Applying a Multiverse to Population Habitat Analyses

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Abstract

abc

Keywords

Movement ecology, simulation, compana, resource selection functions, step selection function, habitat preference, habitat selection, animal movement, multiverse, research choice, researcher degrees for freedom,

1 Introduction

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2 Methods

2.1 Simulating the Scenarios

NLMR v.1.1.1 package (Sciaini et al., 2018), and the animal movement using abmAnimalMovement v.0.1.3.0 (Marshall & Duthie, 2022).

- Landscape simulation.
- abmAnimalMovement settings

2.2 Sampling and Analysis Options

- targets construction targets v.0.14.2 and tarchetypes v.0.7.4 R packages (Landau, 2021a,b)

2.2.1 Sampling

- tracking regime
- sample size

2.2.2 Analysis

- area based: compana, area method, contour, available points, space sampling, type II/III, compana test *adehabitatHS* v.0.3.16 (Calenge & Mathieu Basille, 2023), ctmm package v.0.6.1 (Fleming & Calabrese, 2023)
- ssf: Model Formula (SSF or iSSF), Available Points per Step, Distribution of Step Lengths, Distribution of Turn Angles, Model Averaging Method

amt v.0.1.7 (Signer, Fieberg & Avgar, 2019)

- poisson: Model Formula (SSF or iSSF), Available Points per Step, Distribution of Step Lengths, Distribution of Turn Angles

INLA v.23.4.24 (Rue, Martino & Chopin, 2009; Lindgren, Rue & Lindström, 2011; Martins et al., 2013; Rue et al., 2017; Kourounis, Fuchs & Schenk, 2018)

Muff, Signer & Fieberg (2020)

2.3 Assessing the multiverse

- spec curves
- brm models: one per each analysis method

3 Results

3.1 Specification Curves

(Fig. 1).

(Fig. 2).

(Fig. 3).

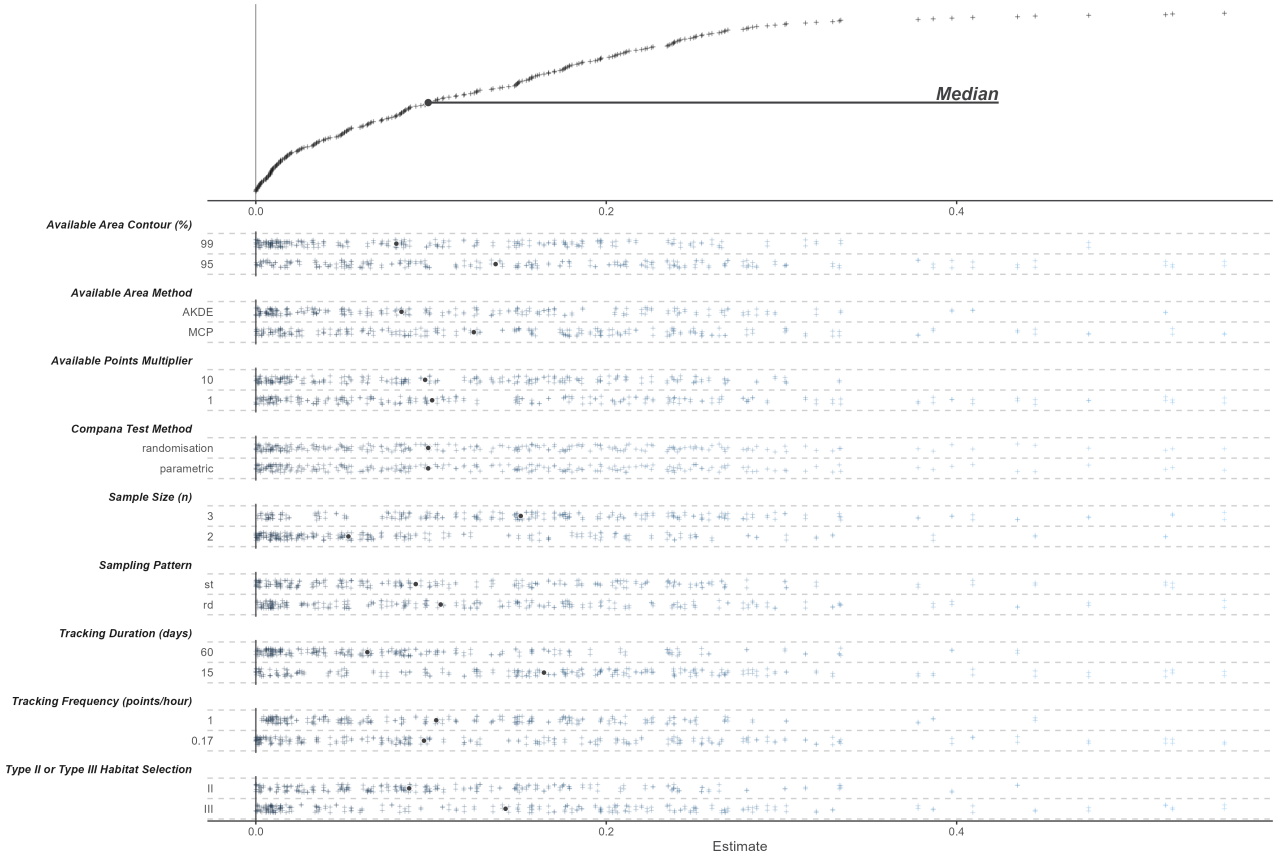

Figure 1. Spec curve

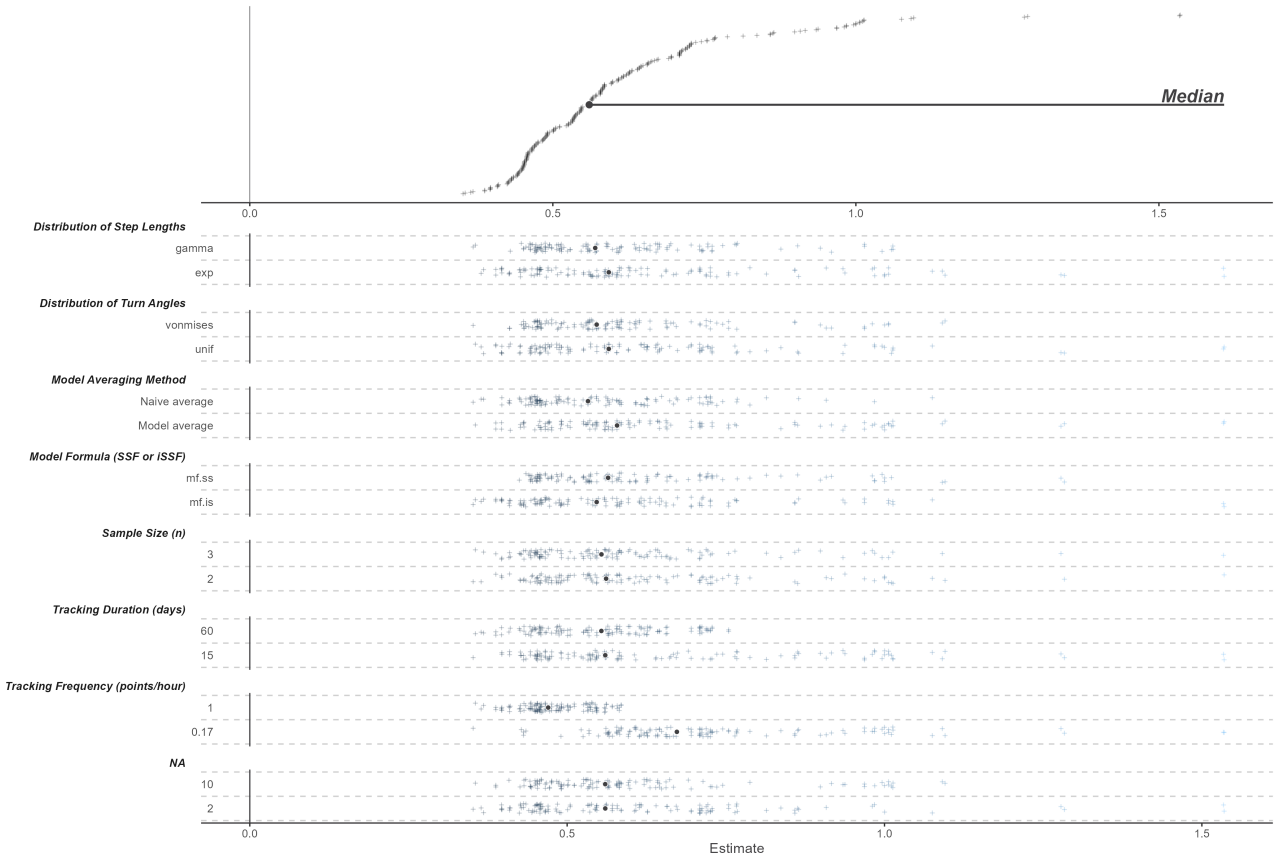

Figure 2. Spec curve

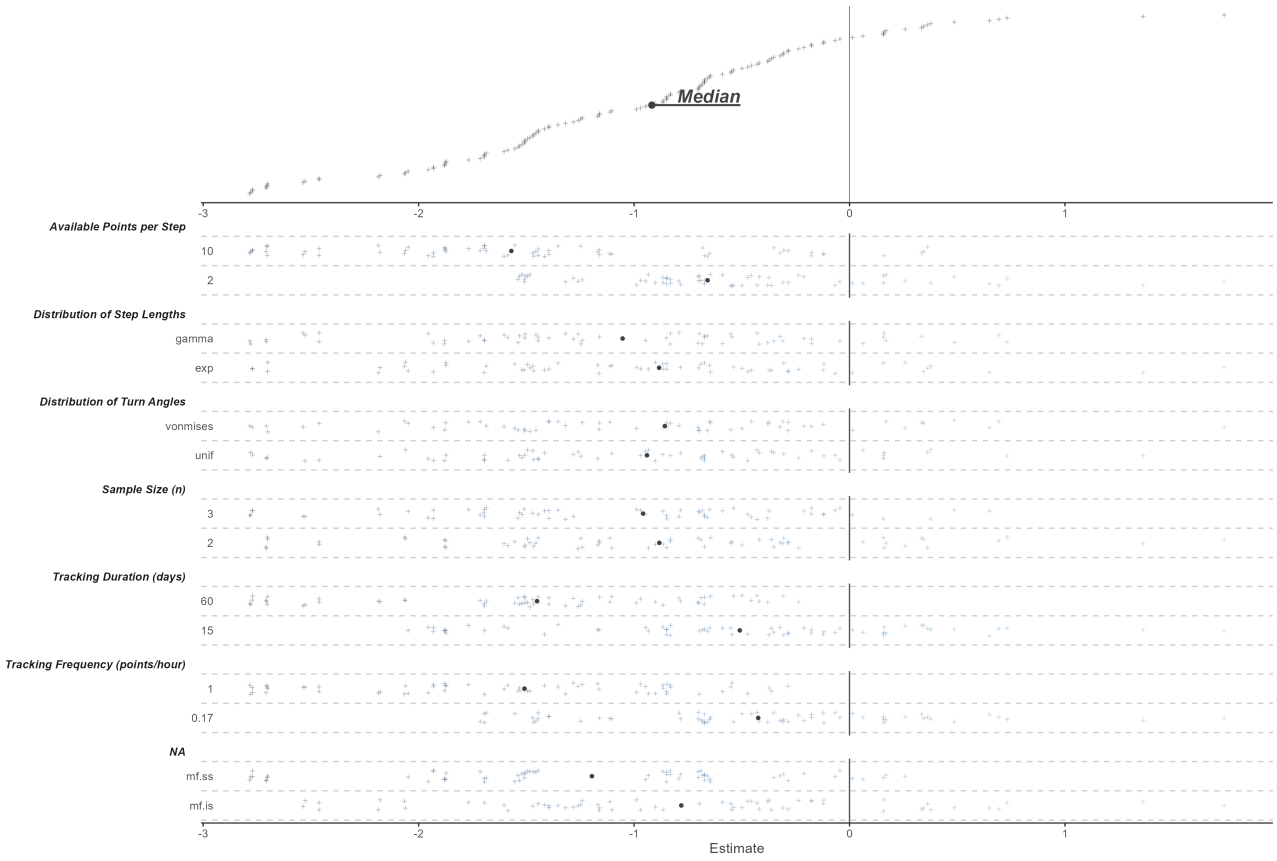

Figure 3. Spec curve

3.2 Model Results

The conditional R^2 values differed for the three models. The Compana results model had a conditional R^2 of 0.33; whereas the SSF model returned 0.59, and the Poisson model returned 0.94.

The marginal R^2 represents the bulk of the conditional R^2 suggesting an important role for the fixed/population effects. The Compana results model had a conditional R^2 of 0.48; whereas the SSF model returned 0.51, and the Poisson model returned 0.83.

The sample size was negatively correlated with deviation from the median estimate (β -0.03; 95% HDCI -1.15 - 1.8).

(Fig. 4).

(Fig. 5).

(Fig. 6).

4 Discussion

4.1 Limitations

4.2 Conclusions

5 Acknowledgements

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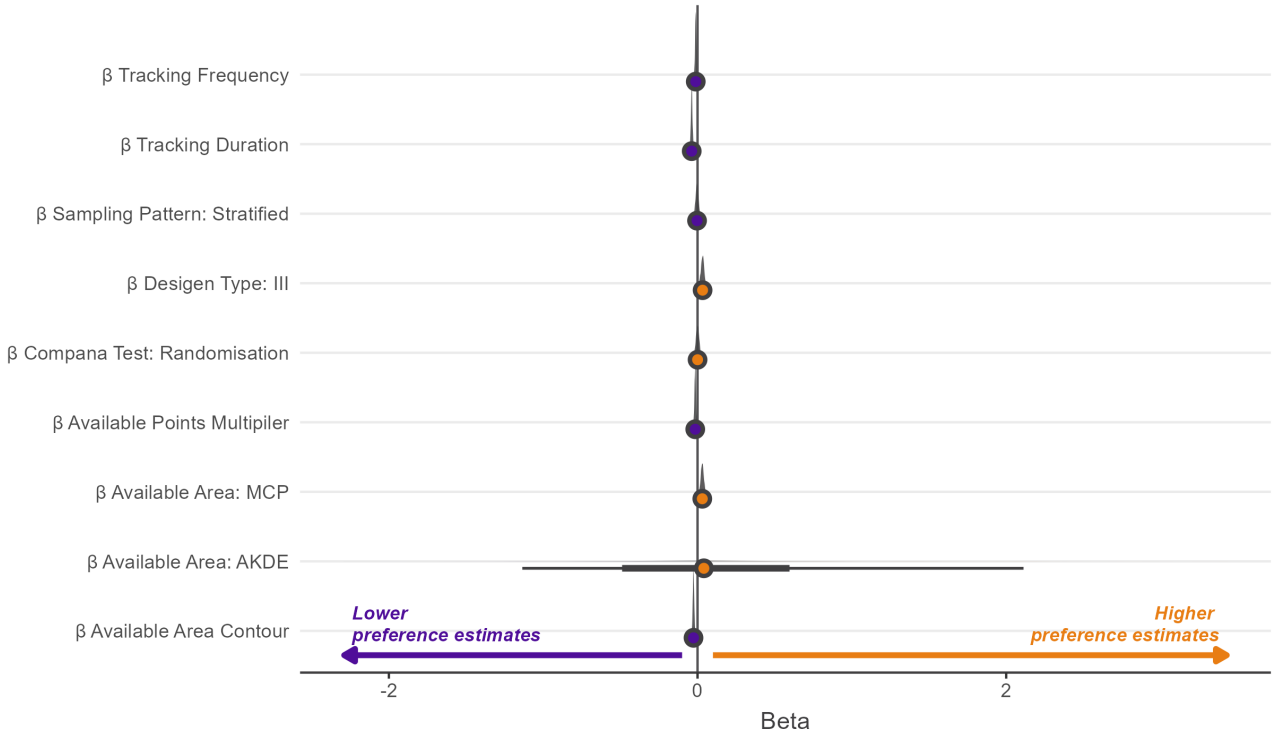

Figure 4. Beta coefs

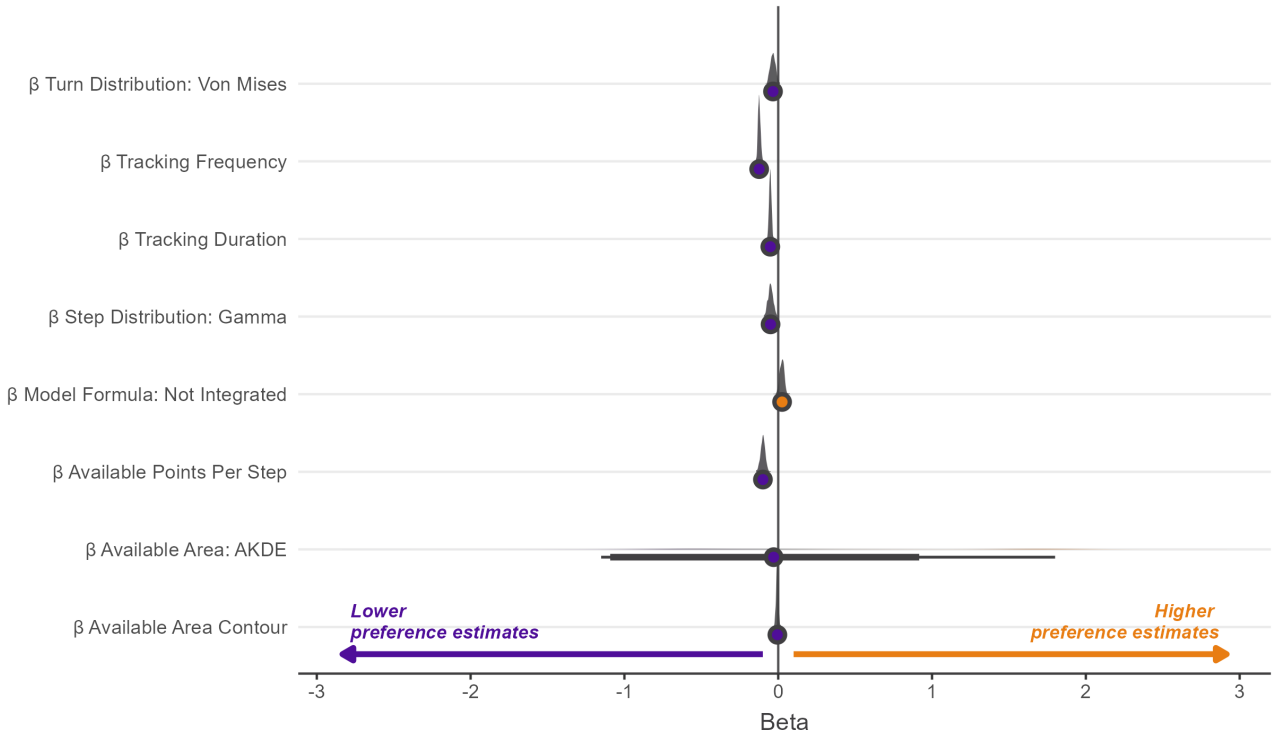

Figure 5. Beta coefs

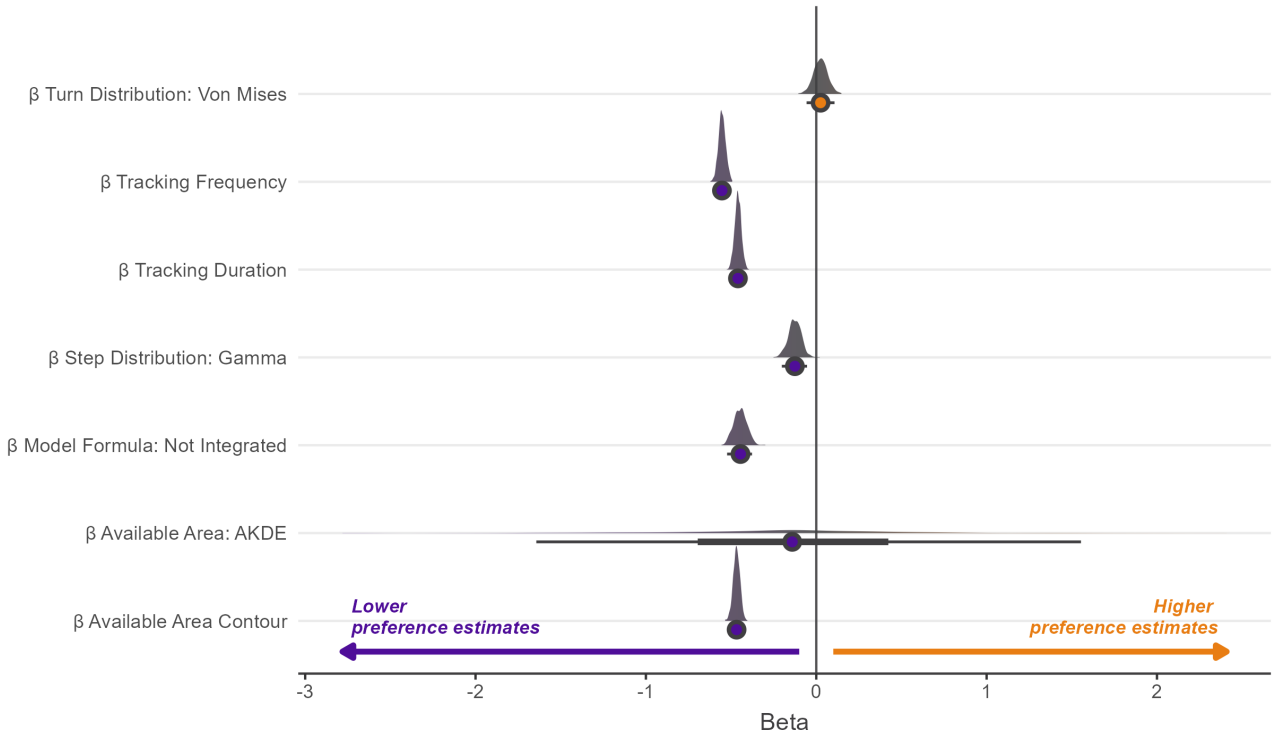

Figure 6. Beta coefs

6 Software availablity

In addition to packages already mentioned in the methods we also used the following.

We used *R* v.4.2.2 (R Core Team, 2023) via *RStudio* v.2023.6.2.561 (RStudio Team, 2022). We used *here* v.1.0.1 (Müller, 2020) and *qs* v.0.25.5 (Ching, 2023) to manage directory addresses and saved objects.

We used *raster* v.3.6.14 (Hijmans, 2023) and *RandomFields* v.3.3.14 (Schlather et al., 2015) to aid landscape raster creation alongside NLMR v.1.1.1 (Sciaini et al., 2018).

We used *ggplot2* v.3.4.2 for creating figures (Wickham, 2016), with the expansions: *patchwork* v.1.1.2 (Pedersen, 2022), *ggridges* v.0.5.4 (Wilke, 2022), and *ggdist* v.3.2.0 (Kay, 2023a).

We used *brms* v.2.19.0 (Bürkner, 2021) to run Bayesian models, with dianogistics generated used *bayesplot* v.1.10.0 (Gabry et al., 2019), *tidybayes* v.3.0.2 (Kay, 2023b), and *performance* v.0.10.2 (Lüdecke et al., 2021).

We used the *dplyr* v.1.0.10 (Wickham et al., 2023), *tibble* v.3.1.8 (Müller & Wickham, 2023), and *stringr* v.1.5.0 (Wickham, 2022) packages for data manipulation.

We used *sp* v.1.5.1 (Bivand, Pebesma & Gomez-Rubio, 2013), *adehabitatHR* v.0.4.20 (Calenge & Scott Fortmann-Roe, 2023), *move* v.4.1.12 (Kranstauber, Smolla & Scharf, 2023) for manipulation of spatial data and estimation of space use not otherwise mentioned in the methods.

We used rmarkdown v.2.19 (Xie, Allaire & Grolemund, 2018; Xie, Dervieux & Riederer, 2020; Allaire et al., 2023), bookdown v.0.33 (Xie, 2016, 2022), tinytex v.0.44 (Xie, 2019, 2023a), and knitr v.1.41 (Xie, 2014, 2015, 2023b) packages to generate type-set outputs.

We generated R package citations with the aid of *grateful* v.0.1.13 (Francisco Rodríguez-Sánchez, Connor P. Jackson & Shaurita D. Hutchins, 2023).

7 Data availabilty

8 Supplementary Material

References

Allaire J, Xie Y, Dervieux C, McPherson J, Luraschi J, Ushey K, Atkins A, Wickham H, Cheng J, Chang W, Iannone R. 2023. *rmarkdown: Dynamic documents for r*.

Bivand RS, Pebesma E, Gomez-Rubio V. 2013. *Applied spatial data analysis with R, second edition*. Springer, NY.

Bürkner P-C. 2021. Bayesian item response modeling in R with brms and Stan. *Journal of Statistical Software* 100:1–54. DOI: 10.18637/jss.v100.i05.

Calenge C, Mathieu Basille contributions from. 2023. *adehabitatHS: Analysis of habitat selection by animals*.

Calenge C, Scott Fortmann-Roe contributions from. 2023. *adehabitatHR: Home range estimation*.

Ching T. 2023. *qs: Quick serialization of r objects*.

Fleming CH, Calabrese JM. 2023. *ctmm: Continuous-time movement modeling*.

Francisco Rodríguez-Sánchez, Connor P. Jackson, Shaurita D. Hutchins. 2023. *grateful: Facilitate citation of r packages*.

Gabry J, Simpson D, Vehtari A, Betancourt M, Gelman A. 2019. Visualization in bayesian workflow. *J. R. Stat. Soc. A* 182:389–402. DOI: 10.1111/rssa.12378.

Hijmans RJ. 2023. *raster: Geographic data analysis and modeling*.

Kay M. 2023a. *ggdist: Visualizations of distributions and uncertainty*. DOI: 10.5281/zenodo.3879620.

Kay M. 2023b. *tidybayes: Tidy data and geoms for Bayesian models*. DOI: 10.5281/zenodo.1308151.

Kourounis D, Fuchs A, Schenk O. 2018. Towards the next generation of multiperiod optimal power flow solvers. *IEEE Transactions on Power Systems* PP:1–10.

Kranstauber B, Smolla M, Scharf AK. 2023. *move: Visualizing and analyzing animal track data*.

Landau WM. 2021b. *Tarchetypes: Archetypes for targets*.

Landau WM. 2021a. The targets r package: A dynamic make-like function-oriented pipeline toolkit for reproducibility and high-performance computing. *Journal of Open Source Software* 6:2959.

Lindgren F, Rue H, Lindström J. 2011. An explicit link between Gaussian fields and Gaussian Markov random fields: The stochastic partial differential equation approach (with discussion). *Journal of the Royal Statistical Society B* 73:423–498.

Lüdecke D, Ben-Shachar MS, Patil I, Waggoner P, Makowski D. 2021. performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software* 6:3139. DOI: 10.21105/joss.03139.

Marshall BM, Duthie AB. 2022. abmAnimalMovement: An r package for simulating animal movement using an agent-based model. *F1000* 0:0.

Martins TG, Simpson D, Lindgren F, Rue H. 2013. Bayesian computing with INLA: New features. *Computational Statistics and Data Analysis* 67:68–83.

Muff S, Signer J, Fieberg J. 2020. Accounting for individual-specific variation in habitat-selection studies: Efficient estimation of mixed-effects models using bayesian or frequentist computation. *Journal of Animal Ecology* 89:80–92. DOI: 10.1111/1365-2656.13087.

Müller K. 2020. *here: A simpler way to find your files*.

Müller K, Wickham H. 2023. *tibble: Simple data frames*.

Pedersen TL. 2022. *Patchwork: The composer of plots*.

R Core Team. 2023. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

RStudio Team. 2022. *RStudio: Integrated development environment for r*. Boston, MA: RStudio, PBC.

Rue H, Martino S, Chopin N. 2009. Approximate Bayesian inference for latent Gaussian models using integrated nested Laplace approximations (with discussion). *Journal of the Royal Statistical Society B* 71:319–392.

Rue H, Riebler AI, Sørbye SH, Illian JB, Simpson DP, Lindgren FK. 2017. Bayesian computing with INLA: A review. *Annual Reviews of Statistics and Its Applications* 4:395–421.

Schlather M, Malinowski A, Menck PJ, Oesting M, Strokorb K. 2015. Analysis, simulation and prediction of multivariate random fields with package RandomFields. *Journal of Statistical Software* 63:1–25.

Sciaini M, Fritsch M, Scherer C, Simpkins CE. 2018. NLMR and landscapetools: An integrated environment for simulating and modifying neutral landscape models in r. *Methods in Ecololgy and Evolution* 00:1–9.

Signer J, Fieberg J, Avgar T. 2019. Animal movement tools (amt): R package for managing tracking data and conducting habitat selection analyses. *Ecology and Evolution* 9:880–890.

Wickham H. 2016. *ggplot2: Elegant graphics for data analysis*. Springer-Verlag New York.

Wickham H. 2022. *stringr: Simple, consistent wrappers for common string operations*.

Wickham H, François R, Henry L, Müller K, Vaughan D. 2023. *dplyr: A grammar of data manipulation*.

Wilke CO. 2022. *Ggridges: Ridgeline plots in 'ggplot2'*.

Xie Y. 2014. knitr: A comprehensive tool for reproducible research in R. In: Stodden V, Leisch F, Peng RD eds. *Implementing reproducible computational research*. Chapman; Hall/CRC,.

Xie Y. 2015. *Dynamic documents with R and knitr*. Boca Raton, Florida: Chapman; Hall/CRC.

Xie Y. 2016. *bookdown: Authoring books and technical documents with R markdown*. Boca Raton, Florida: Chapman; Hall/CRC.

Xie Y. 2019. TinyTeX: A lightweight, cross-platform, and easy-to-maintain LaTeX distribution based on TeX live. *TUGboat*

40:30–32.
Xie Y. 2022. *Bookdown: Authoring books and technical documents with r markdown*.
Xie Y. 2023b. *knitr: A general-purpose package for dynamic report generation in r*.
Xie Y. 2023a. *tinytex: Helper functions to install and maintain TeX live, and compile LaTeX documents*.
Xie Y, Allaire JJ, Grolemund G. 2018. *R markdown: The definitive guide*. Boca Raton, Florida: Chapman; Hall/CRC.
Xie Y, Dervieux C, Riederer E. 2020. *R markdown cookbook*. Boca Raton, Florida: Chapman; Hall/CRC.