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ECOBHVR 2025

Too few, too many, or just right?

Optimizing sample sizes in animal tracking projects

ecoisilva/movedesign

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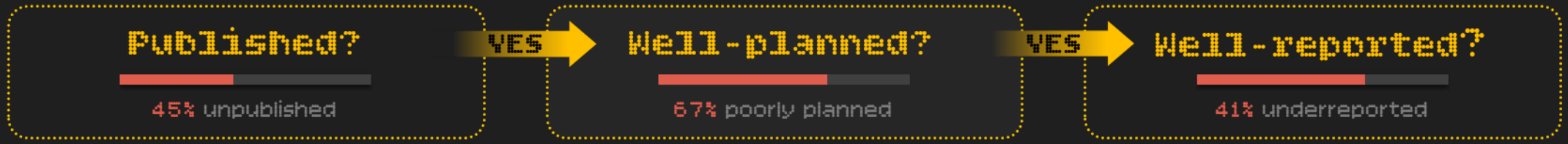
82% wasted

BEST-CASE SCENARIO

All under-reporting appears in poorly planned studies

Adapted from Purgar *et al.* (2022)



Poor planning and under reporting do not happen in the same studies

WORST-CASE SCENARIO

89% wasted

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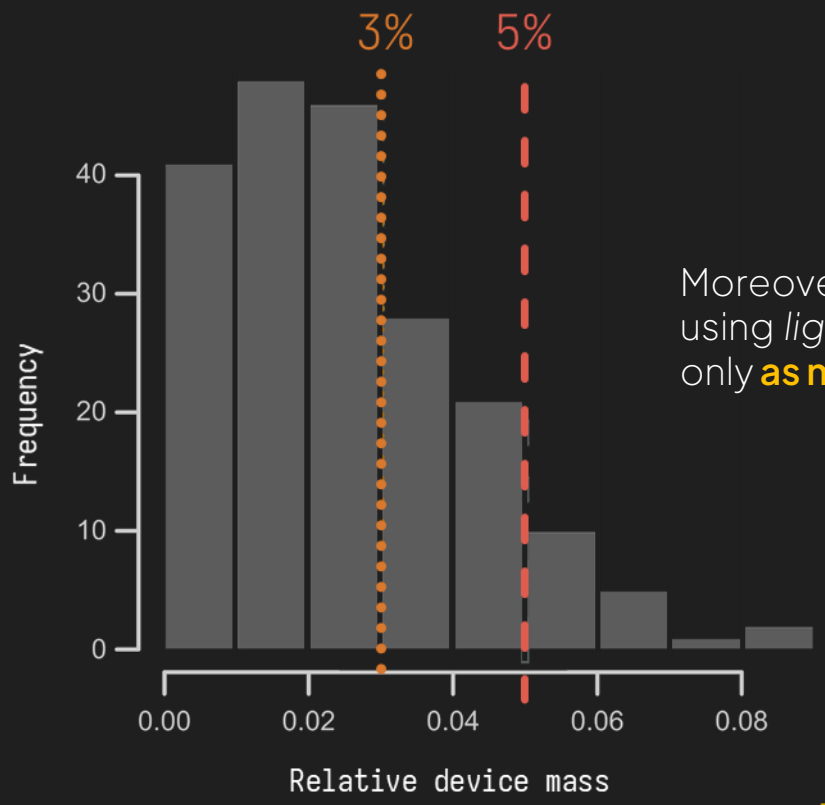
The cost of a single **GPS unit** can reach several thousand dollars,
and each additional tracked individual adds **logistical overheads** (*e.g.*, field time, personnel, travel).

PR Ganapathy

Robert Ronconi

Thanisha Kumar



Moreover, **animal welfare guidelines** require using *lighter, less invasive tags*, and tracking only **as many individuals as necessary**.

Adapted from Portugal & White (2018)

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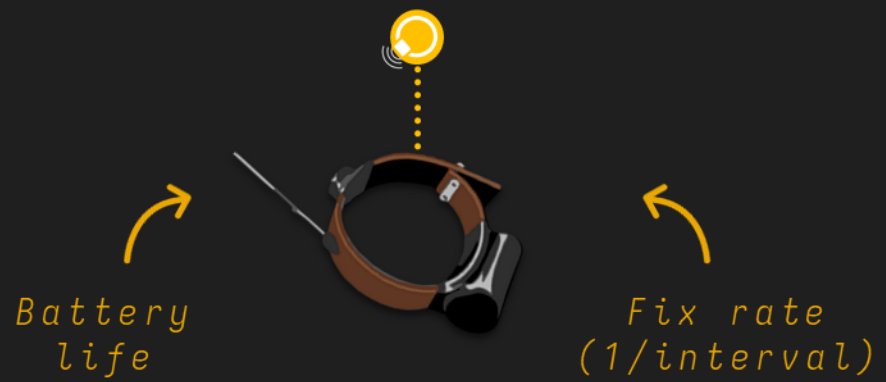
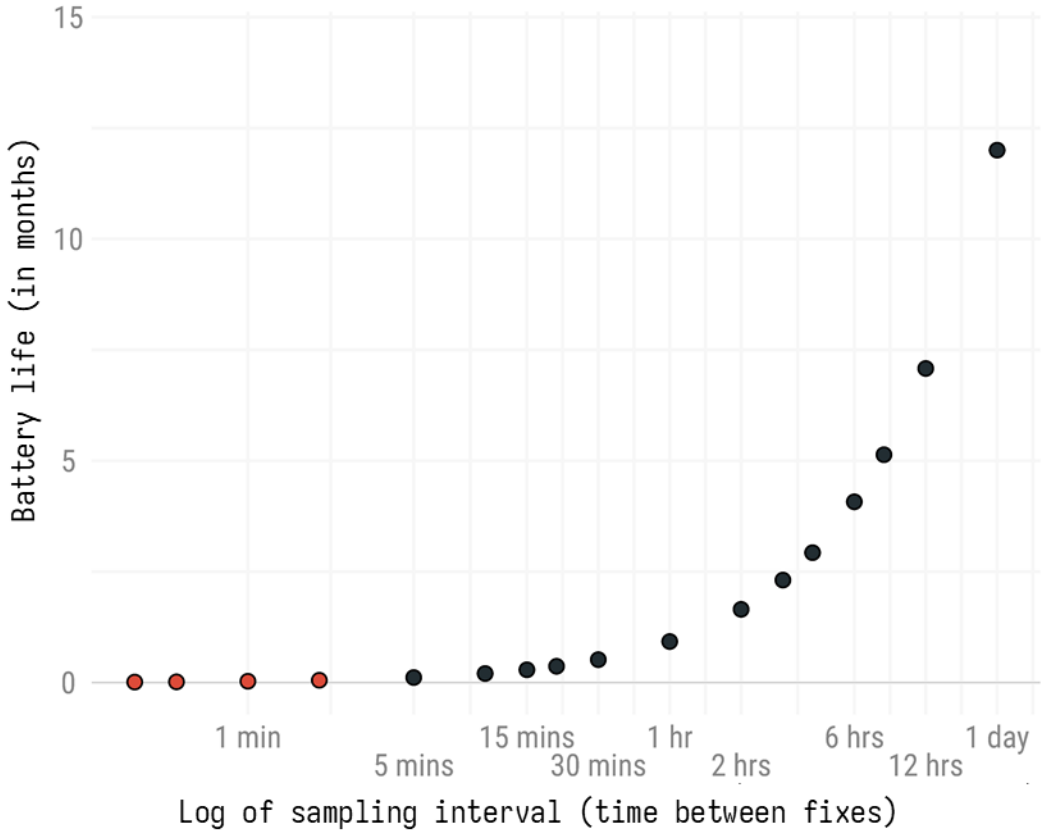
GPS
biologgers



Increasing resolution (e.g., sampling rate or fix frequency) consumes more power, **reducing battery life** and limiting tracking duration.

Trade-off between battery life and resolution:



Silva *et al.* (2023)

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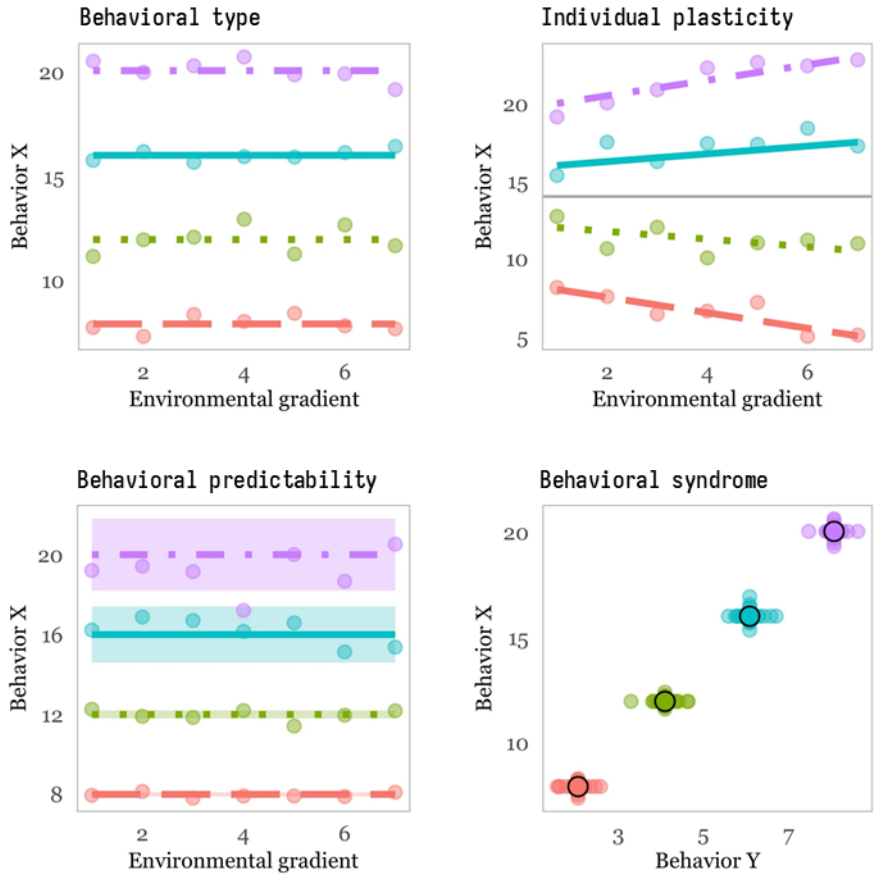
The intrinsic **behavioral variability** within populations increase the risk of producing biased or unreliable estimates.



Hertel *et al.* (2020)

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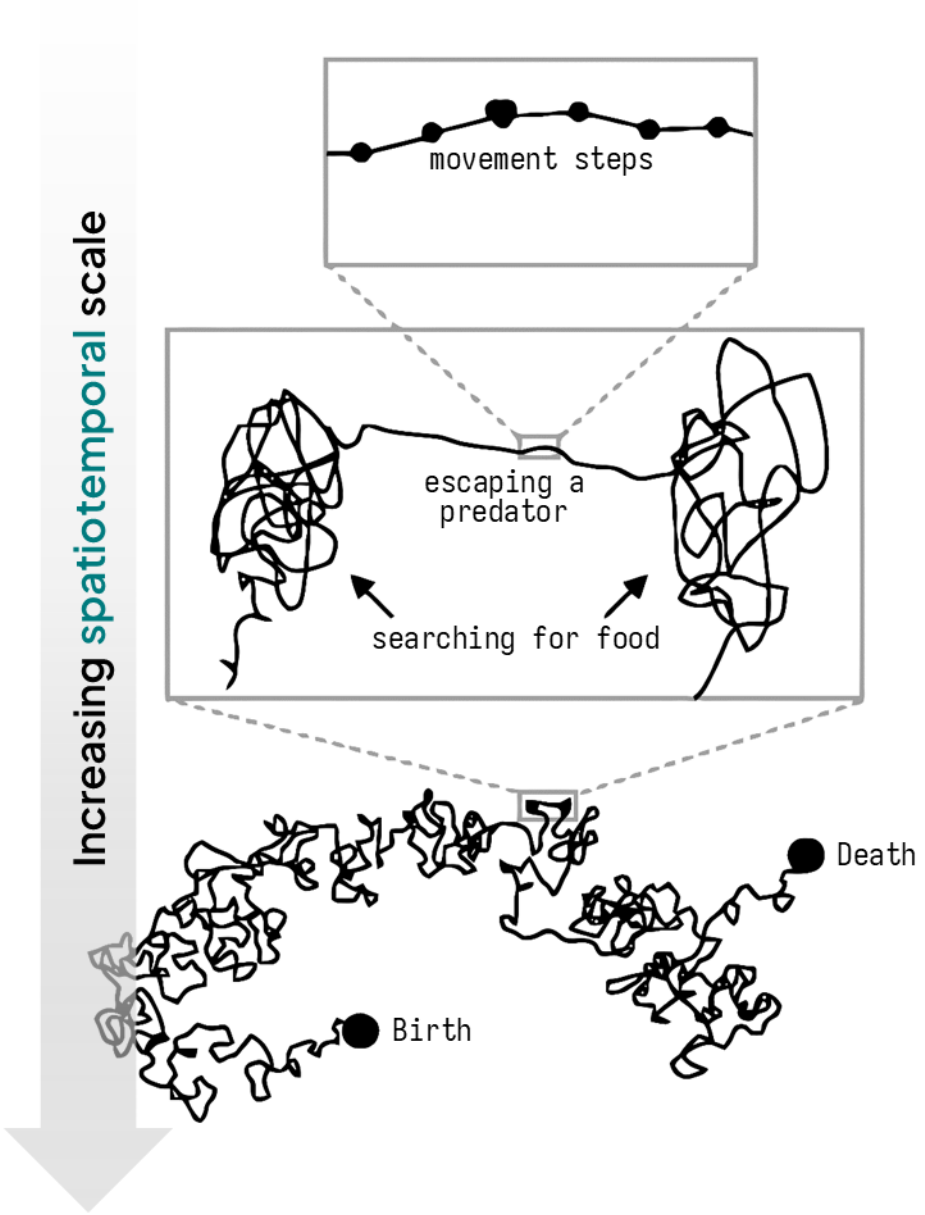
Fine-scale processes

e.g., Movement speed
Distance traveled

Adapted from Nathan *et al.* (2008)



Large-scale processes

e.g., Home range area

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- *Define* research questions
- *Identify* spatiotemporal scales
- *Determine* sampling parameters
- *Collect* animal tracking data
- *Analyze* data, mitigate biases
- *Assess* conclusions

1 **Sampling duration:**
How long should each individual be monitored?

2 **Sampling frequency:**
How often should locations be recorded?

3 **Sample size:**
How many individuals should be tracked?

Ideally, researchers would track *as many animals as possible*, *for as long as possible*, and *as frequently as possible*.

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Objectives


```
> install.packages(movedesign)
```

Create a systematic approach, akin to statistical power analysis, to determine **optimal sampling parameters** in animal tracking projects.

Silva *et al.* (2023)
Silva *et al.* (2025)

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Conceptualization

- *Define* research questions
- *Identify* spatiotemporal scales
- *Determine* sampling parameters
- *Collect* animal tracking data
- *Analyze* data, mitigate biases
- *Assess* conclusions

1 Animal movement paths are realizations of **continuous stochastic processes**,

2 Behavior can be summarized 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 sample sizes.

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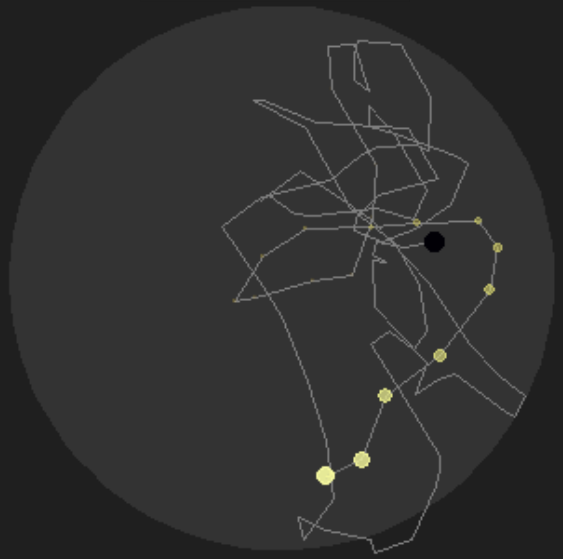
τ_p

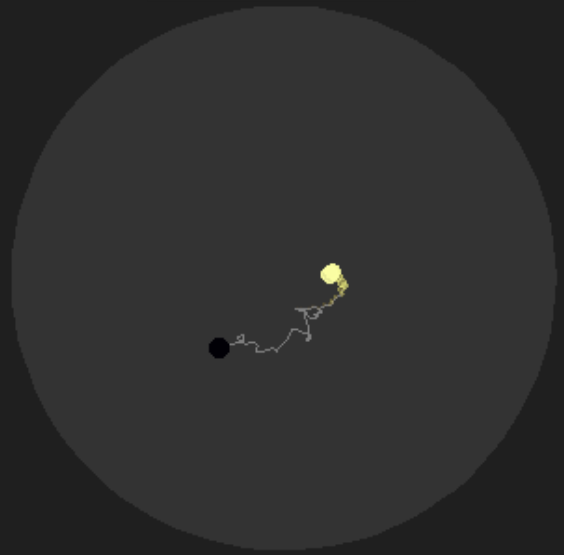
Position autocorrelation timescale

τ_p = 1 hour



τ_p = 1 day

τ_p = 5 days



τ_p = 10 days

T

SPACE-USE ⟵ **SAMPLING DURATION** ⟶ **MOVEMENT BEHAVIOR**

☑ Home range

How long is an animal tracked for?

☐ Speed & distance

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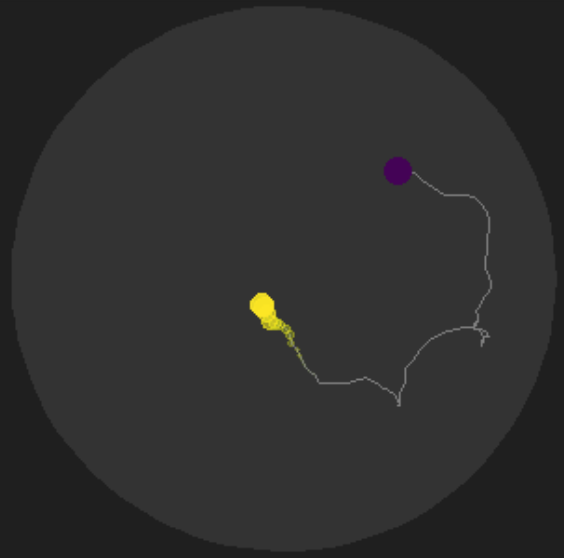
τ_v

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 INTERVAL ⋯▸ **MOVEMENT BEHAVIOR**

How frequently are locations collected?

☑ Speed & distance

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It is physically impossible for animal movement to be *uncorrelated*.

Now, this raises three key questions:

1. Can we *detect* a signature of these correlations in the data?
2. Is the sampling schedule sufficient to *produce reliable estimates* of key metrics?
3. Is the population sample size sufficient to *capture individual variation*?

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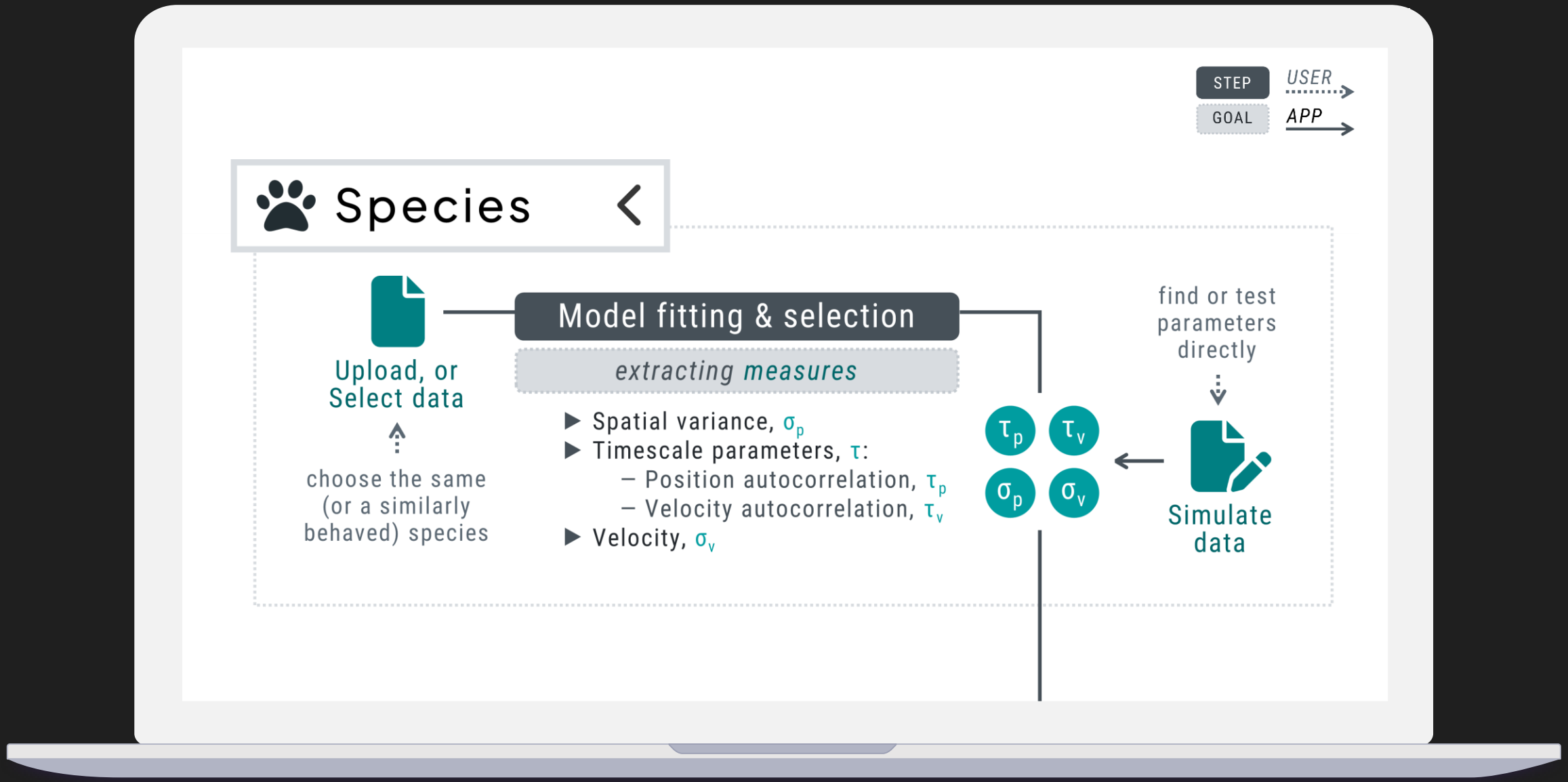

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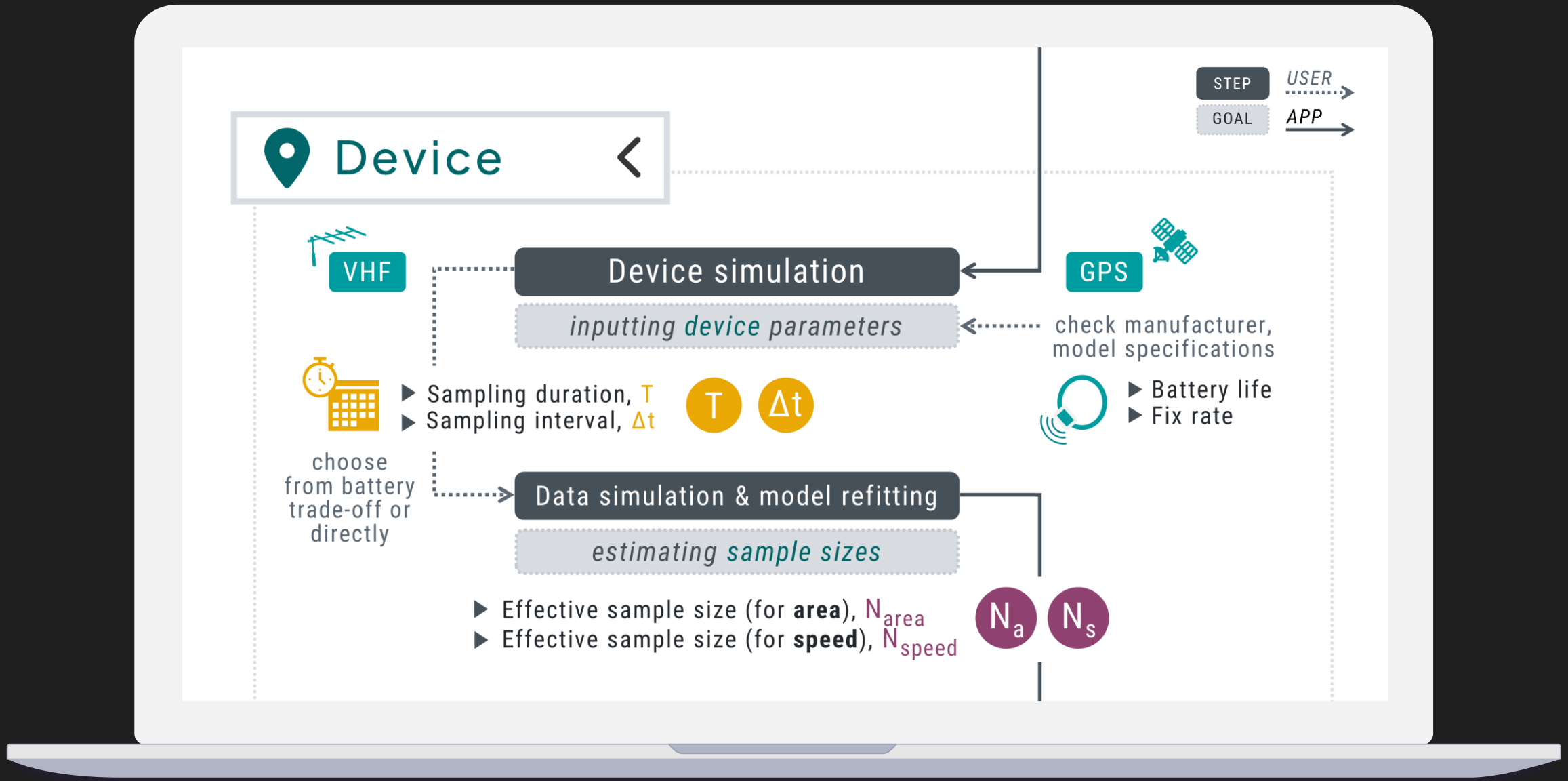

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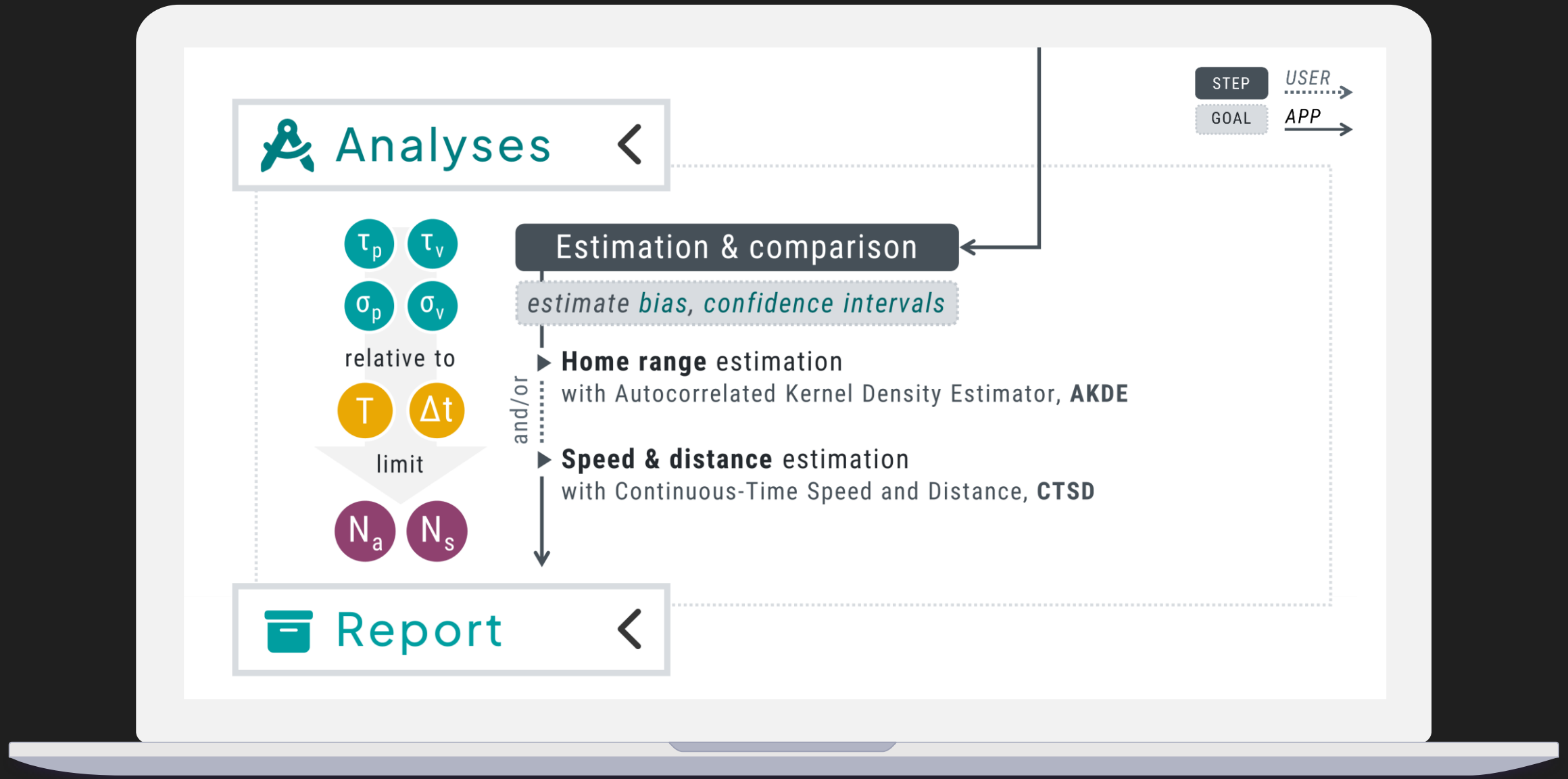

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Extended workflow

Planning to track a specific number of animals?

YES

Simulate a *set number of tags* from the model fit

NO

Iteratively simulate more tags until threshold

Get population-level inferences:

- mean of sampled population,
- compare means of sampled groups. (*e.g.*, males/females)

Run simulations

Add sources of bias (if applicable):

- Location error
- Data loss (*e.g.*, fix success rate)
- Device loss or mortality event
- Storage limits

Test sampling designs,
Assess estimation accuracy and precision.

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Cross *et al.* (2013)

NT

Species

African buffalo

(Syncerus caffer)

Position autocorrelation (τ_p)

10.3 days

(8.2–12.8)

Velocity autocorrelation (τ_v)

32.2 minutes

(22.6–45.7)

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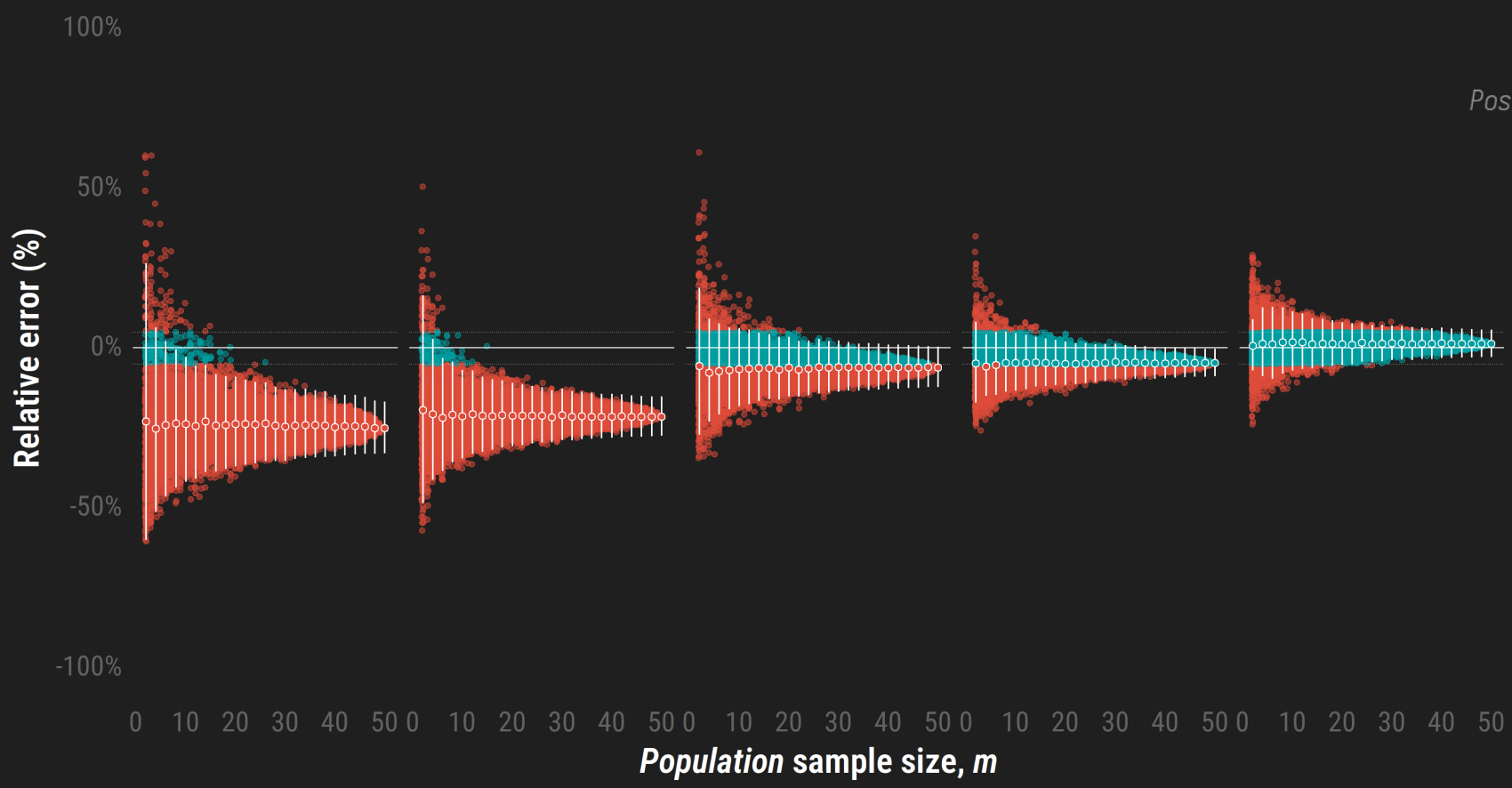
Population-level inferences — *mean* home range areas

Species
African buffalo
(Syncerus caffer)

Error threshold
5%

Position autocorrelation
10.3 days
(8.2–12.8)



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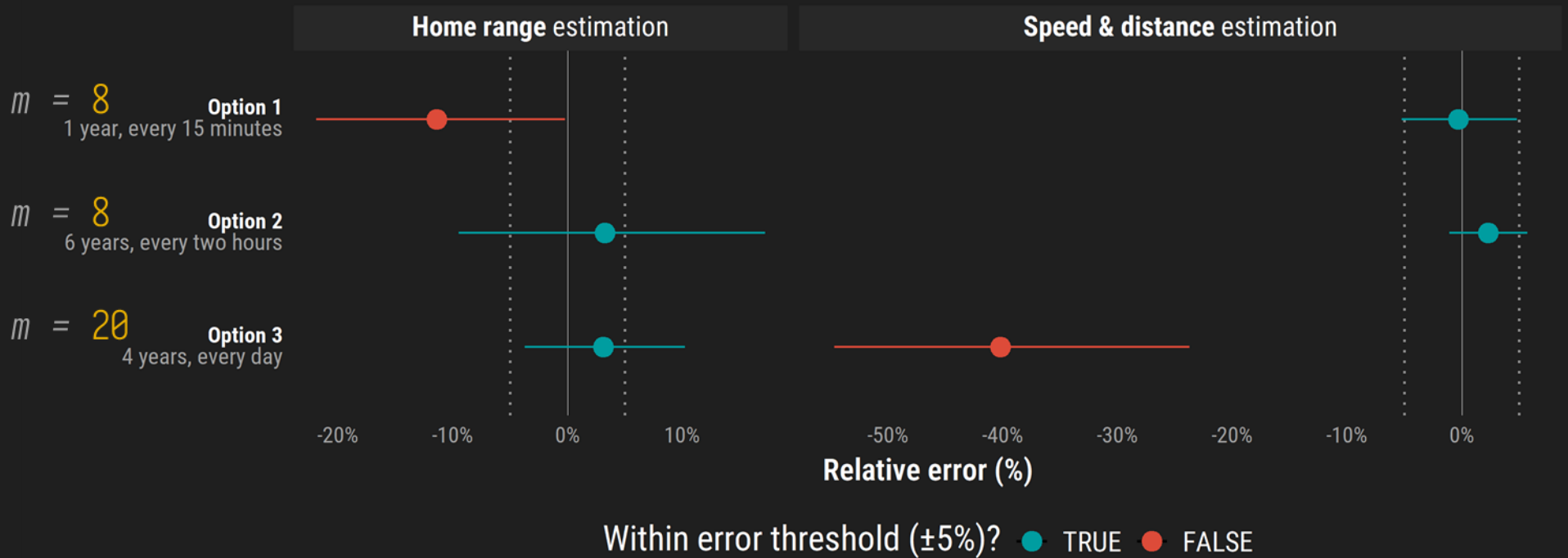
Species
African buffalo
(Syncerus caffer)

What if we want to obtain a reliable estimate (within a 5% error threshold) of both **mean home range area** and **mean movement speed**?



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Practical uses

1. *Justify* **resource allocation**

   Support funding proposals with quantitative rationale,

2. *Refine* **study design**

   Use pilot data to optimize methods before full data collection,

3. *Monitor* **reliability during data collection**

   Iteratively assess if results are robust as more data becomes available,

4. *Evaluate* **research outcomes**

   Assess any findings a posteriori and inform future research.

The latest release (v0.3.2) of the movedesign R Shiny application is available on CRAN or GitHub.

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Special thanks to

Justin Calabrese
Chris Fleming
Michael Noonan
William Fagan
Jesse Alston

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Thank you! Any questions?

Check the R package here!

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