Appendix 7 – Worked example (limitations)

Modelling habitat selection using tracking data from central place foraging species: A practical guide for ecologists

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While the simulations presented in the *Worked Example* section of the main text provide a useful benchmark for comparing model performance, they represent an idealised depiction of seabird movement and habitat selection and rely on simplifying assumptions that should be considered when interpreting the results.

First, we simulated a static binary habitat layer (arranged as a chequerboard) with abrupt transitions between habitat types. This highly regular structure is unrepresentative of natural systems, where habitats are typically continuous, and heterogeneous. Comparisons of model performance under more realistic conditions (e.g., resource patchiness, environmental gradients, or temporal dynamics) may therefore be less clear than in our worked example.

Second, the movement process used to generate tracks was deliberately simplified; the imposed behavioural states, transition rules, and movement kernels likely produce trajectories with more regular and more clearly separated movement phases than would be expected in real data, and do not explicitly capture additional drivers of seabird behaviour such as wind forcing (e.g., Thorne *et al.*, 2023), memory (e.g., Collet *et al.*, 2025), site/route fidelity (e.g., Regan *et al.*, 2024), social cues (e.g., Monier, 2024), sex (e.g., Militão *et al.*, 2023), body condition (e.g., Rishworth *et al.*, 2014), or prey availability (e.g., Fayet *et al.*, 2021; Legard *et al.*, 2025). If animals exhibit weaker central place attraction or more gradual switching between behavioural states, differences among models may become less apparent.

Third, we assumed that movement and selection processes were correctly specified and stationary, such that all individuals behave identically under equivalent conditions. In reality, patterns of movement and space use can vary substantially among individual seabirds, as well as between foraging trips, breeding stages, environmental conditions, and times of day (Phillips *et al.*, 2017; O'Hanlon *et al.*, 2024). Such variability could be accommodated by including random effects for individuals or trips in the models (e.g., Trevail *et al.*, 2021). Initial movement directions were also generated independently of habitat, whereas in practice the bearing followed upon leaving the colony may already reflect prior knowledge, environmental cues, or habitat preferences, which could influence subsequent patterns of space use and selection.

Fourth, we treated all locations as being measured without error (in line with simulation assumptions). However, in real studies, positional uncertainty can be non-negligible and may bias parameter estimates if it is not accounted for.

Fifth, the simulated movement process did not include interactions with dynamic attractors such as fishing vessels (Pirotta *et al.*, 2018) or conspecifics. In natural systems, animals may respond to transient features that vary in space and time, and may not follow a fixed or predictable sequence of behavioural states (Pirotta *et al.*, 2018). We expect that incorporating this additional complexity further blur the distinction between movement behaviour and habitat preference, making differences among models likely less pronounced.

Sixth, our conclusions may depend on the temporal resolution of the tracks and the spatial grain of the habitat field. Because serial dependence is particularly strong in high-resolution tracking data, differences among models may be more or less pronounced at different sampling intervals. In this context, our simulations are best viewed as a controlled way to compare how models behave under plausible ecological scenarios (and imperfect modelling of behavioural processes), rather than as a full reconstruction of real-world ecological complexity.

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