Simulating Space Use of Animals from RSF and SSF

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Problem: How to quantify and predict space use by animals?

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2. How to obtain accurate estimates of space use?
3. Is it possible to predict space use of animals in novel or altered landscapes?

Why not use home ranges?

- Traditional home-range concept[1] is complex and nontrivial to quantify.

[1] Burt, W. (1943). Territoriality and home range concepts as applied to mammals. Journal of mammalogy, 24(3), 346-352.

[2] Signer, J. et al. (2017). Estimating utilization distributions from fitted step-selection functions. Ecosphere, 8(4), e01771.

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- Most home range estimators do not provide a mechanistic model linking space use to habitat characteristics and movement $\rightarrow$ prediction.
- Simulations from integrated Step Selection Functions (iSSFs) are an interesting alternative to home ranges to quantify space use[2].

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Integrated Step Selection Functions (iSSFs)

- Estimate distribution for step lengths and turning angles.
- Pair each observed step with J random steps.
- Extract covariate values at the end of each step.
- Estimate selection coefficients β with a conditional logistic regression.

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- iSSF: including movement related covariates (e.g., step length and turning angles) is equivalent to fitting a biased correlated random walk to the data[1].

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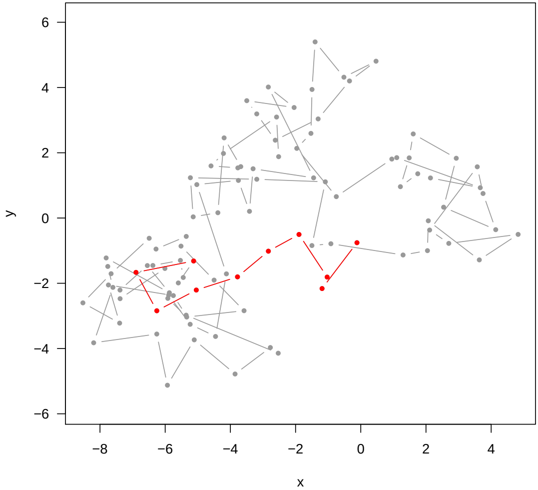
Integrated Step-Selection Functions (iSSF)



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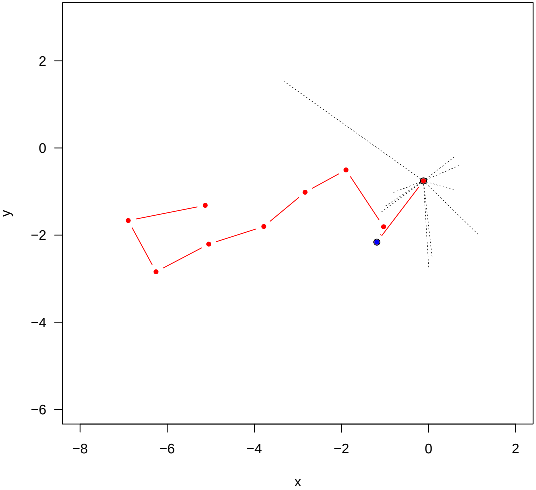

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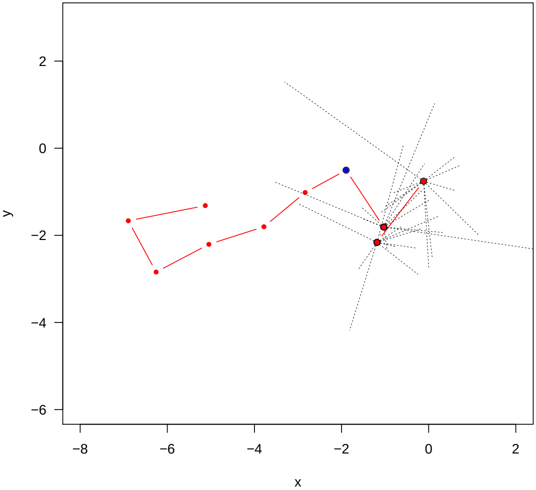

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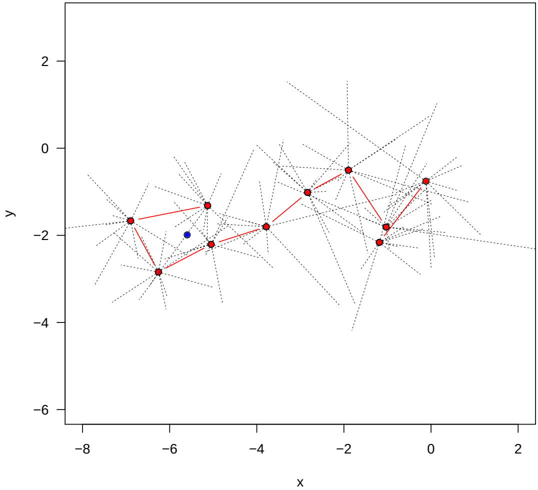
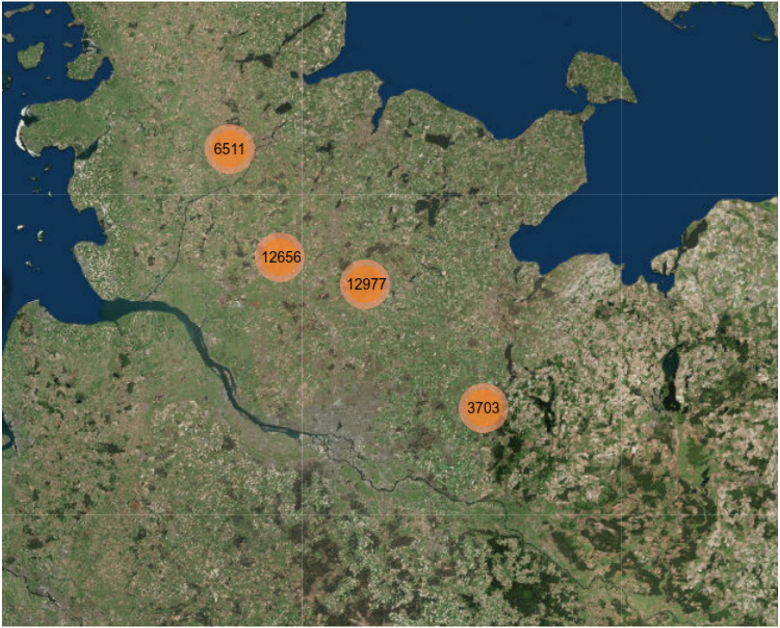


A case study: red deer in Germany

- 24 red deer collared in northern Germany from 2008 to 2013
- 6 hours sampling rate (the number of relocations range from 430 to 3600)
- Each observed step was paired with 9 random steps
- iSSF as mixed Poisson Regression[1] with package `amt`[2]

[1] Muff, S. et al. (2018). Accounting for individual-specific variation in habitat-selection studies: Efficient estimation of mixed-effects models using Bayesian or frequentist computation. bioRxiv, 411801.

[2] Signer, J. et al. (2018. Animal Movement Tools (amt): R-Package for Managing Tracking Data and Conducting Habitat Selection Analyses. arXiv preprint arXiv:1805.03227.


6511
12656
12977
3703

With the following covariates

- Land cover (forest or open)
- Distance to urban areas
- Distance to home-range center
- Step length
- Interactions with time of day

Results

Fixed effects:

Term	Estimate
Forest (time of day = day)	2.36^{***}
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Distance to center (time of day = day)	-3.36^{***}
Distance to center (time of day = night)	3.28^{*}

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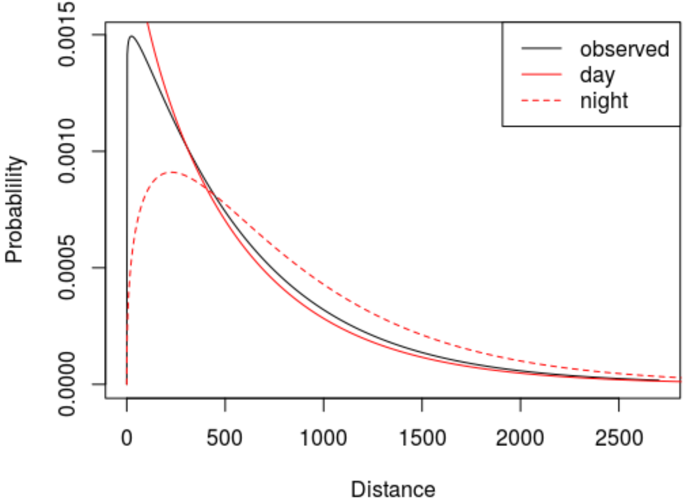
Distance to center (time of day = day)	-3.36^{***}
Distance to center (time of day = night)	3.28^{*}
log(step length) (time of day = day)	-0.11^{***}
log(step length) (time of day = night)	0.46^{***}

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

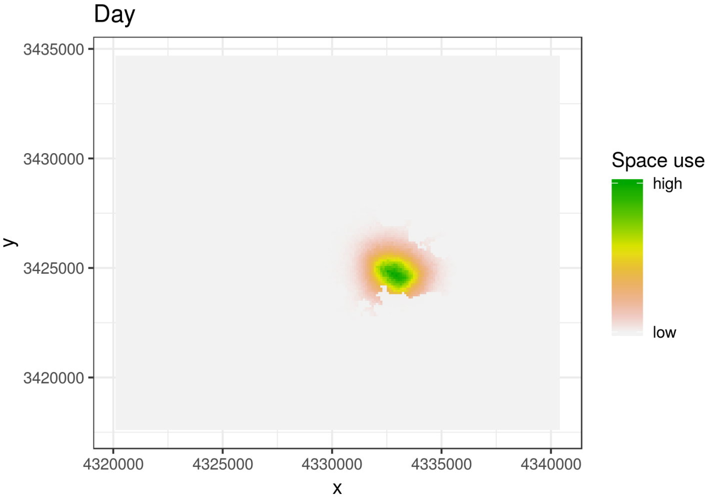
Underlying step-length distribution differs between day and night:



Simulate and predict space use from fitted iSSF

1. A typical animal (fixed effects only)
2. Use random effects of a specific animal
3. For prediction: random effects of a similar animal (in environmental space)

A typical animal (fixed effects only)



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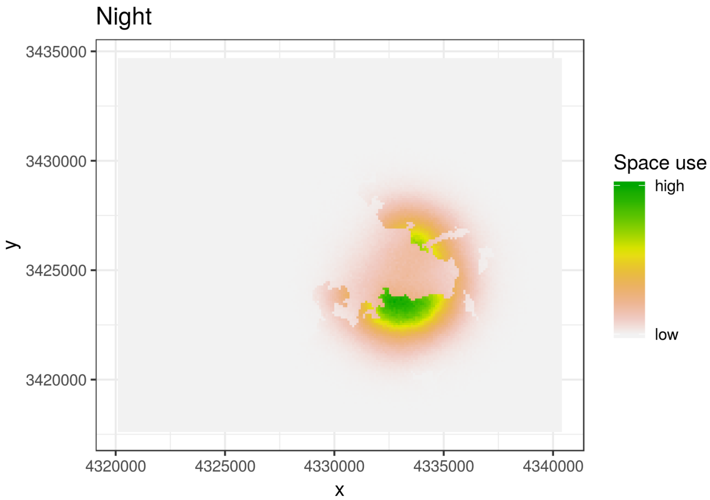
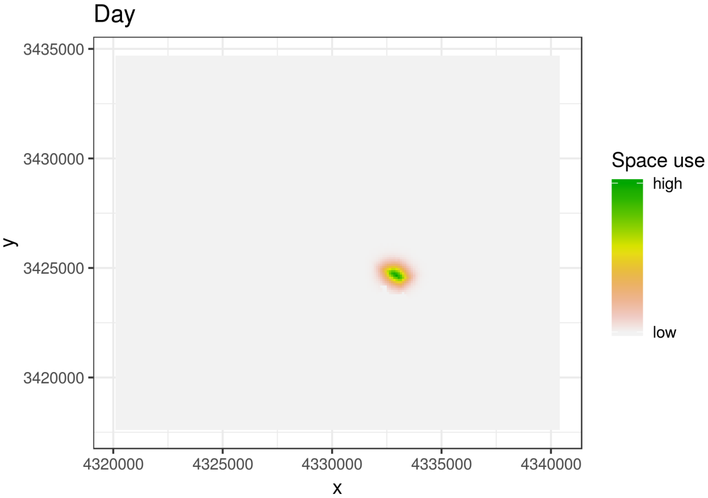


This animal (random effects)



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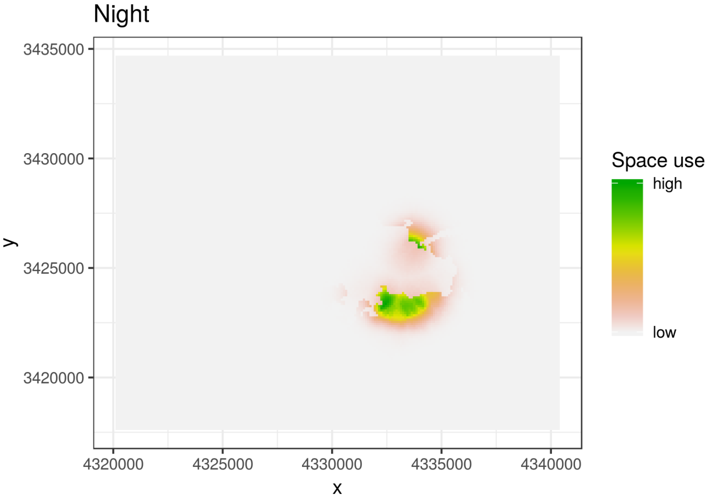
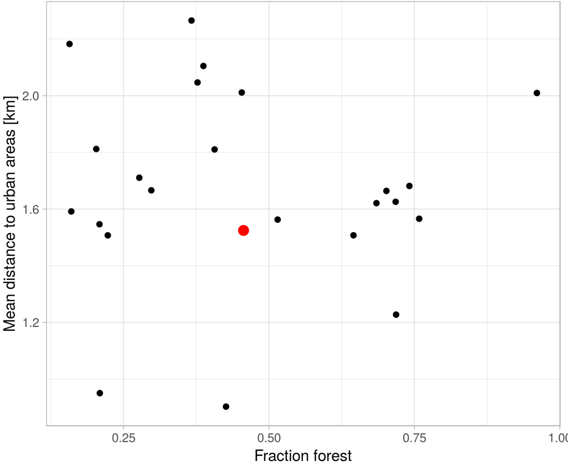
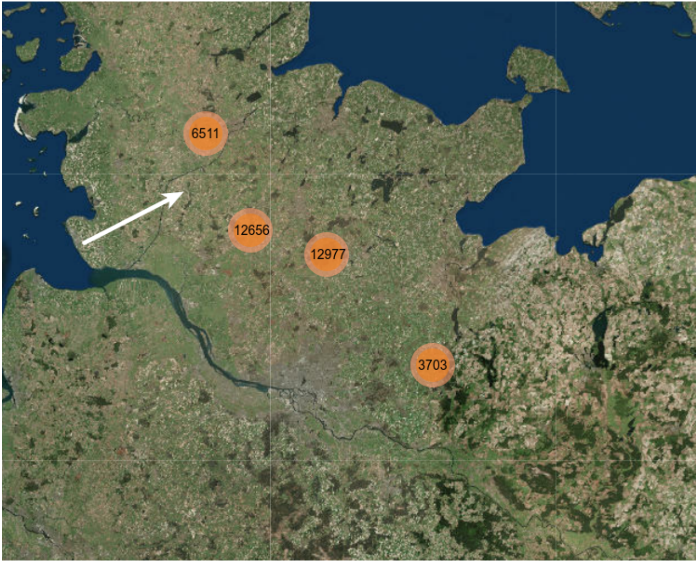


Predict space use in a novel environment

Find animal that is closest to the new environment in environmental space...



... and predict space use in novel environment.



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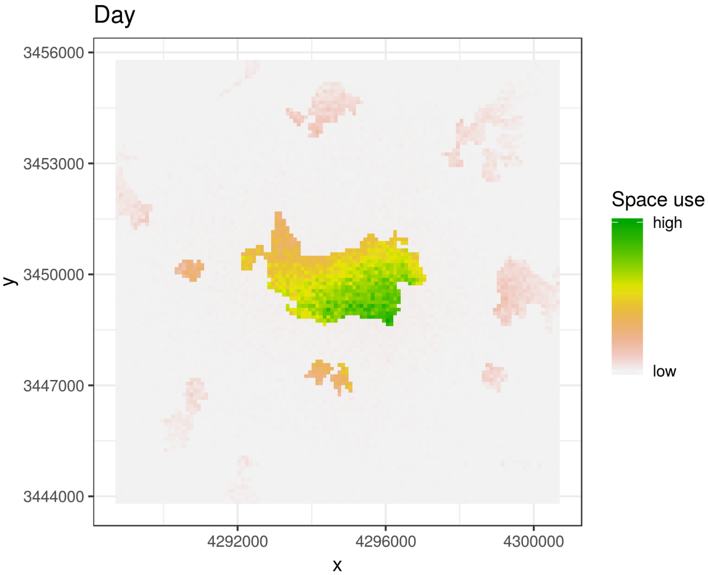

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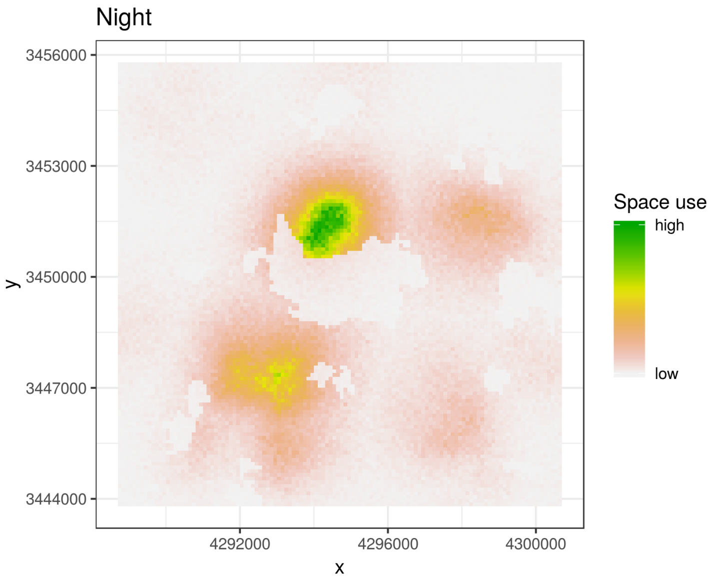

Summary and outlook

- Space use depends on time of day and the environment.
- iSSFs provides a simple but powerful mechanistic movement model, that allows simulations.
- We are working on more sophisticated simulations (time varying covariates).

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Appendix

Model

$$
\begin{aligned}
y_{ntj} &= \text{Poisson}(\lambda_{ntj}) \\
\log(\lambda_{ntj}) &= \alpha_{nt} + \beta_{1n} forest + \beta_{2n} dist\_urban + \beta_{3n} log\_sl \\
&+ \beta_{4n} forestnight + \beta_{5n} dist_u rbannight + \beta_{6n} dist\_cent \\
&+ \beta_{7n} log\_slnight + \beta_{8n} dist\_cent \\
&+ \beta_{9n} dist\_centnight
\end{aligned}
$$

With

- $n = 1 \dots N$ individuals
- $t = 1 \dots T_n$ time points (= strata)
- $j = 1 \dots J$ steps per stratum.
- $y_{ntj} = 1$ for observed steps and 0 for random steps.
- $\alpha_{nt} \sim N(0, 10^6)$

Random effects were uncorrelated.