Model Structure

In "Winds of Change: Renewable Energy and its Impacts on Wolves"

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To model temporal changes in wolf territory occupancy states, we used a **Bayesian dynamic multistate occupancy model**, assuming perfect detection.

We consider three discrete ecological states representing different levels of territory use:

1 = Unoccupied - territories that are unoccupied (includes the time before its first appearance and temporary or permanent abandonment)

2 = Occupied by Pair - territories occupied by a pair

3 = Occupied by Pack - territories occupied by a pack

A. Initial state distribution

The starting state for each territory i is drawn from a categorical distribution with the same probability:

$$\psi_{init} \sim Dirichlet(1, 1, 1)$$

B. Transition process

For each origin state $s \in 1, 2, 3$, transitions are split into:

- ψ (psi) - Probability of Occupancy
  - From any current state s at time t, ψ_s gives the probability that at time $t+1$, the territory is occupied (either as a pair or a pack) instead of unoccupied.
  - Linear predictor (logit scale):

$$logit(\psi_s(i, t)) = \alpha_{\psi_s} + \beta_{\psi_s} \times wind_{i,t} + \epsilon_{\psi_s}(t)$$

where:

α_{ψ_s} = intercept

β_{ψ_s} = wind turbine exposure effect

$\epsilon_{\psi_s}(t) \sim Normal(0, \sigma_{\psi_s})$ = year-specific random effect

- R - Probability of Territory being Occupied by a Pack
  - Given that the territory does become occupied at $t+1$, R_s represents the probability that the territory is in the Pack state (state 3) rather than in the Pair state (state 2).
  - Linear predictor (logit scale):

$$logit(R_s(i,t)) = \alpha_{R_s} + \beta_{R_s} \times wind_{i,t} + \epsilon_{R_s}(t)$$

where:

α_{R_s} = intercept

β_{R_s} = wind turbine exposure effect

$\epsilon_{R_s}(t) \sim Normal(0, sigma_{R_s})$ = year-specific random effect

C. Transition probability matrix (TPM)

For each origin state s, territory i, and year t:

- Probability the territory stays or becomes unoccupied:

$$TPM[s,i,t,1] = 1 - \psi_s(i,t)$$

- Probability the territory stays or becomes occupied by a pair:

$$TPM[s,i,t,2] = \psi_s(i,t) \times (1 - R_s(i,t))$$

- Probability the territory stays or becomes occupied by a pack:

$$TPM[s,i,t,3] = \psi_s(i,t) \times R_s(i,t)$$

D. Observation model (perfect observation)

- First year:

$y_{i,1} \sim Categorical(\psi_{init})$

- Subsequent years:

$y_{i,t} \sim Categorical(TPM[y_{i,t-1}, t-1, , i])$
where the TPM row for the previous state determines the probabilities of the next state.

E. Variable effects

- The wind turbine exposure variable, $wind_{i,t}$ is specific to each territory-year.
- Each β_{ψ_s} and β_{R_s} captures the transition-specific effect of wind exposure.

F. Random year effects

- Each state-specific ψ_s and R_s process includes a normally distributed year effect with its own variance σ^2, allowing for unobserved temporal variability.