HZDR HELMHOLTZ-ZENTRUM DRESDEN-ROSSENDORF

CASUS CENTER FOR ADVANCED SYSTEMS UNDERSTANDING

MARE-Madeira 2025

Optimizing animal tracking projects

Using the 'movedesign' application

Inês Silva

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Uniwersytet Wrocławski

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Freistaat SACHSEN

What can I do with the data
I’ve already collected?

What are your priorities?

I want to know everything!

- Define research questions
- Identify spatiotemporal scales
- Choose sampling design
- Collect animal tracking data
- Analyze data, mitigate biases
- Assess conclusions

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Cost of devices (& data transfer), challenges during deployment, and technological limitations,

can all constrain study design.

“To consult the statistician after an experiment is finished is often merely to ask him to conduct a postmortem examination. He can perhaps say what the experiment died of.”

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Fine-scale processes:

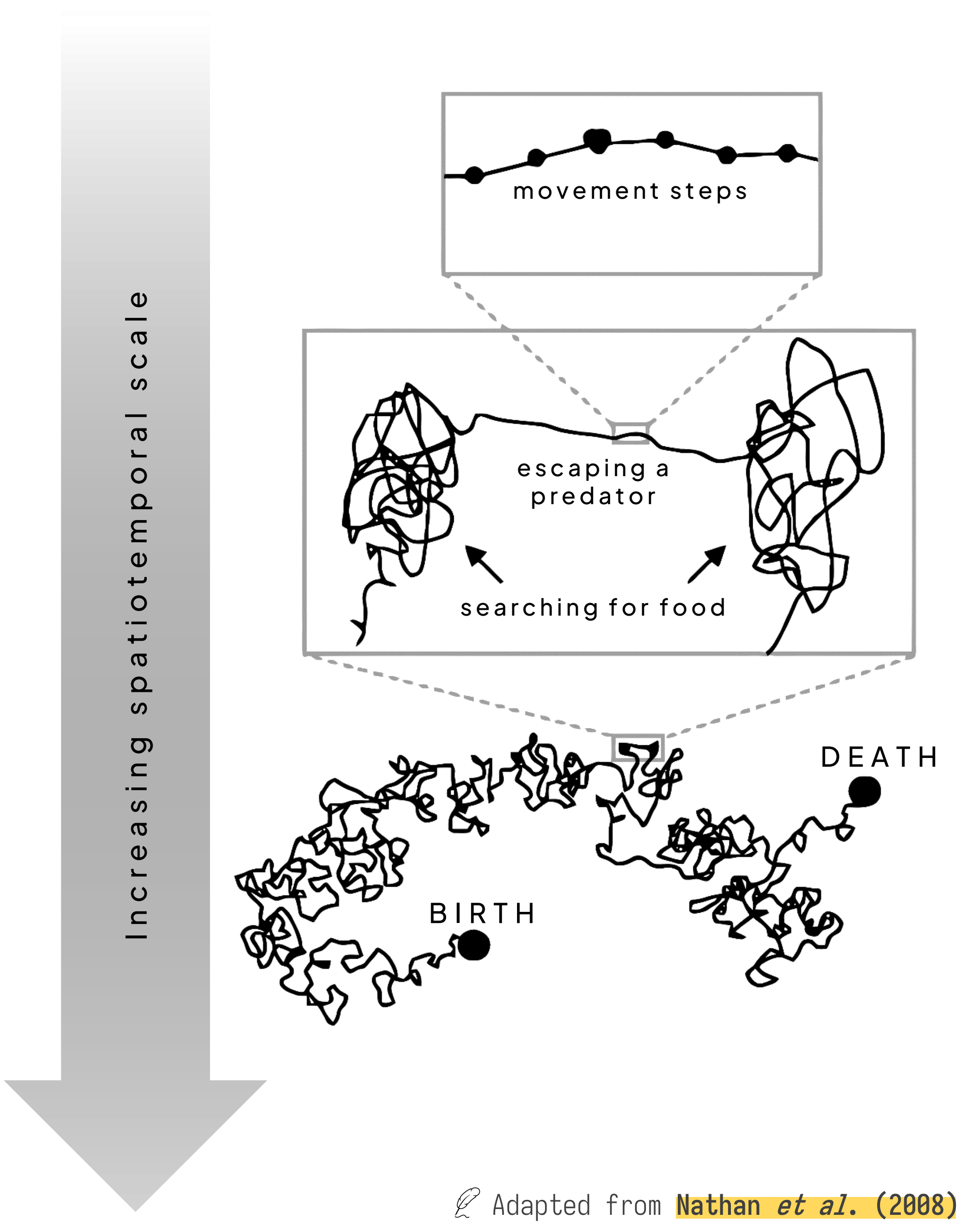
SPEED/DISTANCE — capture how far animals travel (and rate at which these distances are covered).

– To link behavior and energetics,
– As indicators of anthropogenic disturbance.

Large-scale processes:

HOME RANGE — capture the area repeatedly used throughout an animal's **lifetime**.

– For protected area delineation,
– To reduce human-wildlife conflict,
– To control the spread of infectious diseases.



Adapted from **Nathan *et al.* (2008)**

Define research questions

Identify spatiotemporal scales

Choose sampling design

Collect animal tracking data

Analyze data, mitigate biases

Assess conclusions

Battery life

Fix rate

T

SAMPLING DURATION

How long is an animal tracked for?

Δt

SAMPLING FREQUENCY

How frequently are locations collected?

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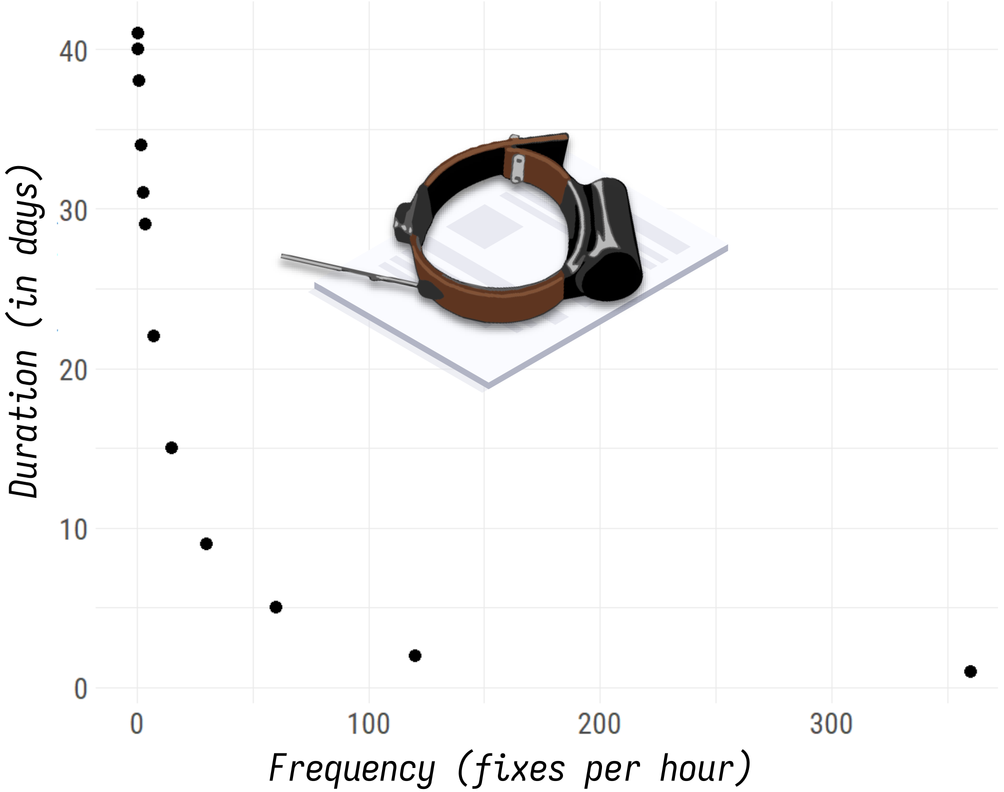
Trade-off between long battery life and high resolution of GPS devices.

Choosing a higher fix rate leads to lower battery life.



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1.

Animal movement paths are realizations of continuous stochastic processes,

2.

Summarize behavior using characteristic timescales,

τ_p

Position autocorrelation timescale

τ_v

Velocity autocorrelation timescale

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Velocity autocorrelation timescale

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These timescales impose constraints on sampling design that *must* be met for sufficiently large (*effective*) sample sizes.

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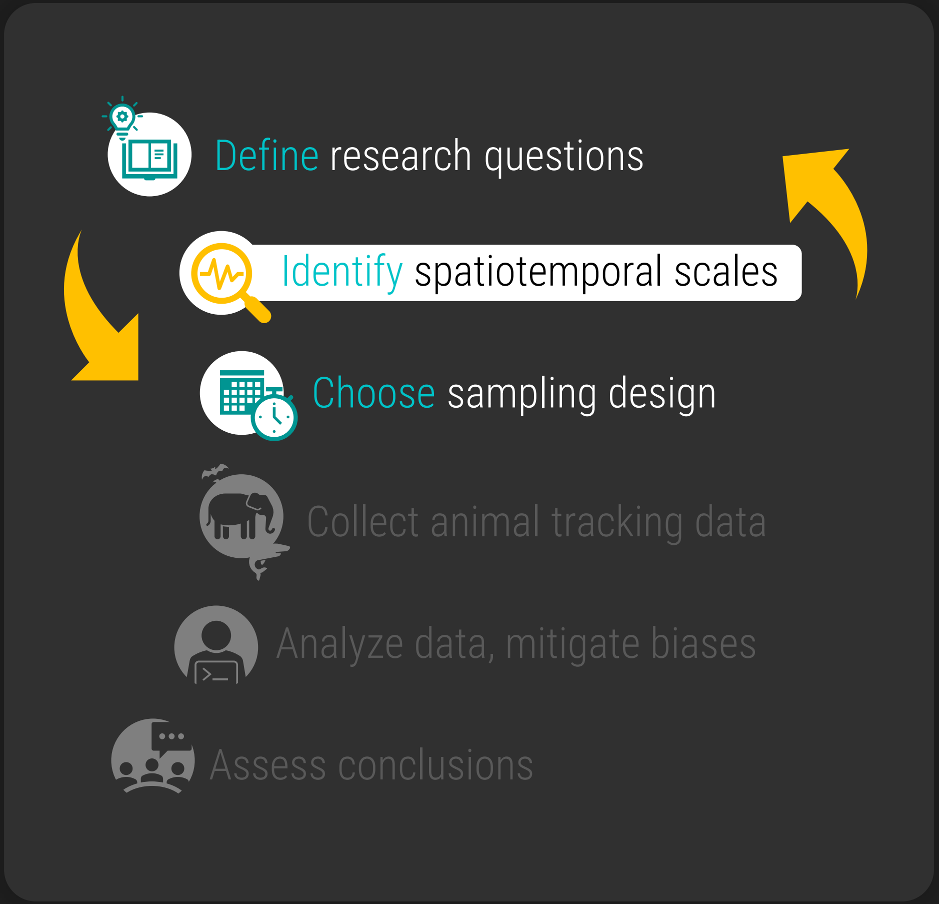

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Animal movement paths are realizations of continuous stochastic processes,

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Summarize behavior using characteristic timescales,

τ_p — *Position autocorrelation timescale*

τ_v — *Velocity autocorrelation timescale*

3.

These timescales impose constraints on sampling design that *must* be met for sufficiently large (*effective*) sample sizes.

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'movedesign'
Silva *et al.* (2023)

Objectives:
Develop a systematic approach, akin to statistical power analysis, to determine optimal sampling parameters in animal tracking projects.

Analytical targets:
We considered three common estimates —home range area, speed and distance traveled.

Like any statistical tool, these methods still require sufficiently large ***effective sample sizes*** to achieve high accuracy.

A successful animal tracking project requires a sampling schedule that leads to sufficiently ***large (effective) sample sizes***.

Sample sizes

Absolute sample size
Total number of locations

n

T + Δt

Sampling **duration**

How long is an animal tracked for?

Sampling **frequency**

How frequently are locations collected?

$\neq$

Effective sample size

N_{area}

number of ***statistically independent locations***

N_{speed}

number of ***statistically independent velocities***

For autocorrelated data, $N < n$, and often $N \ll n$

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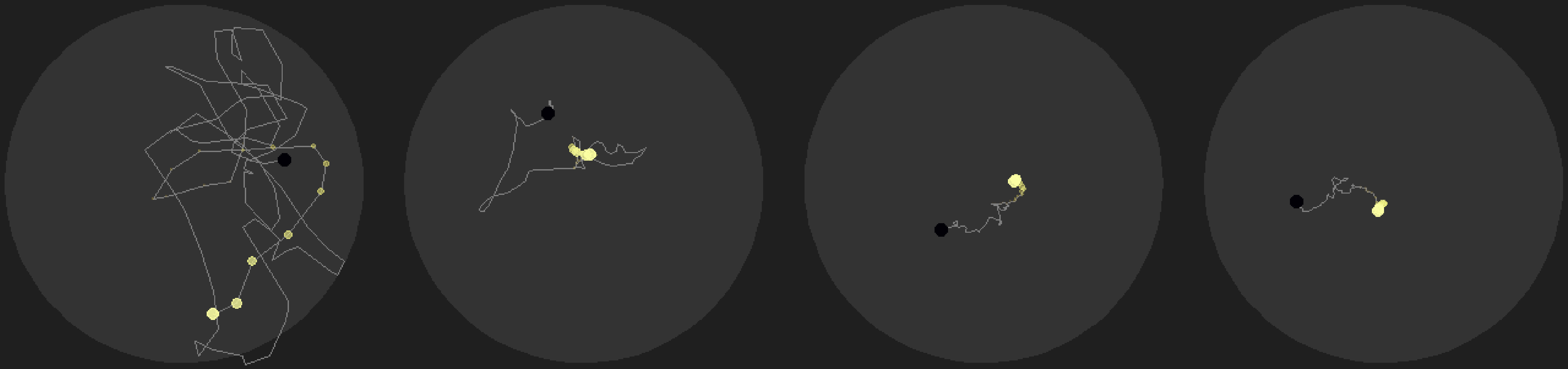
Understanding sample sizes

τ_p

Position autocorrelation timescale

τ_p = 1 hour | τ_p = 1 day | τ_p = 5 days | τ_p = 10 days



T

SPACE-USE

☑ HOME RANGE

SAMPLING DURATION

How long is an animal tracked for?

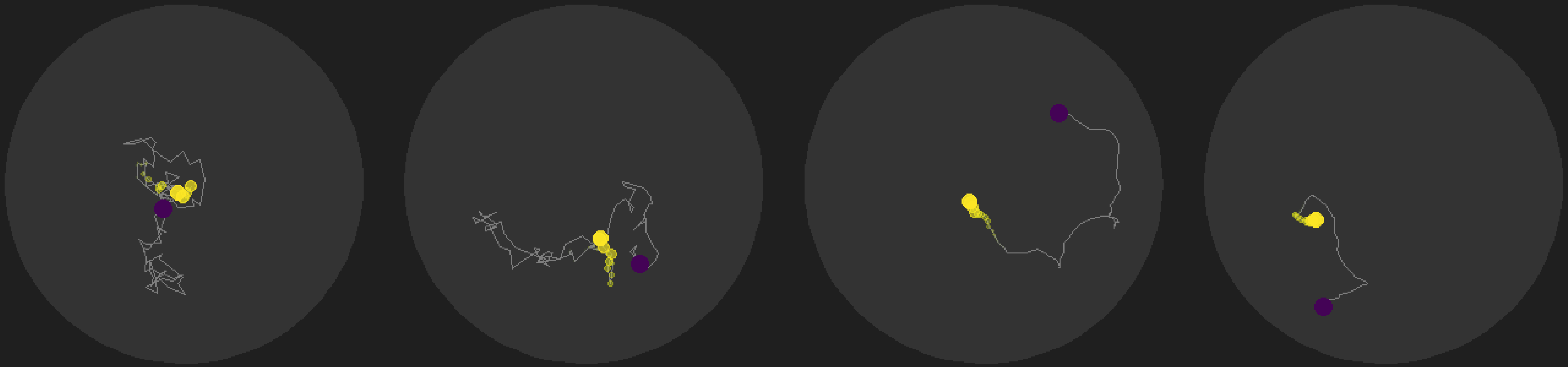
MOVEMENT BEHAVIOR

☐ SPEED & DISTANCE

τ_v

Velocity autocorrelation timescale

τ_v = 1 minute τ_v = 1 hour τ_v = 12 hours τ_v = 1 day



Δt

SPACE-USE
☐ HOME RANGE

SAMPLING FREQUENCY → MOVEMENT BEHAVIOR

How frequently are locations collected?

☑ SPEED & DISTANCE

- Define research questions
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It is not physically possible for animal movement to be uncorrelated. Now, the questions are:

1. Can you detect a signature of these correlations in your data?

2. And is this data sufficient to answer specific research questions?

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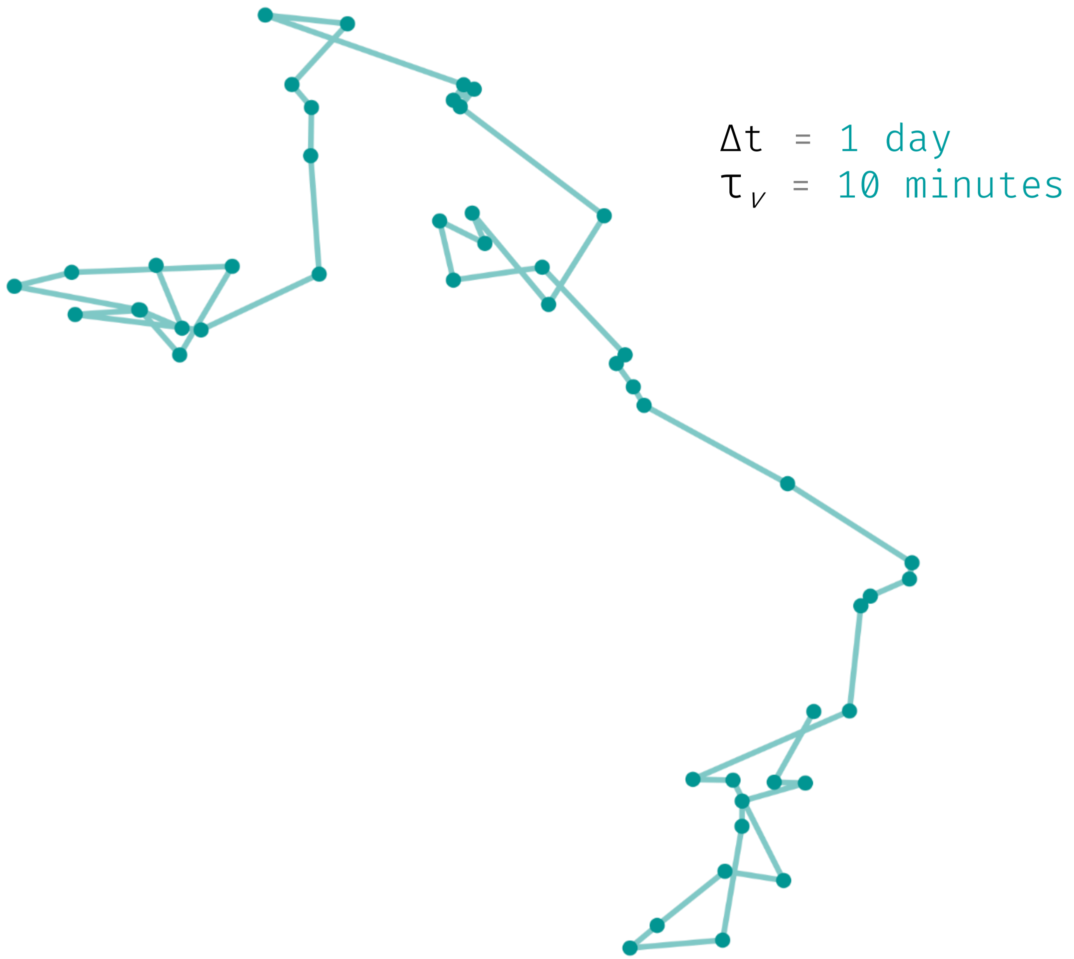
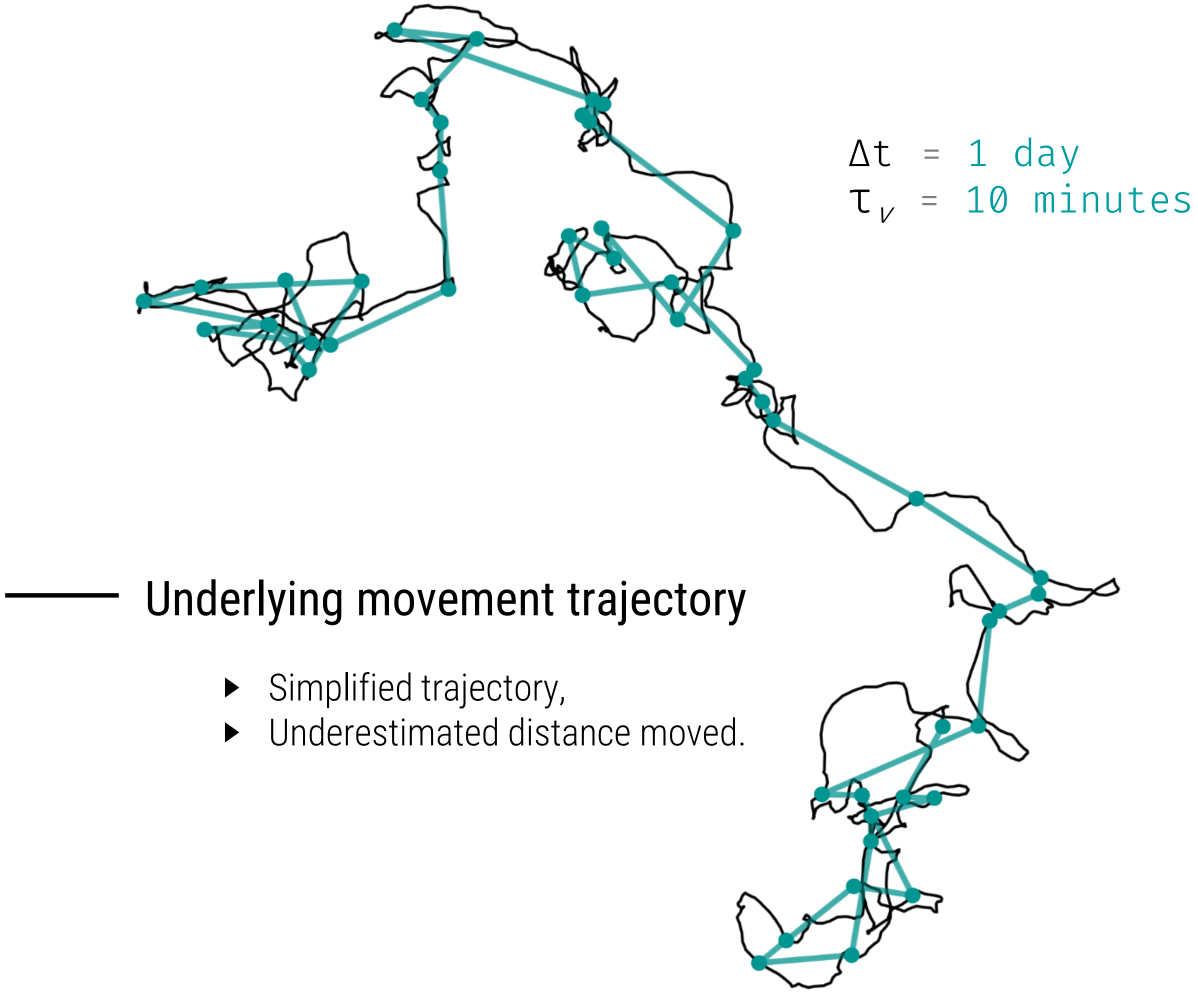
Simulated tracking dataset with a new location once per day, $\tau_v > \Delta t$.



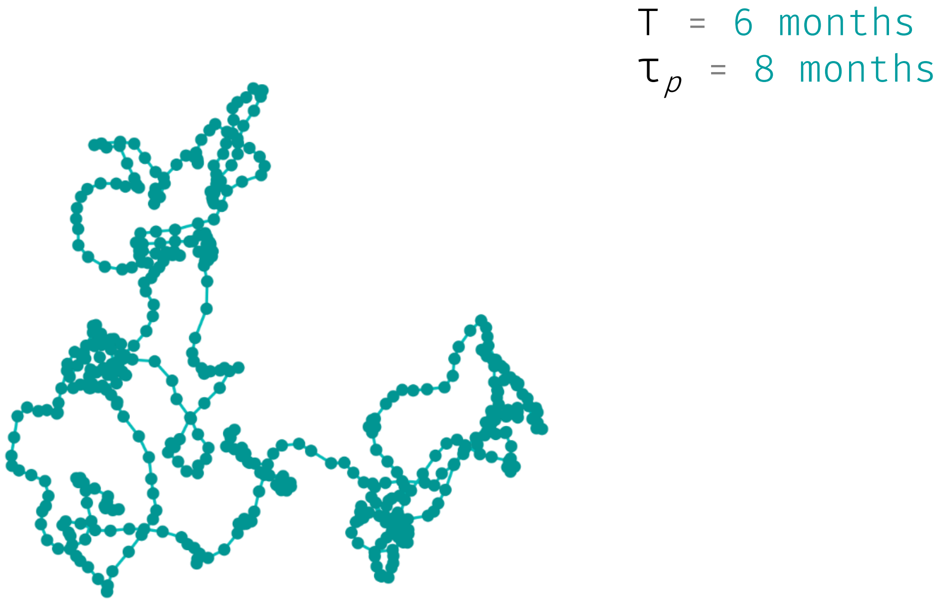
Simulated tracking dataset with a new location once per day, $\tau_v > \Delta t$.

We must carefully consider the frequency of data collection!

For the same Δt, this bias will be greater for individuals with more tortuous movement (shorter τ_v).



Simulated tracking dataset with a duration of 6 months, $\tau_p > T$.



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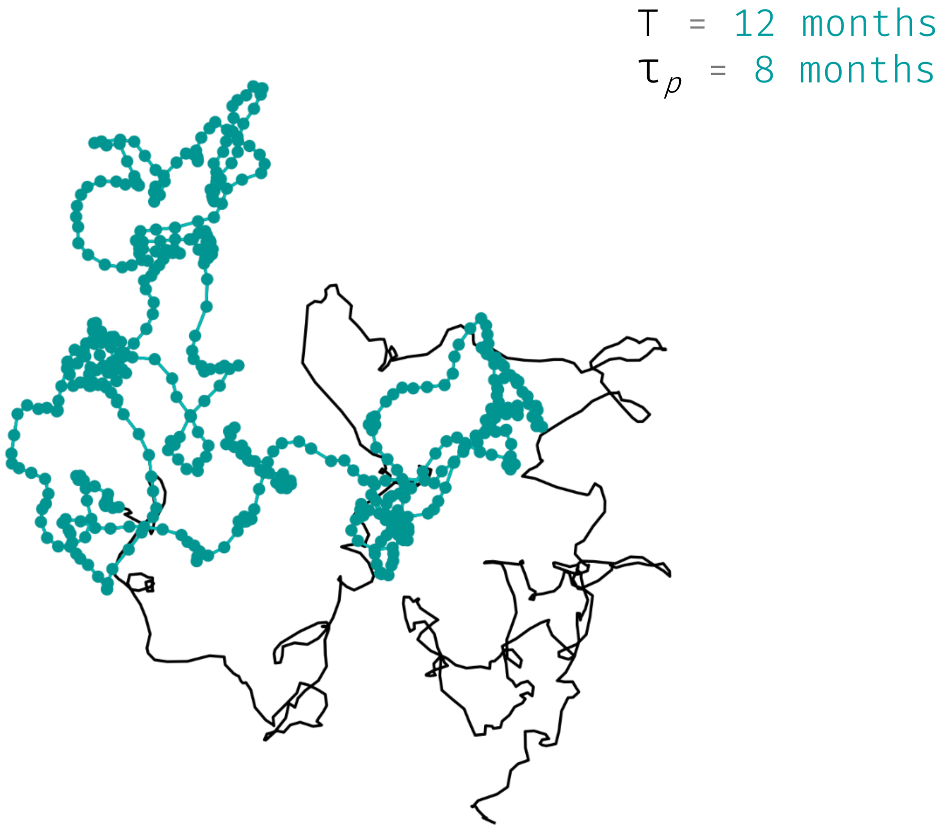
Simulated tracking dataset with a duration of 6 months, τ_p > T.

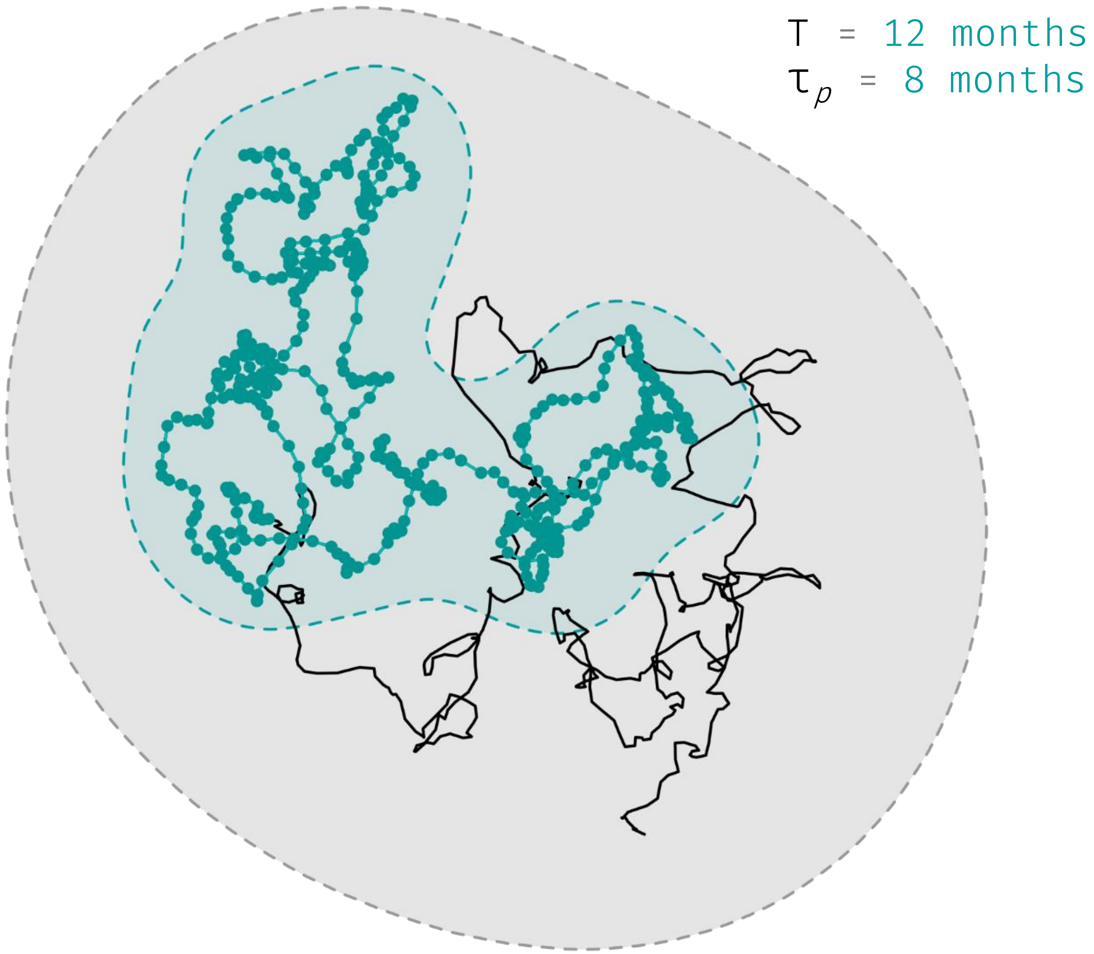


Movement trajectory for the following **6 months**.

Simulated tracking dataset with a duration of 6 months, τ_p > T.

We must carefully consider the duration of data collection!

For the same T, the extent of this bias will be greater for individuals with longer crossing times (τ_p).

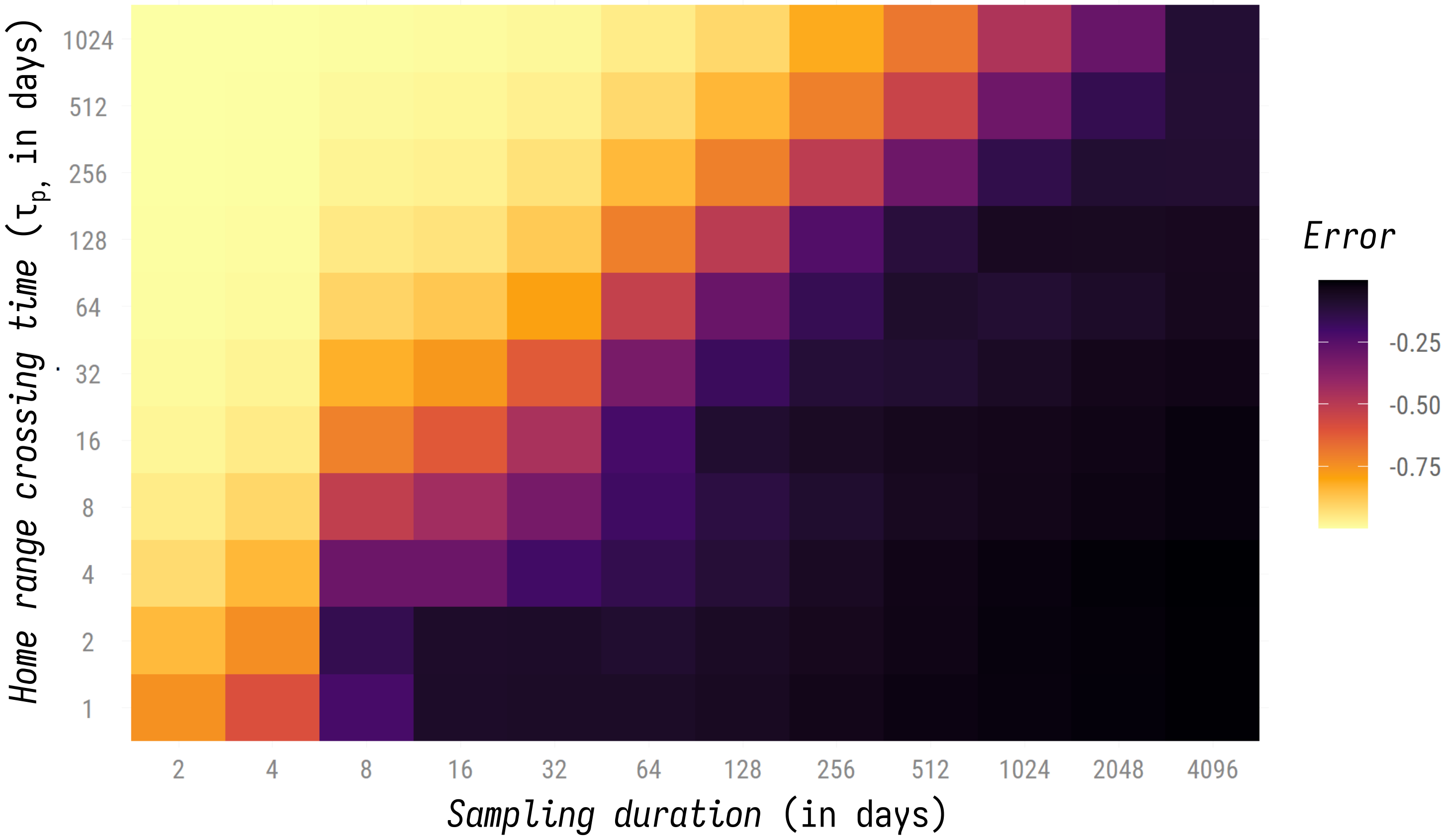


Movement trajectory for the following **6 months**.

- Sampling missed used areas.
- Underestimated home range.

1. Home ranges — **Autocorrelated** Kernel Density Estimator **(AKDE)**:

Fleming *et al.* (2015)



1. Home ranges — **Autocorrelated** Kernel Density Estimator **(AKDE)**:

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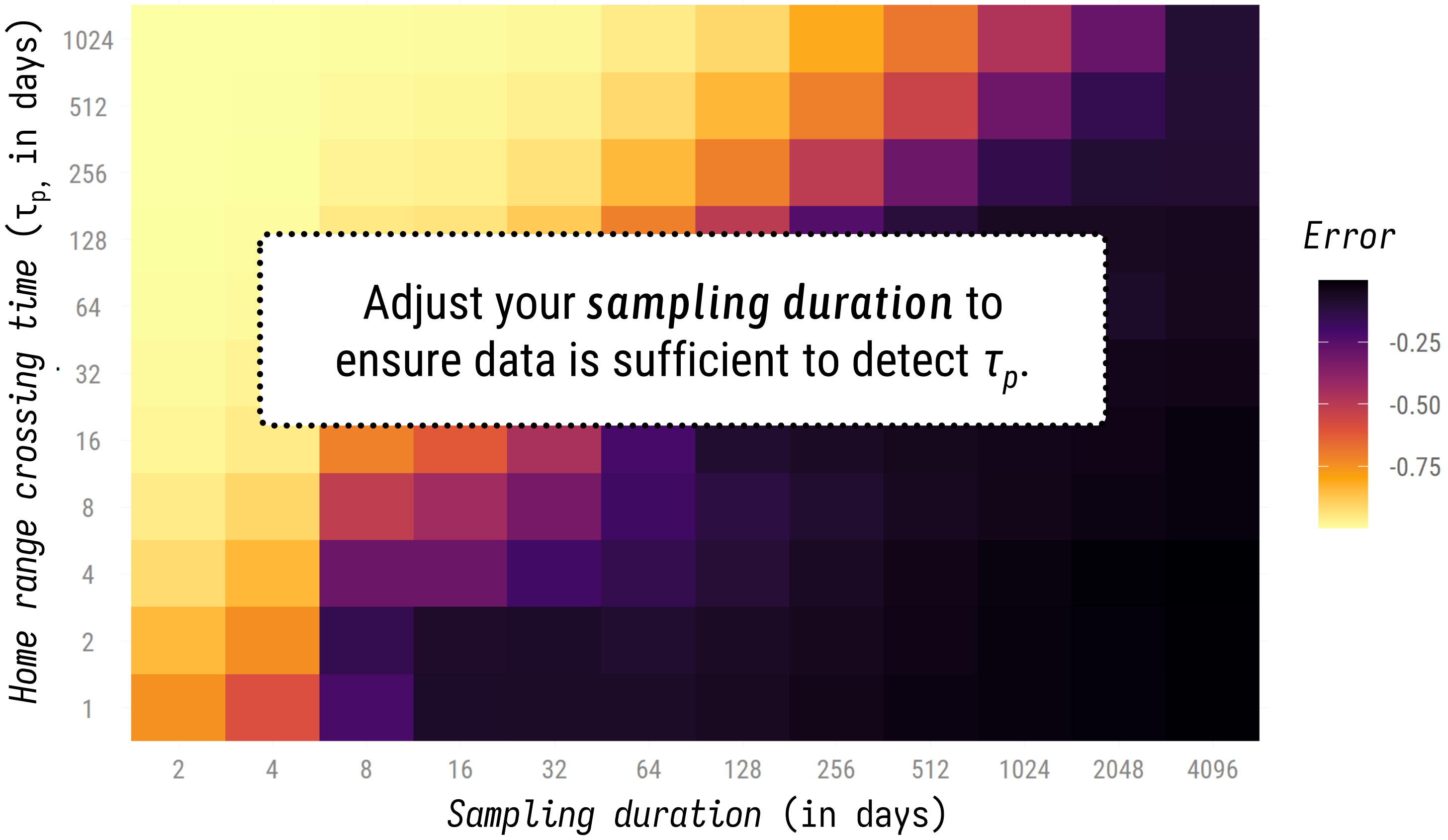
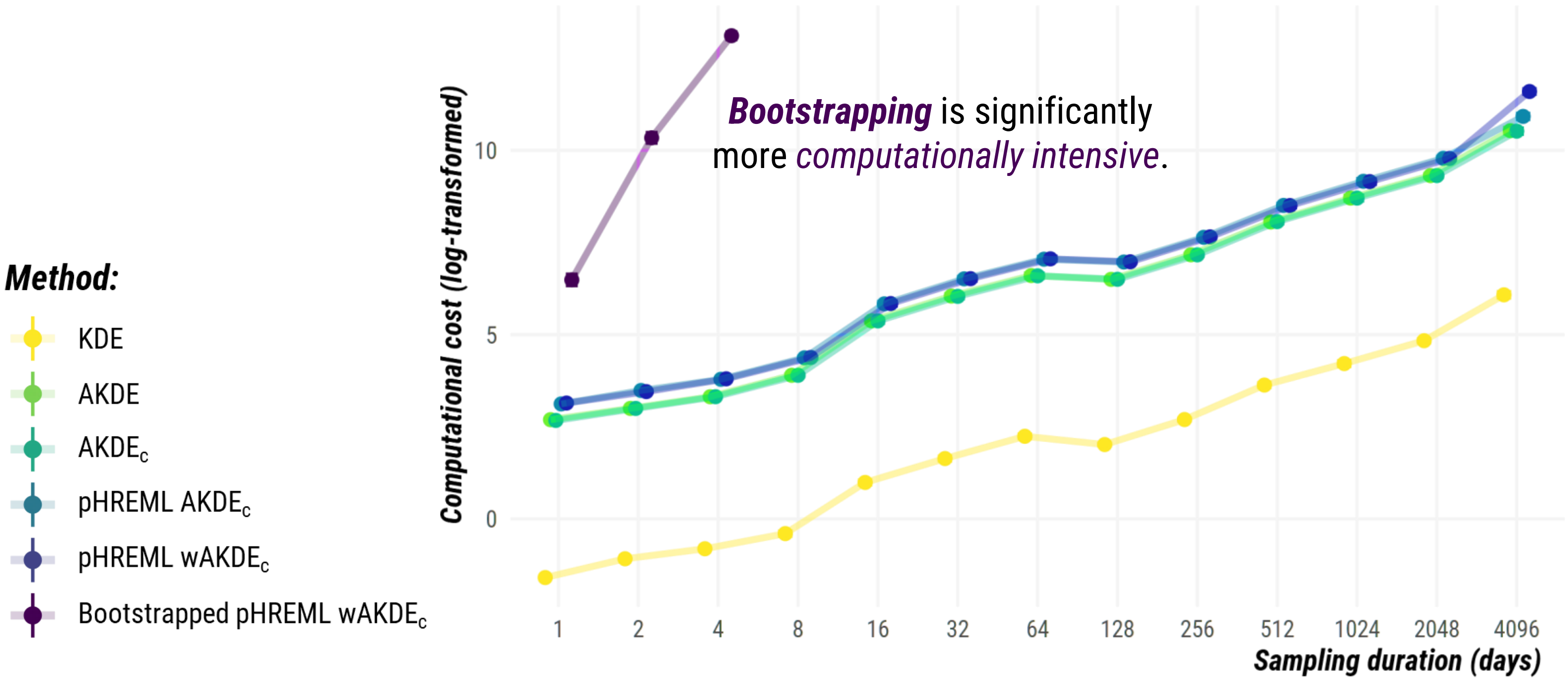


1. Home ranges — Autocorrelated Kernel Density Estimator (AKDE):

Fleming *et al.* (2015)

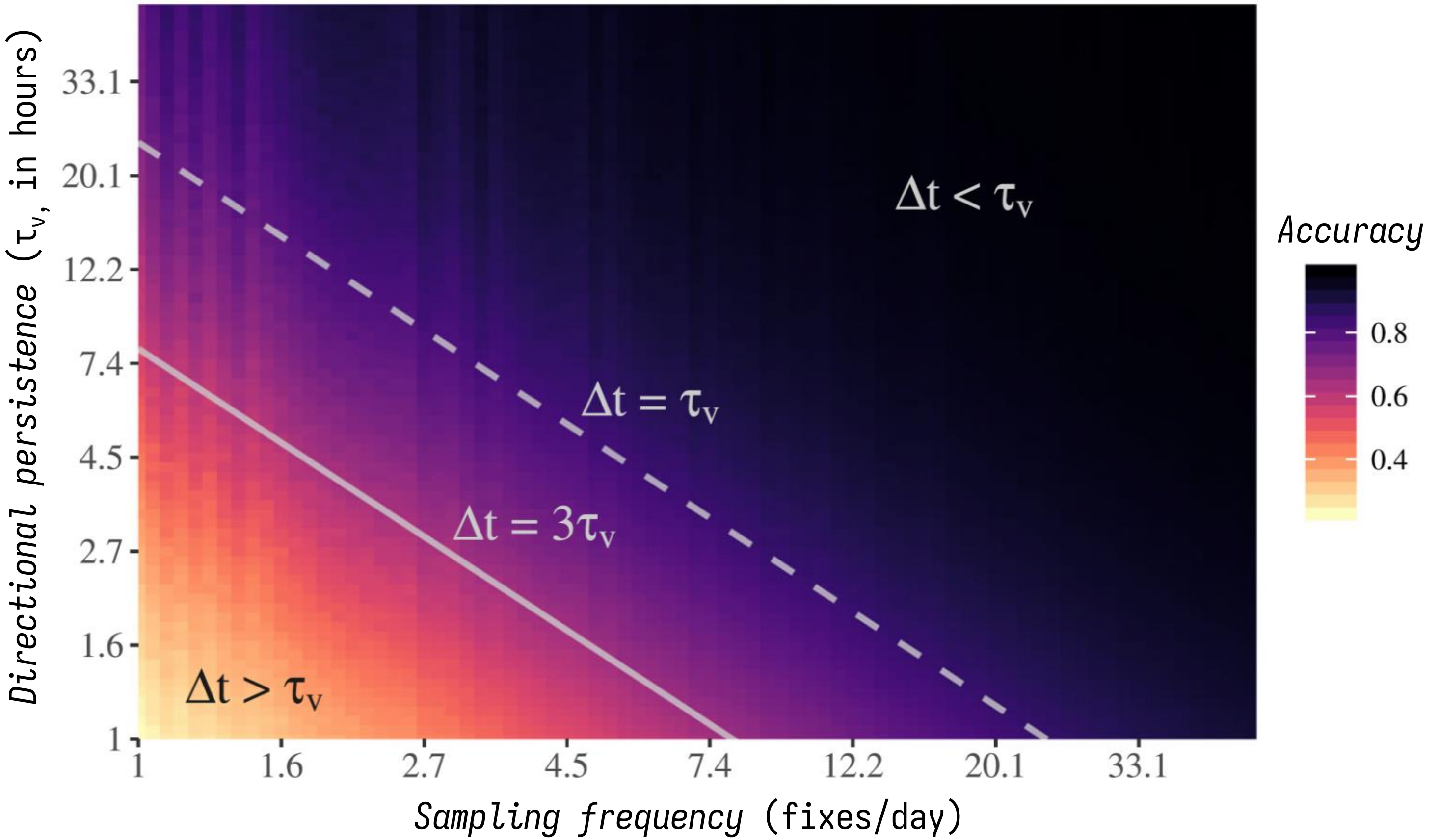
Given a relative target bias of ≈5%,

Minimum N_{area} for **ML** is ≈ 20;
Minimum N_{area} for **pHREML** is ≈ 4.5;
Minimum N_{area} for **bootstrapped pHREML** is ≈ 2.7.



2. Speed & distance — **Continuous-time speed and distance (CTSD)**:

Noonan *et al.* (2019)

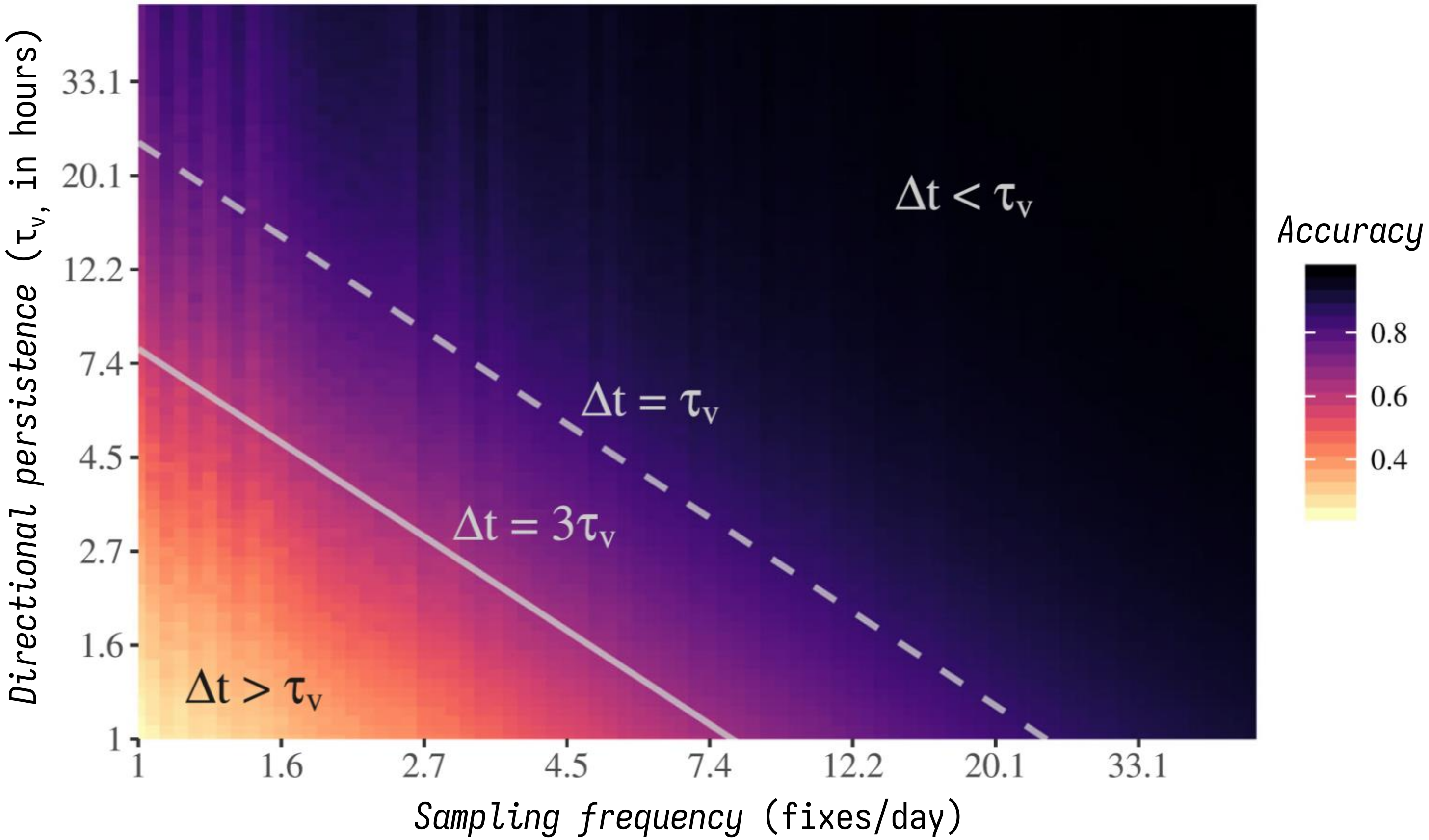


If $\Delta t > 3\tau_v$, no statistically significant signature of the animal's velocity will remain in the location data.

If $3\tau_v > \Delta t > \tau_v$, there will be some positive bias (τ_v can not be accurately estimated).

2. Speed & distance — **Continuous-time speed and distance (CTSD)**:

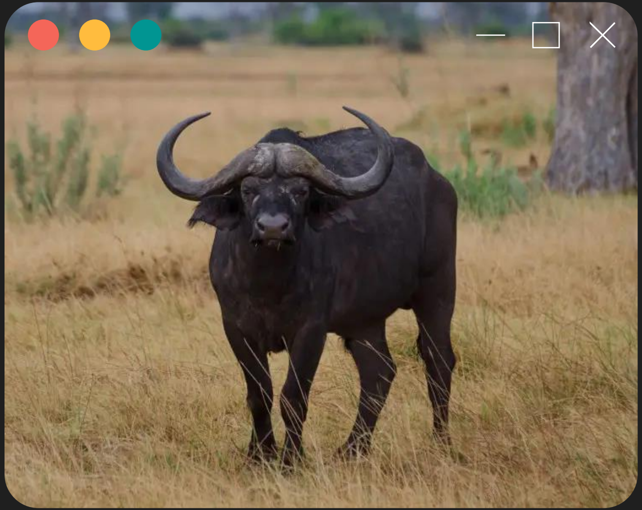
Noonan *et al.* (2019)



Adjust your ***sampling interval*** to ensure data is of ***sufficient resolution*** to detect τ_v.

$$\Delta t \leq 3\tau_v$$

African buffalo
(Syncerus caffer)



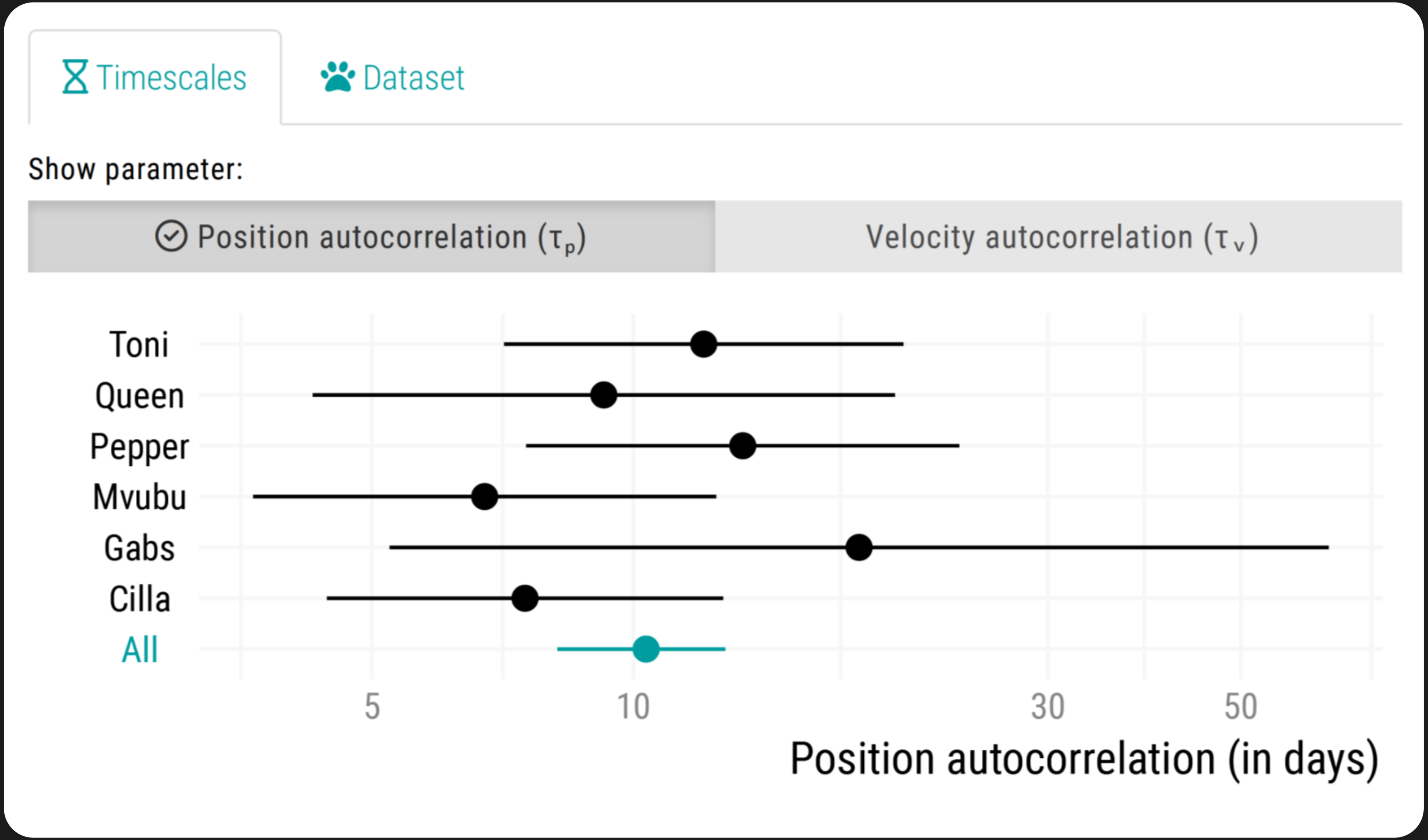
Position autocorrelation

10.3 days

8.2 – 12.8

(τ_p)

These parameters are fairly **conservative** at the species- and population-level.



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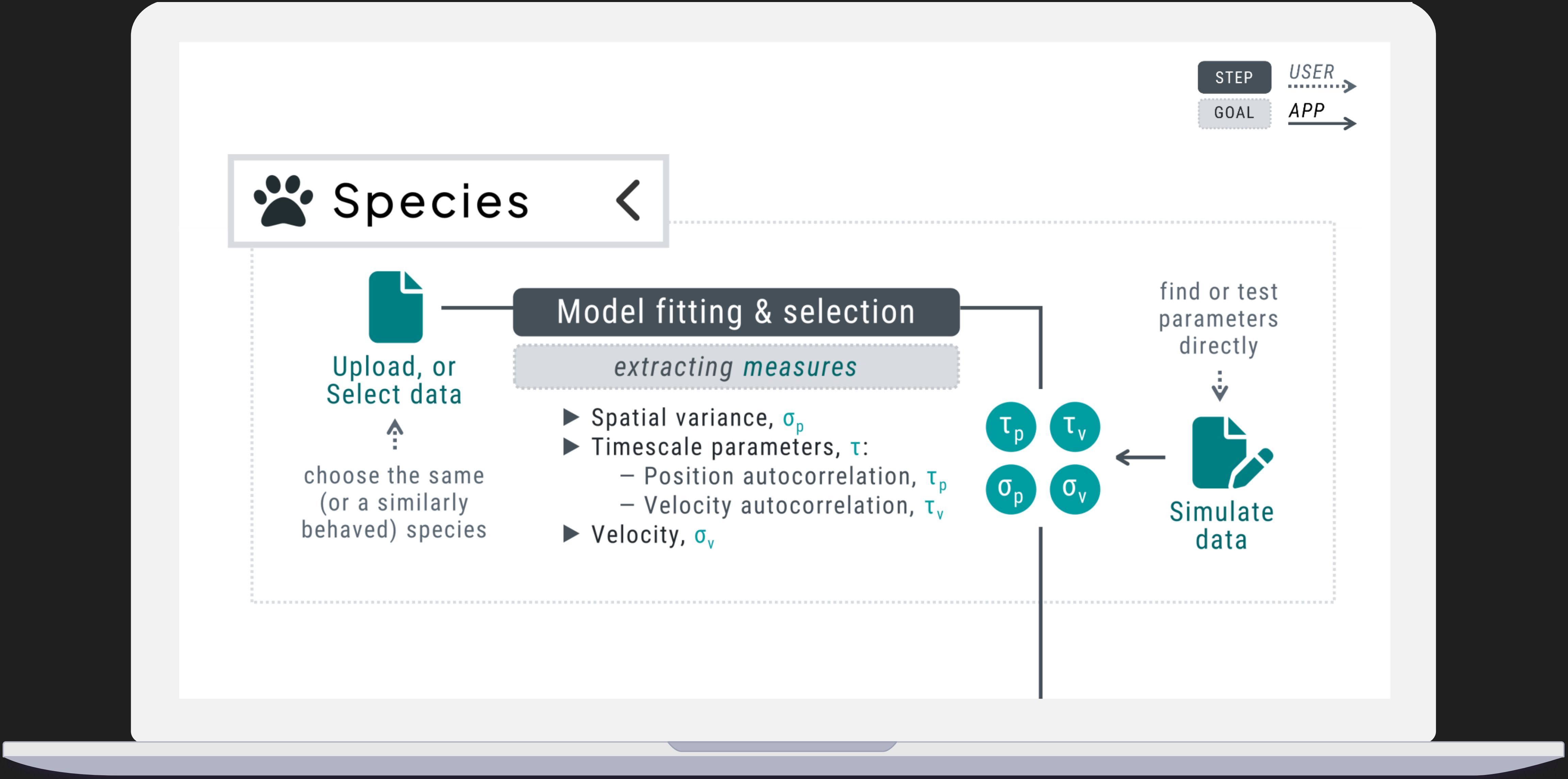

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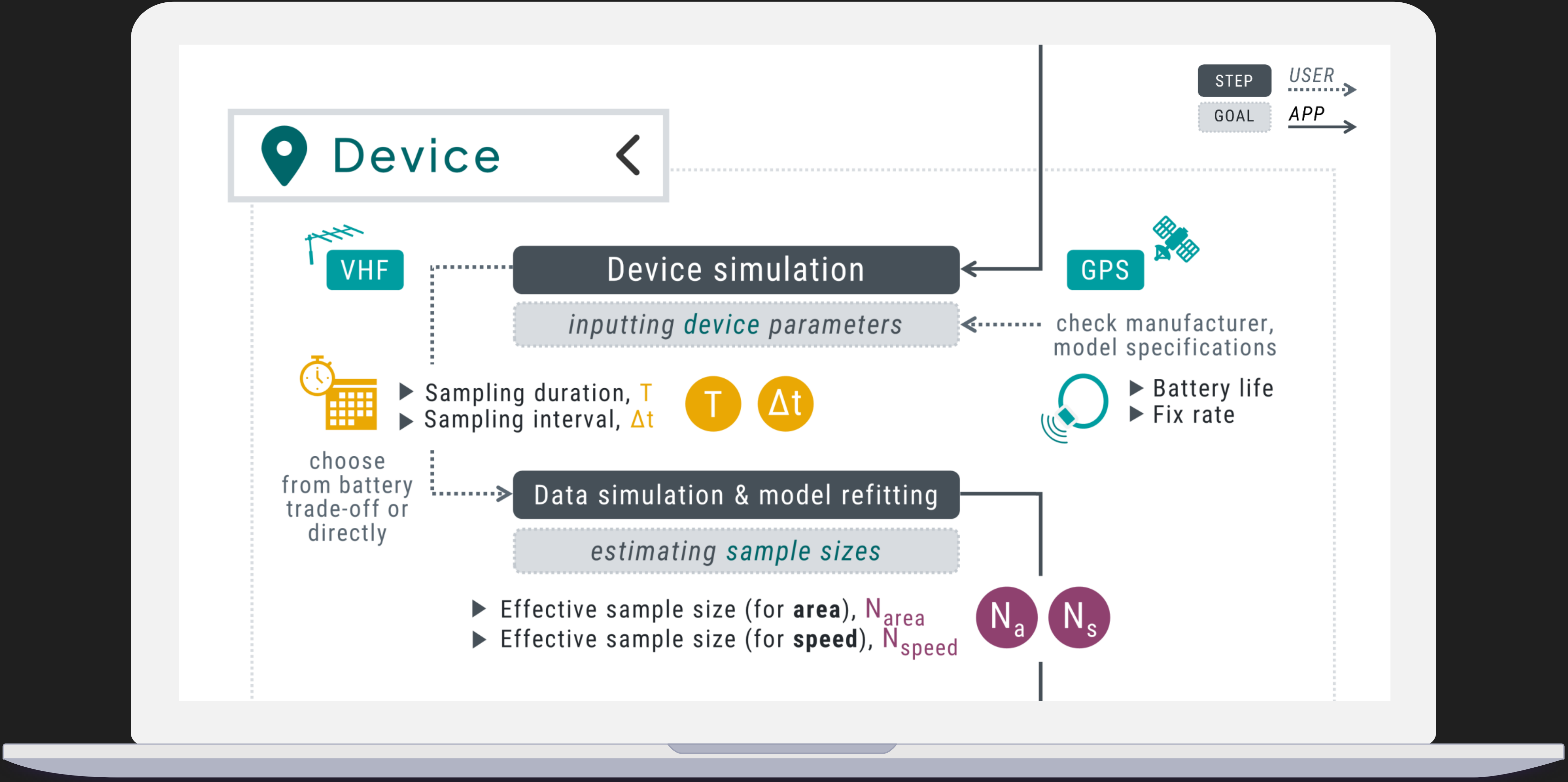

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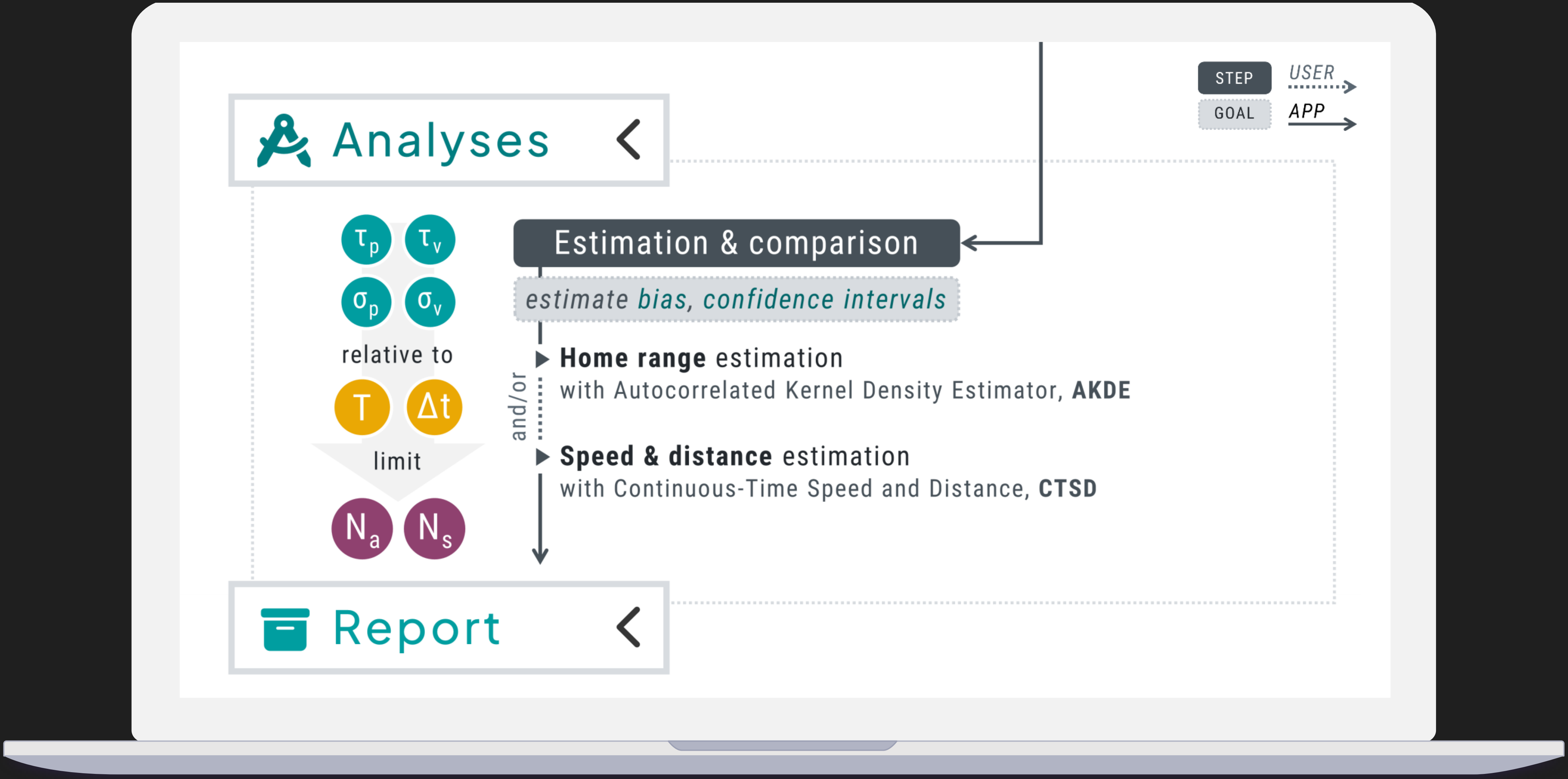

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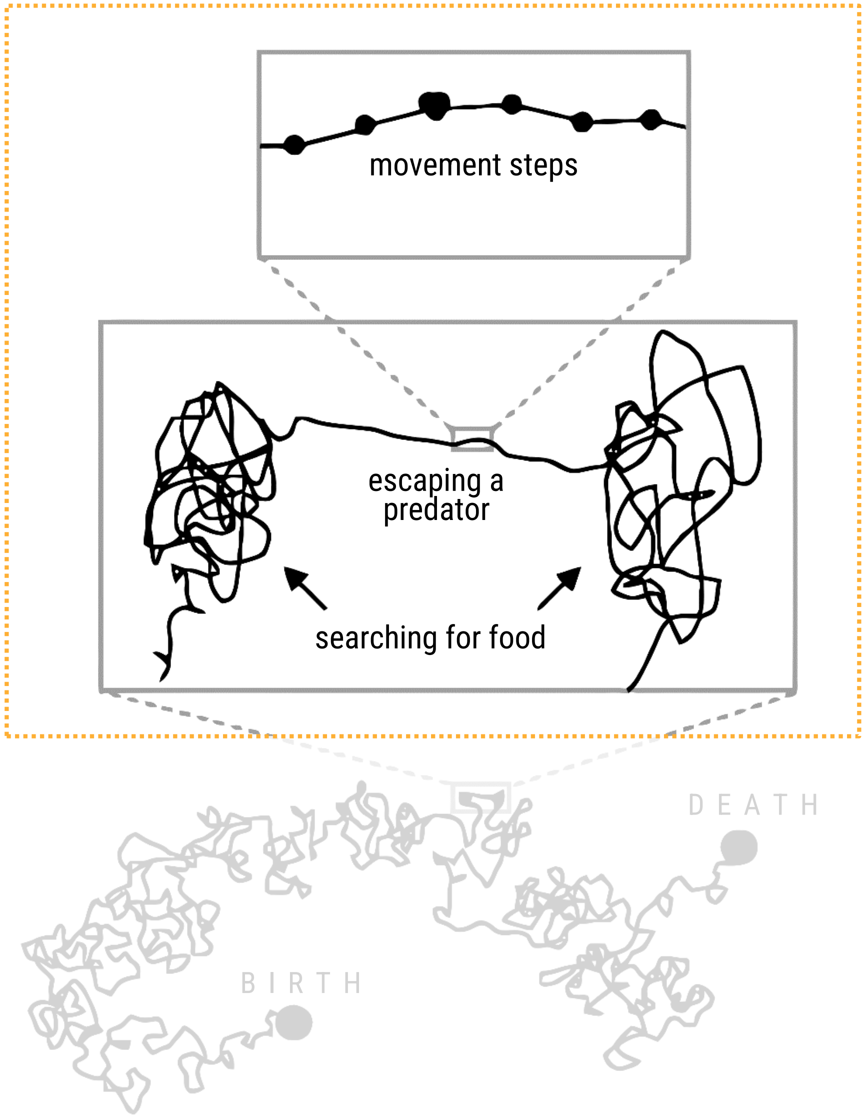
Nathan *et al.* (2008)



If the goal is speed & distance estimation, adjust your ***sampling interval*** (Δt) to ensure data is of sufficient resolution to detect τ_v.

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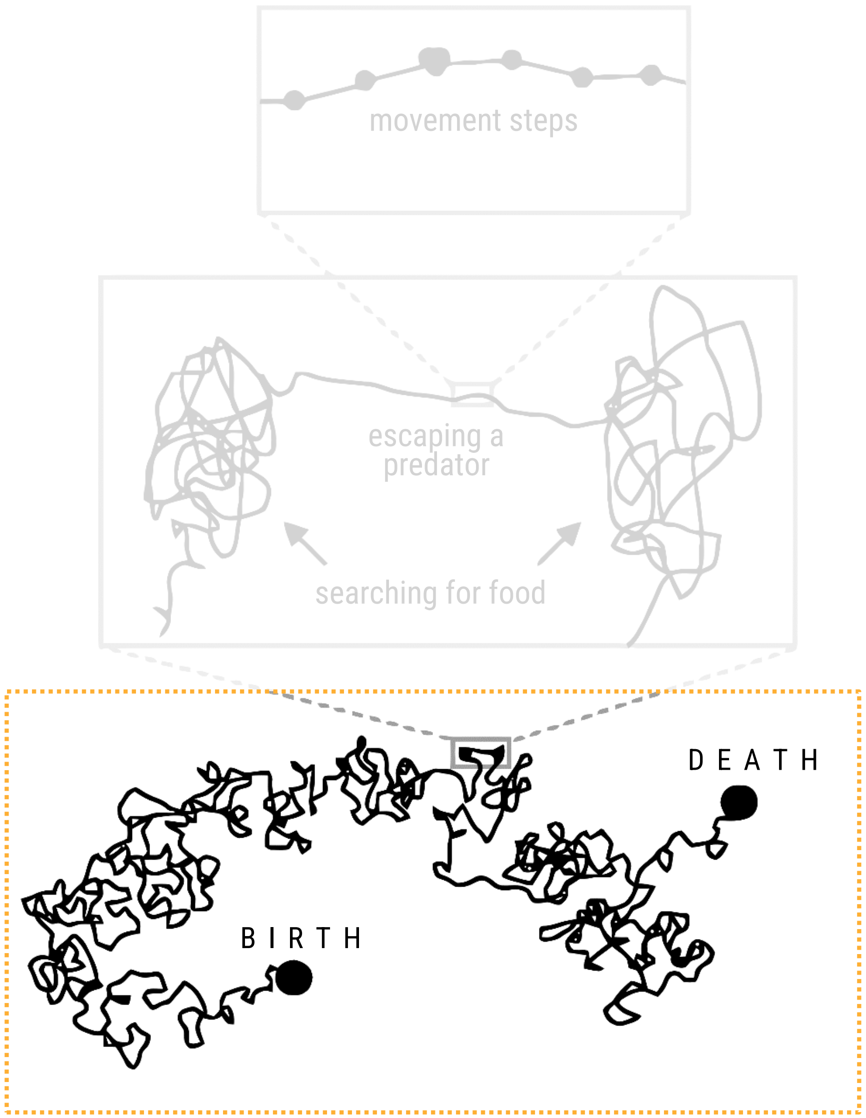
Nathan *et al.* (2008)



*If the goal is **speed & distance estimation**,* adjust your ***sampling interval*** (Δt) to ensure data is of sufficient resolution to detect τ_v.

*If the goal is **home range area estimation**,* adjust your ***sampling duration*** (T) to ensure data is sufficient to detect τ_p.

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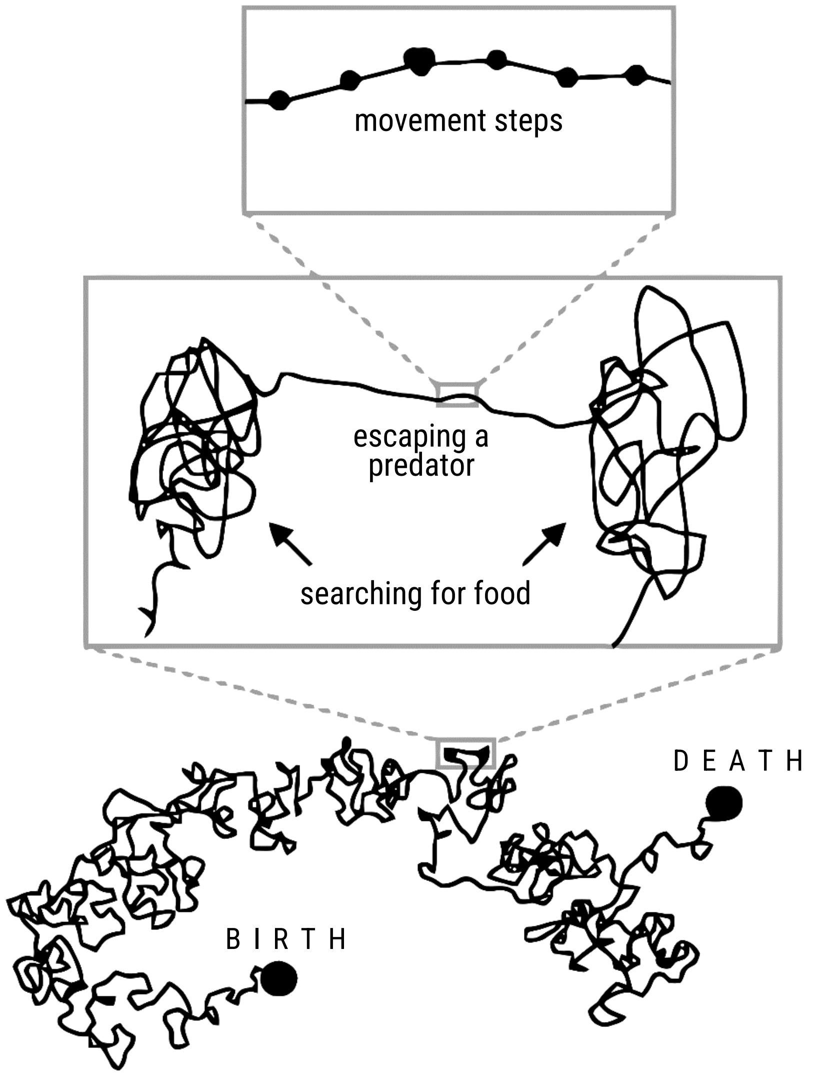
Nathan *et al.* (2008)



If the goal is speed & distance estimation,
adjust your ***sampling interval*** (Δt) to ensure data is of sufficient resolution to detect τ_v.

If the goal is home range area estimation,
adjust your ***sampling duration*** (T) to ensure data is sufficient to detect τ_p.

If both,
You may be able to address large-scale and fine-scale questions, but not always ***concurrently***.

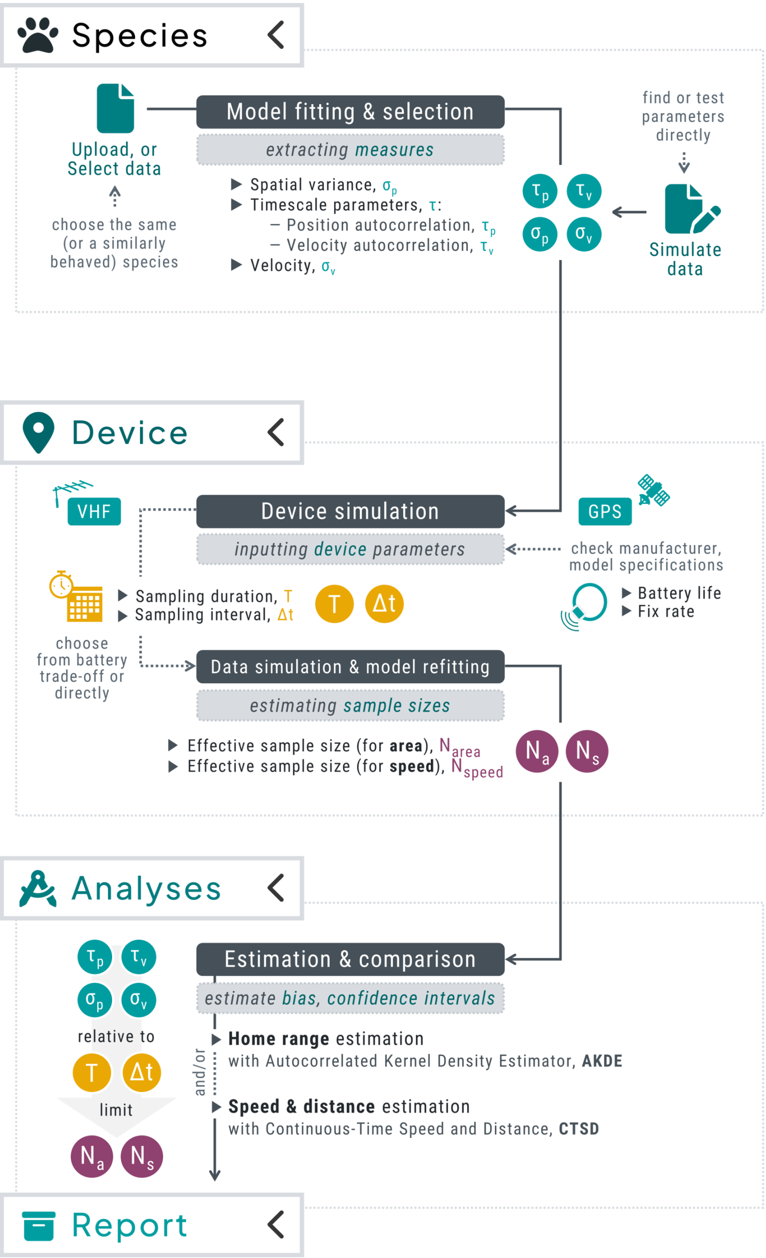
movedesign

New version (v0.3.0):

- Run multiple simulations for:
  - a predefined (*population*) sample size,
  - an iteratively higher sample size,

  until error is below a specified threshold.

- Get estimates for:
  - mean of sampled population,
  - compare means of two sampled populations. (*e.g.*, males/females)



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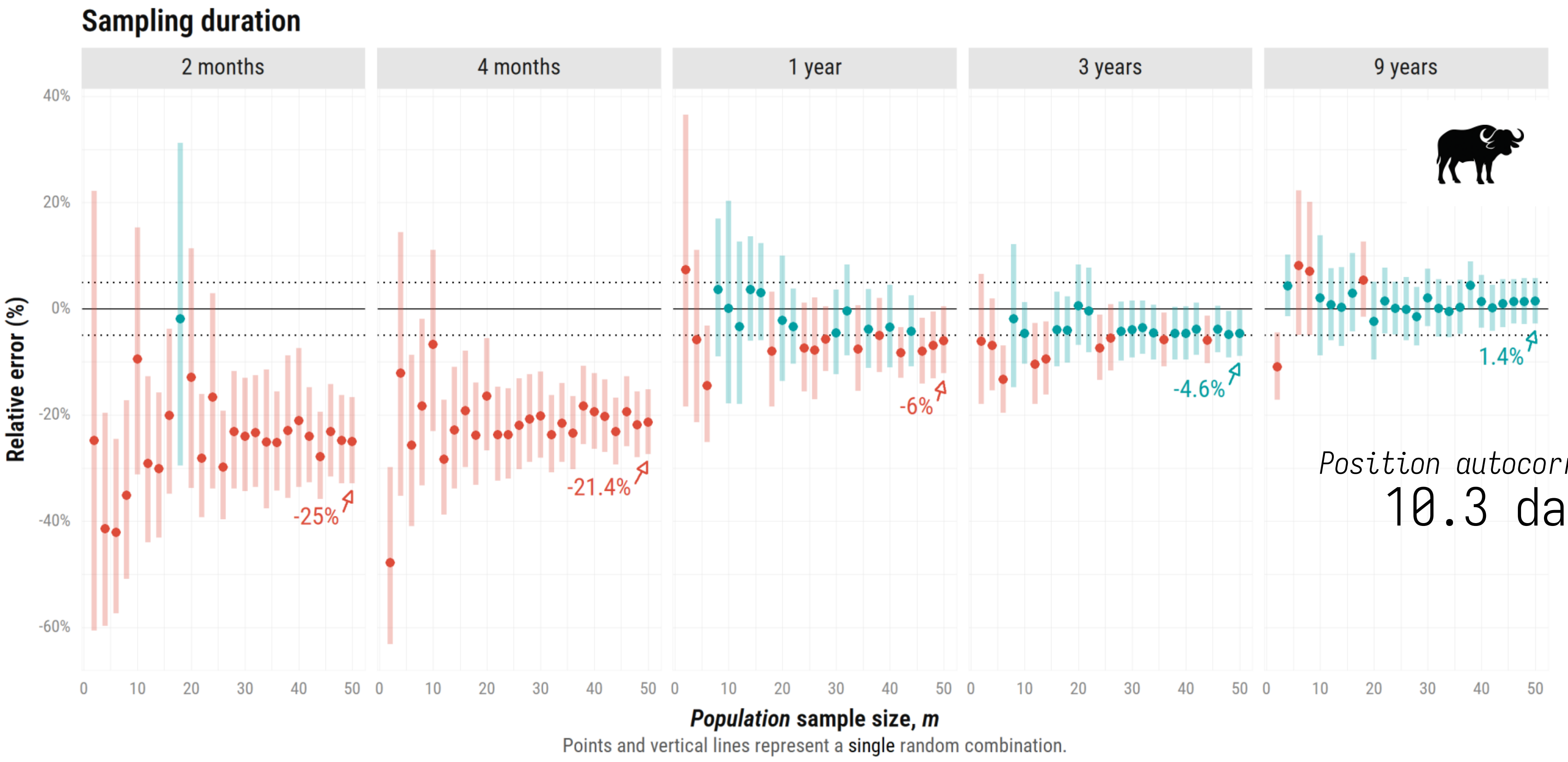
3.1. Population-level inferences — mean home range areas



Position autocorrelation
10.3 days

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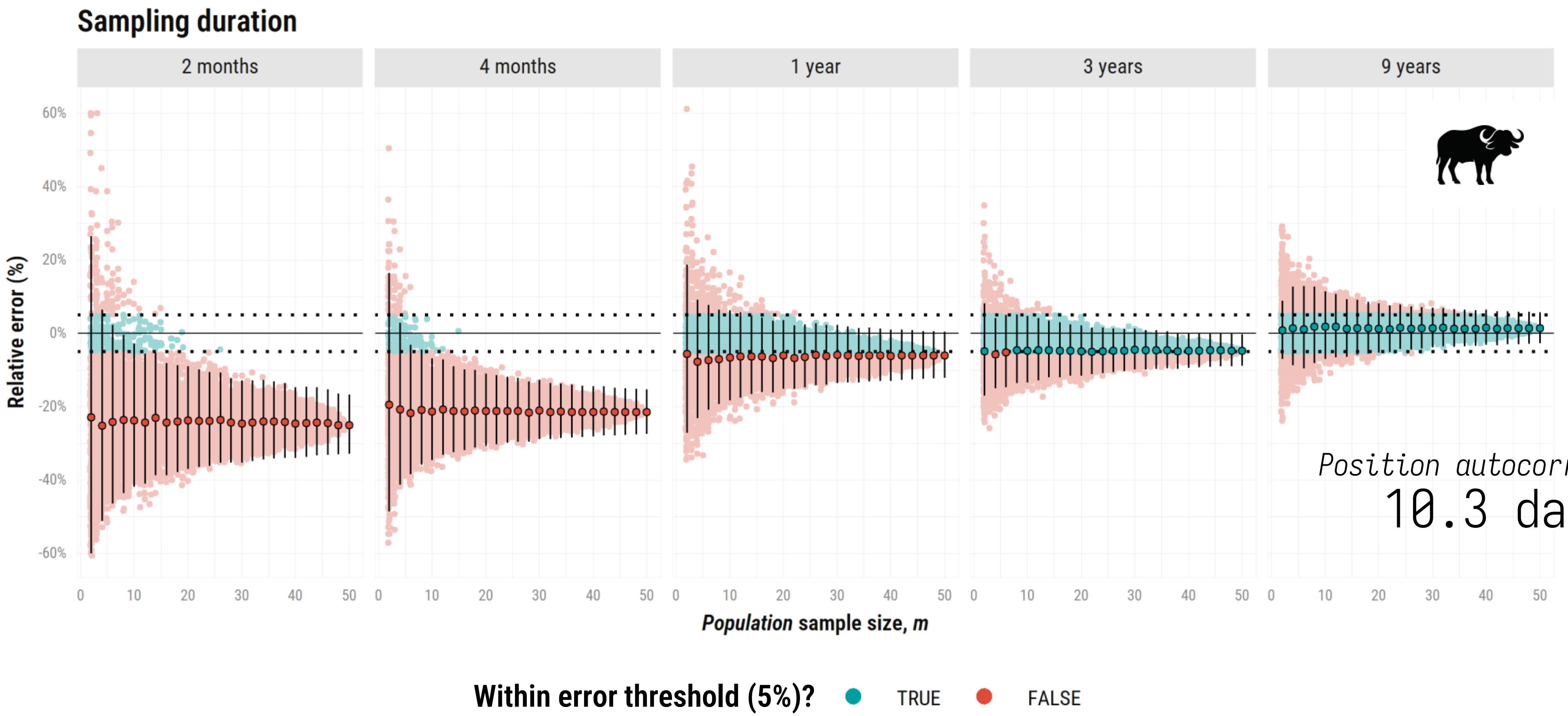

Position autocorrelation
10.3 days

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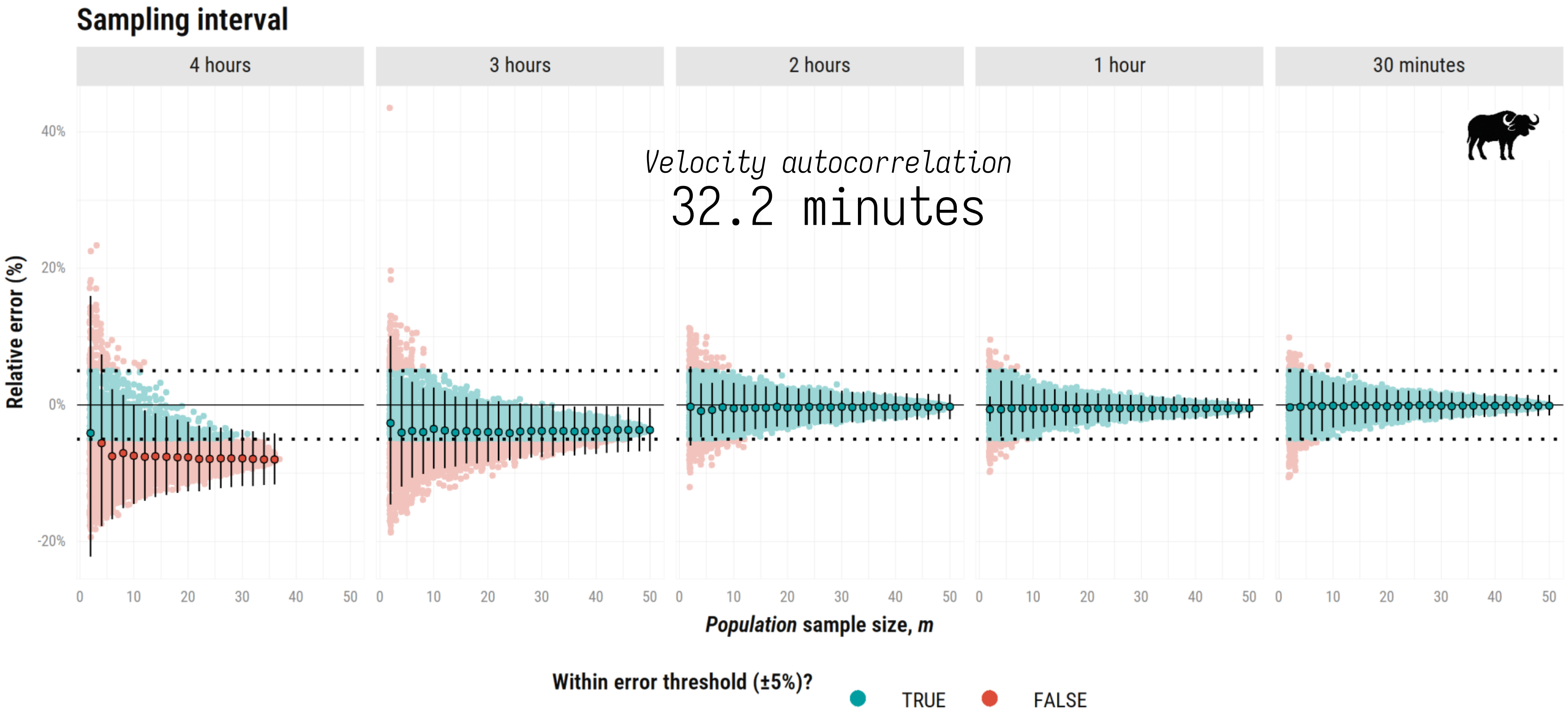
3.2. Population-level inferences — mean movement speed



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