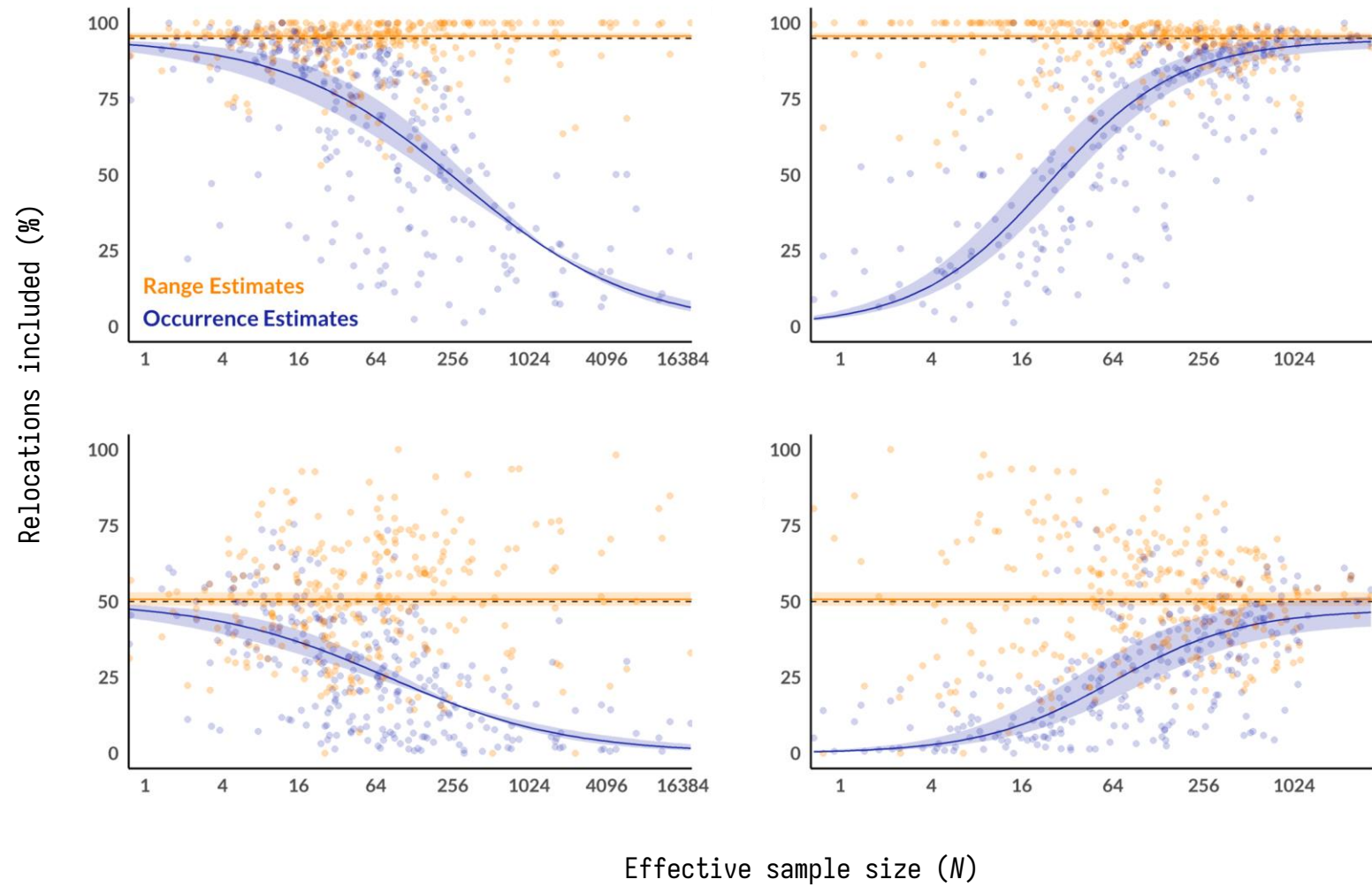
Simulated examples

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





Empirical examples
Holds up in real world data!



Generalized time-series **Kriging** framework:

✍ Fleming *et al.* (2016)

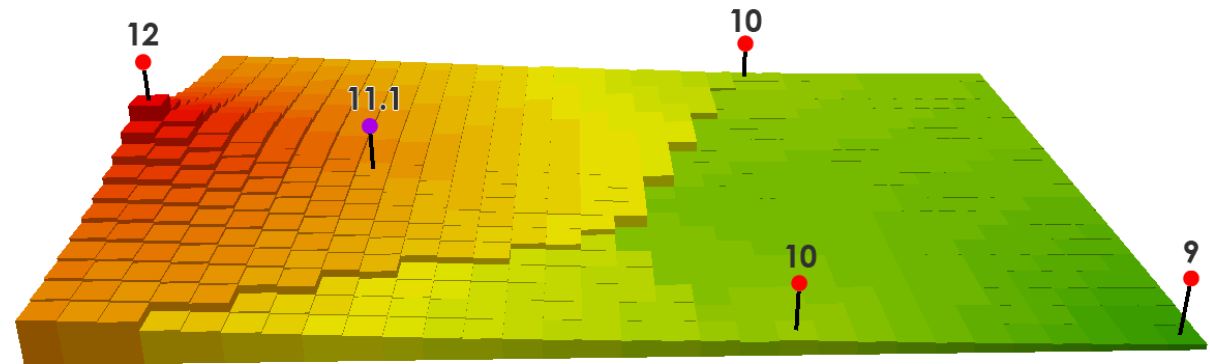
———— **Kriging** is a widely used tool in geostatistics, engineering, and computer science. It is a statistically optimal framework for **interpolating between discrete locations**, with well-known statistical properties.

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Fig. spatially interpolated temperature from weather stations.

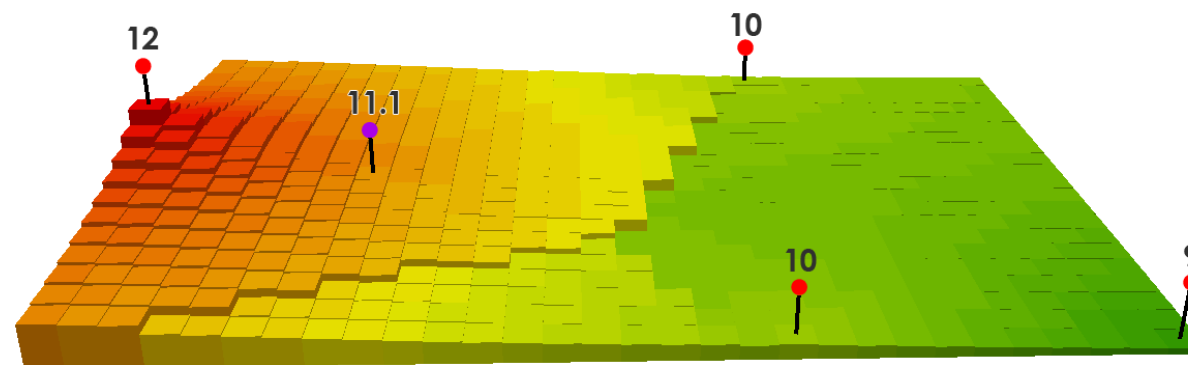


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Fig. spatially interpolated temperature from weather stations.



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

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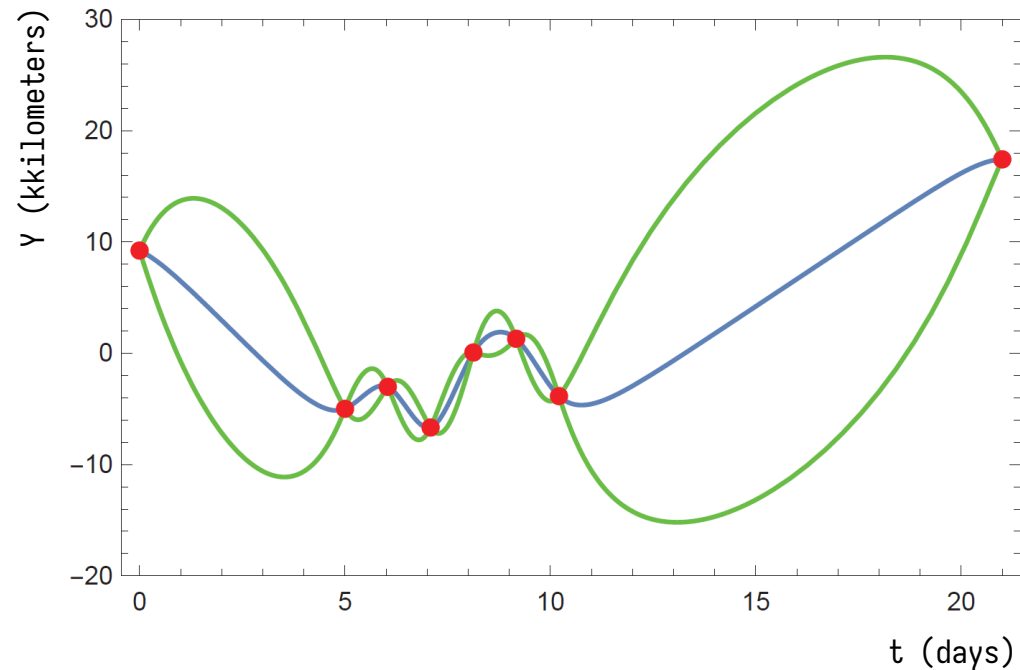


Fig. Time series of Mongolia Gazelle locations (red), with Kriging interpolated locations (blue) and 95% contour intervals (green).

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.

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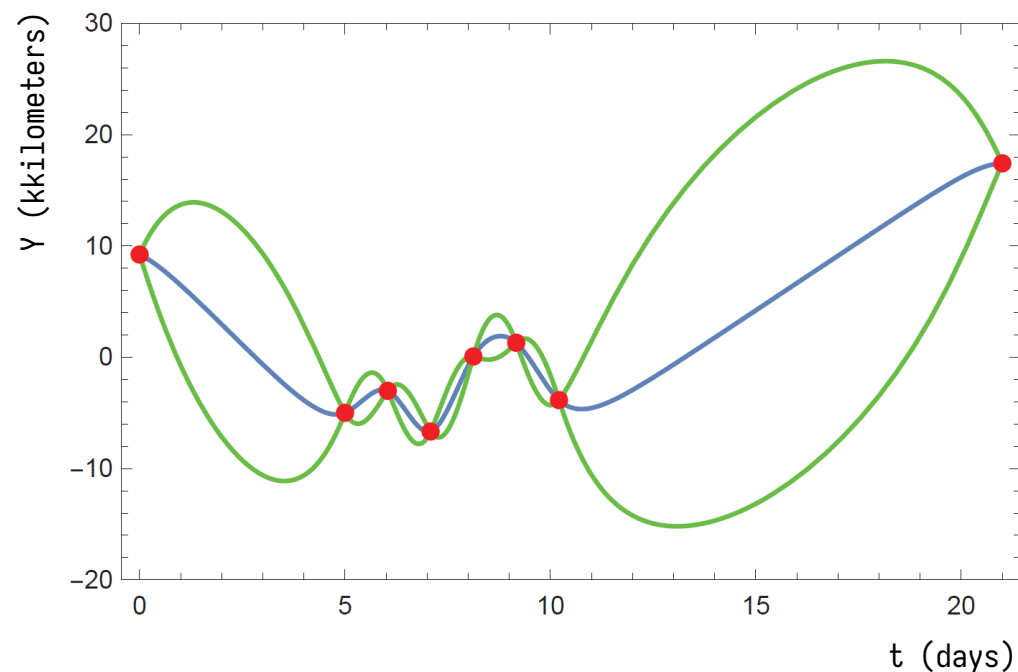


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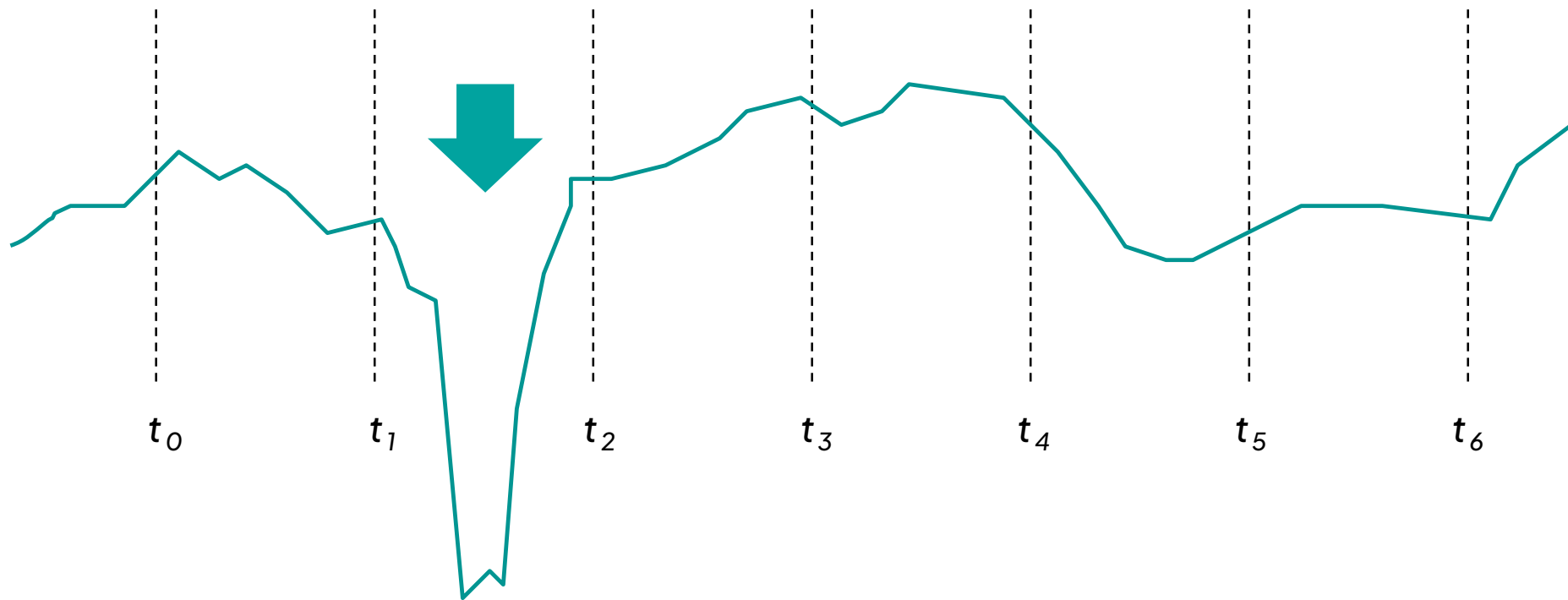
Not only does **Kriging** provide an optimal prediction surface, but it also delivers a measure of confidence of how likely that prediction will be true.

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)

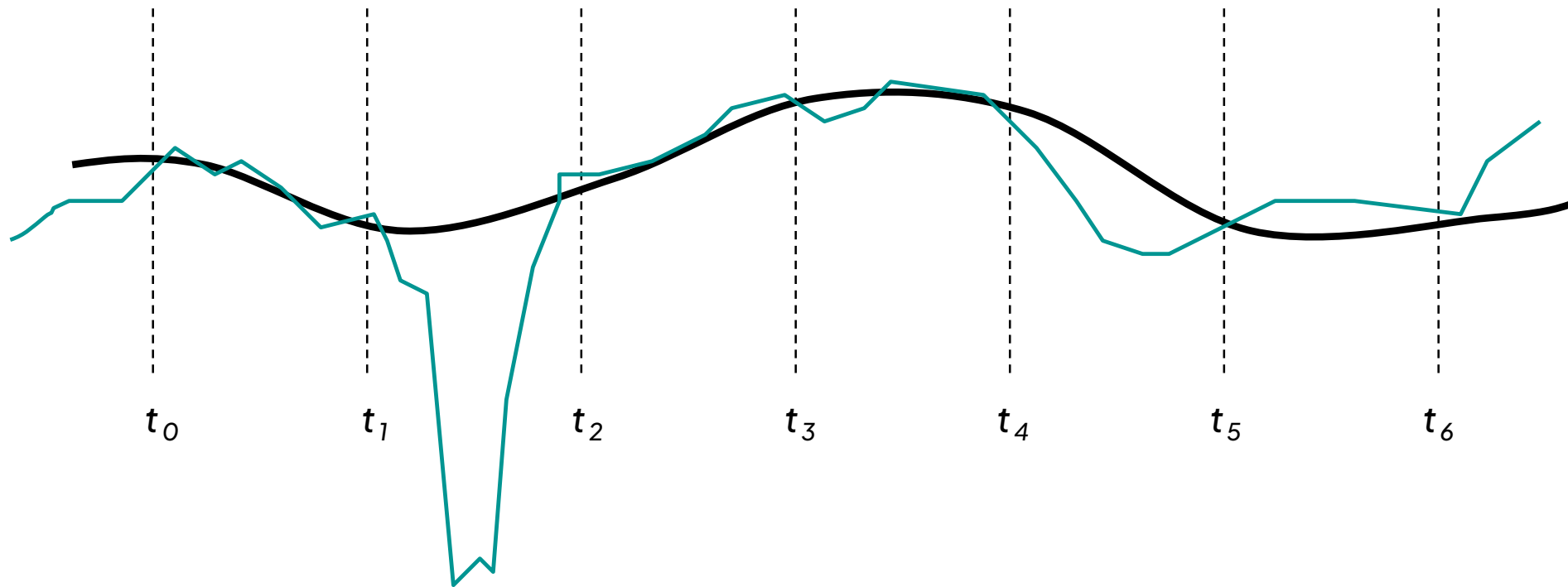
An occurrence region is sampling-dependent.

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



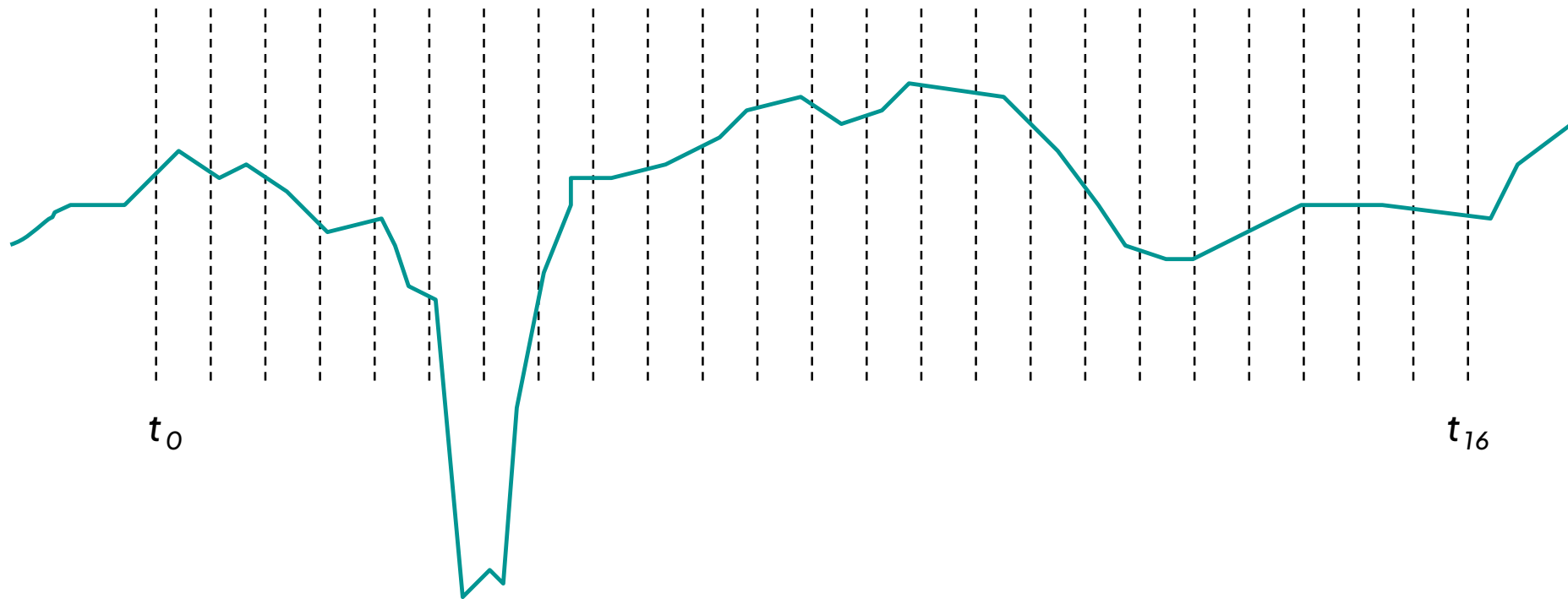
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Our interpolated surface (represented in 1-D by the black line) would look like this.



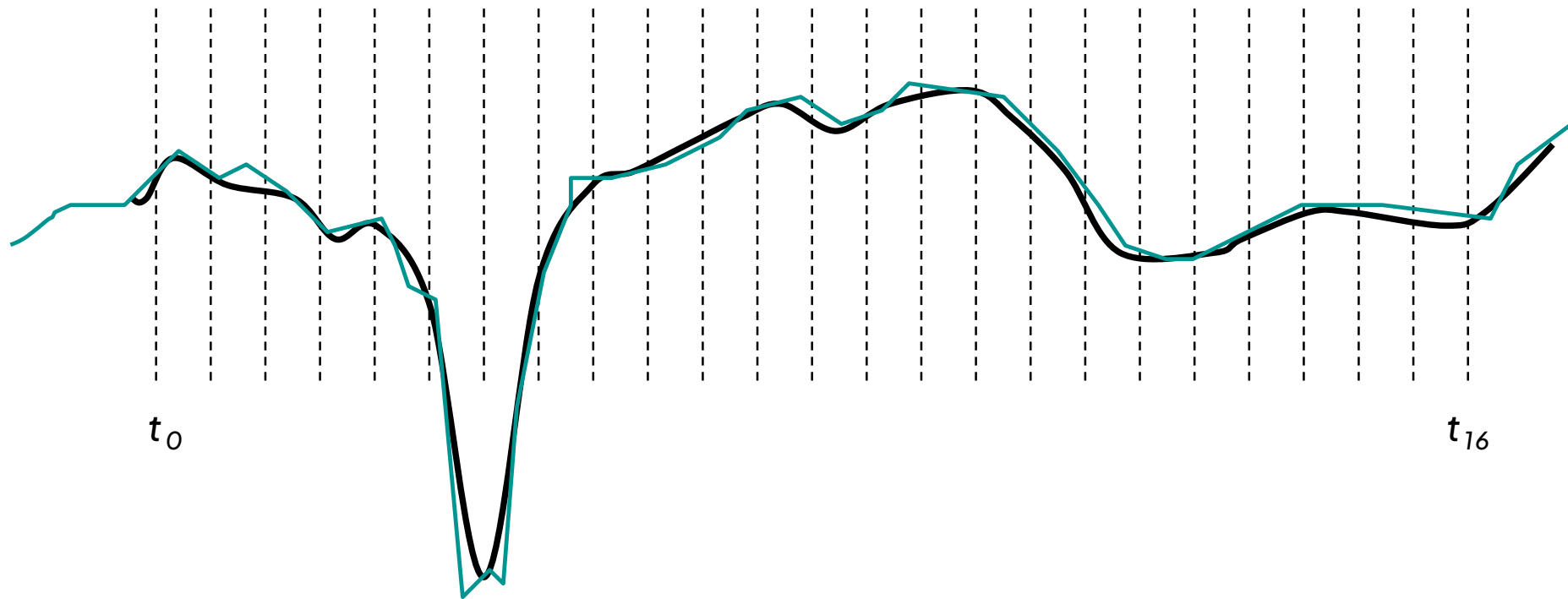
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Only by increasing the sampling frequency, would we pick up that local variation.



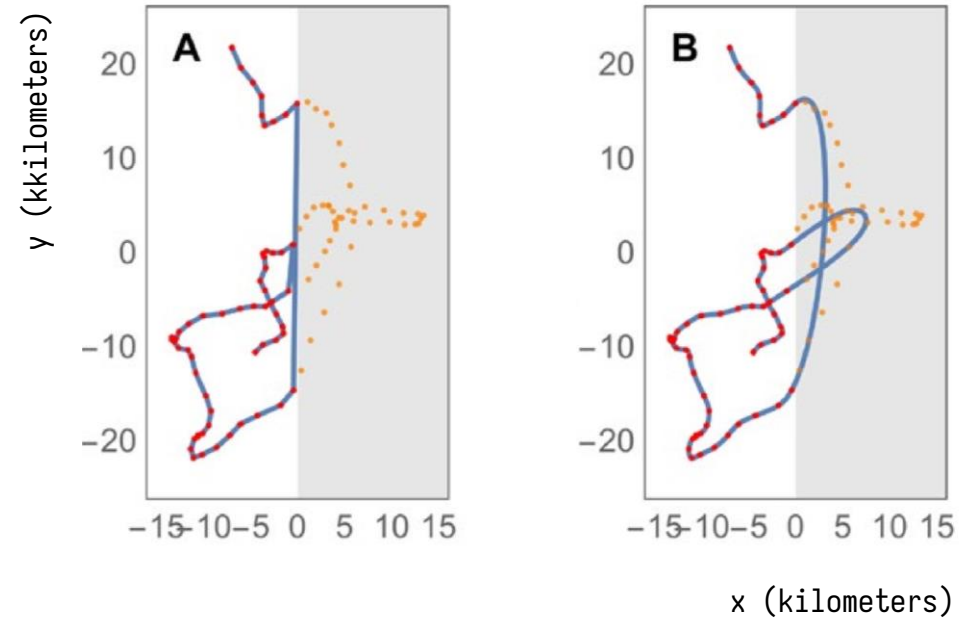
*An occurrence region is **sampling-dependent**.*

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.



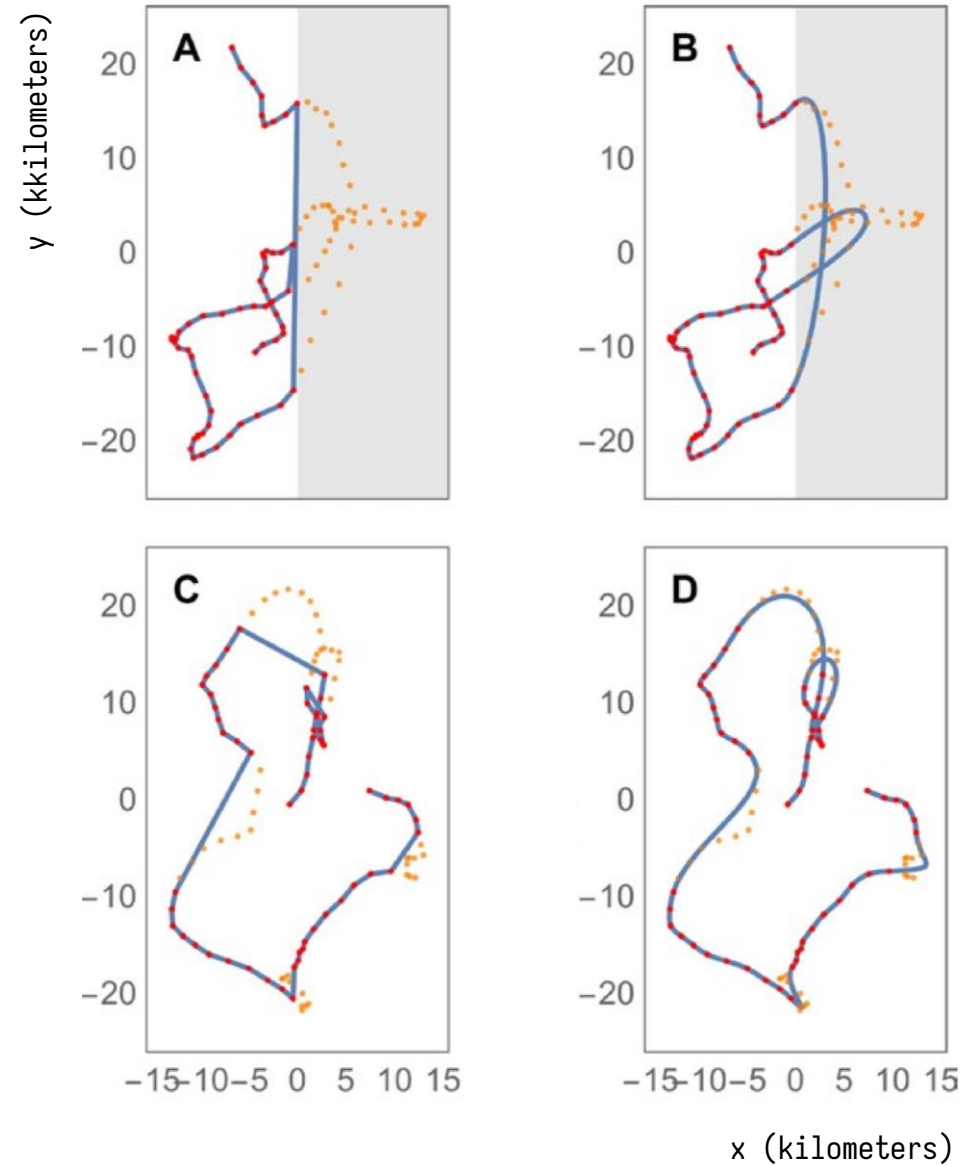
Now that we know how to interpolate, we can:

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



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

