Using an agent-based model to inform sampling design for animal social network analysis

Journal: Behavioral Ecology and Sociobiology

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Appendix

I.1 Decision making process of an individual

Figure A shows a summary of the decision-making process.

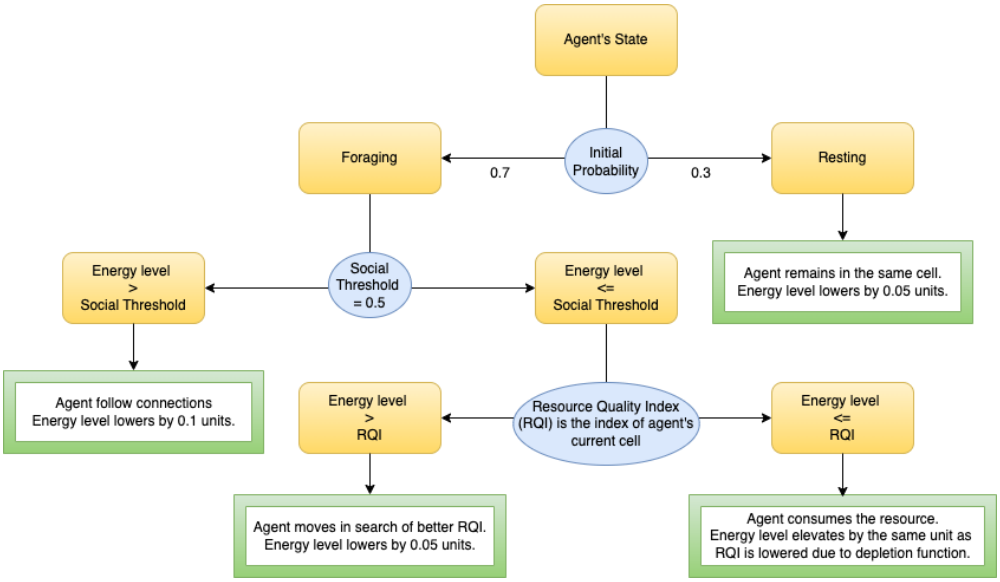


Fig. A A flowchart depicting an agent's movement decisions at each time point

I.2 Agent's movement when multiple connections are present in multiple neighbouring cells

The agents were designed to undertake a two-step decision process to decide where their next move should be (Fig. B).

1. Step 1: In the first step of this process, agents take an initial decision to move and choose a cell for movement based on the presence of their connections in neighbouring cells. If the connections were present in multiple neighbouring cells, agents decided to move randomly towards one of them. At this step, the agents do not make a move yet but just take an initial decision at this point. All the agents in the simulation decide simultaneously their initial choices but do not move just yet.
2. Step 2: In step two of this process, it's time to make a final movement. The final movement decision is based on the choices made by the agents in the first step. For an agent (say A) in the simulation, it's connections are considered whose initial decision would land them within the immediate neighbourhood of agent A. We then took the mean of all those cells and that rounded up mean value becomes the location of agent A's final move.

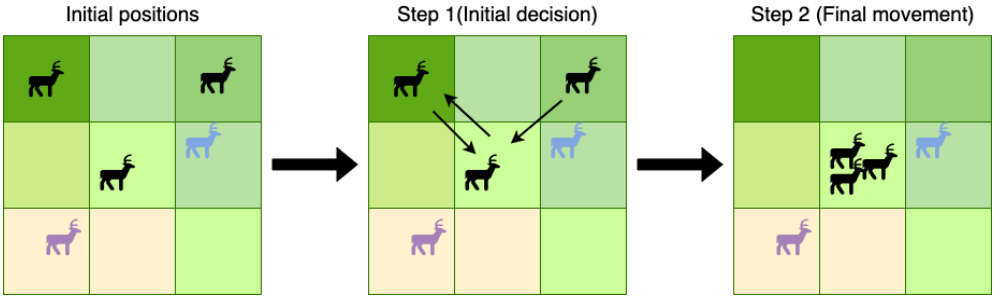


Fig. B: Agents' two-step decision process when multiple connections are present in the multiple cells of the neighbourhood. The black agents belong to the same group and are all in foraging state with energy levels greater than the social threshold. Their movement decisions are influenced by the presence of their group members in the neighbourhood. In the first step of the process, agents take a decision to move influenced by the presence of their connections but do not make any movement yet. In the second step of the process, they make a collaborative decision. Note that the movement decisions of agents in the black group are not influenced by the presence of other group members in the neighbourhood.

I.3 Model calibration

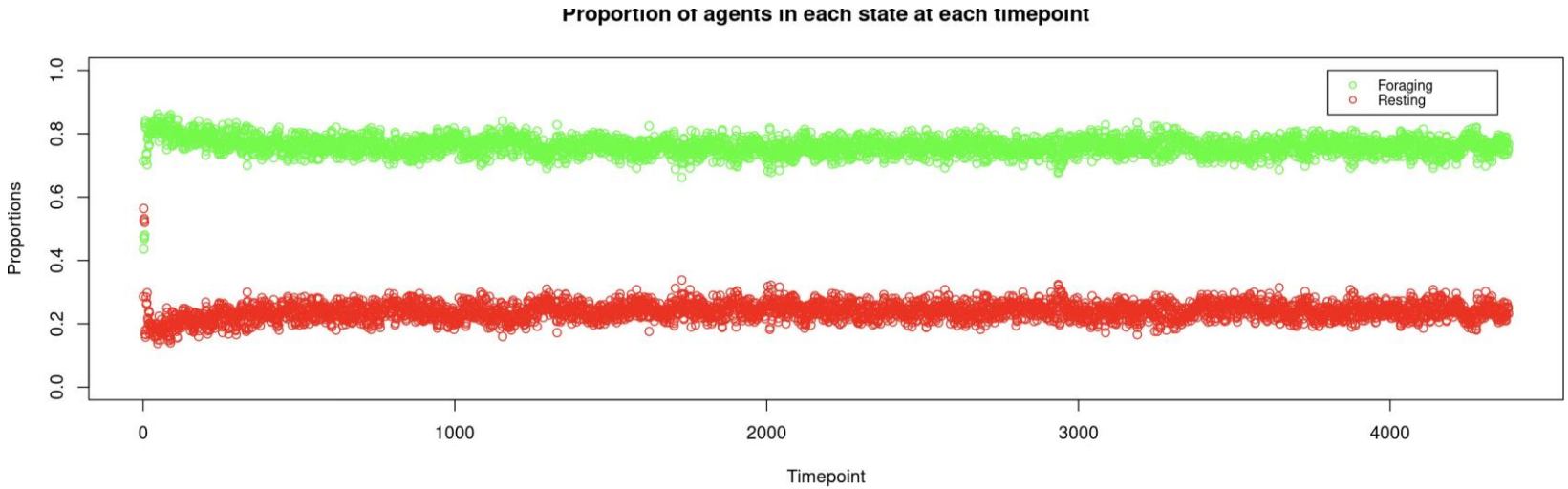
In the simulations, we calibrated multiple parameters based on agent and environmental properties such that a balance was maintained among the resource availability, agents' energy levels and their state. For example, the minimum resting threshold was chosen such that it maintained a constant ratio of agents in the foraging and resting state at each timepoint (Fig. Ca). Fig. C depicts the variations in the energy level of an agent at each time point. This value was influenced by the state of the agent as well as the land resource quality index of agent's current position at each timepoint.

1. Replenish value: Amount by which the resources got replenished at each time point. This value was a function of the current resource value of each cell, total number of agents present in the simulation as well as the size of the grid. The value was defined as:

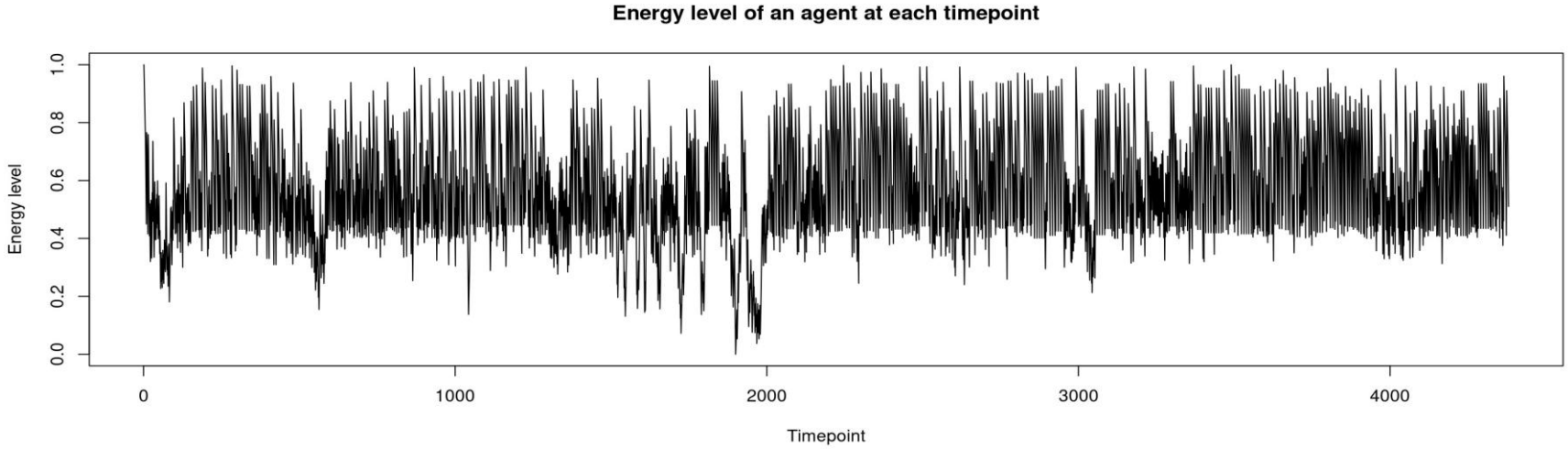
$$\text{NRI} = \text{CRI} + \text{Replenish constant} * \text{CRI}$$

where,
NRI = New resource index,
CRI = Current resource index,
Replenish constant = $0.25 * \frac{Number\ of\ agents}{40 * 40}$

2. Social threshold: It referred to the energy level at which agents prioritize seeking better resources over following their connections. In this context, the social threshold value was set at 0.5.
3. Energy depleted when moving: The quantity of energy expended during movement without resource consumption. This value was 0.1.
4. Energy depleted when resting: Amount of energy depleted while resting. This value was 0.05.
5. Minimum resting threshold: It referred to the minimum energy level at which the agent would choose to forage rather than continue resting. In this instance, the value was set at 0.75.
6. Searching span: It referred to the distance within which agents can search for their connections and subsequently follow them in a given direction. In this context, the search span was configured to extend 2 cells in each direction.
7. Movement span: Number of cells the agents can move at each time point. This value was set to one.



(a) This plot shows the proportion of individuals in each of the states of foraging and resting at each time point. The green points depict the proportion of agents in foraging state and the red points depict the proportion of agents in resting state.



(b) This plot depicts how the energy levels are varied across the duration of simulation for the agent 10. The energy levels were influenced by the resource quality of the agents's location at a timepoint and their internal state.

Fig. C Plots used for model caliberation

I.3 Plots for random versus group-wise sampling

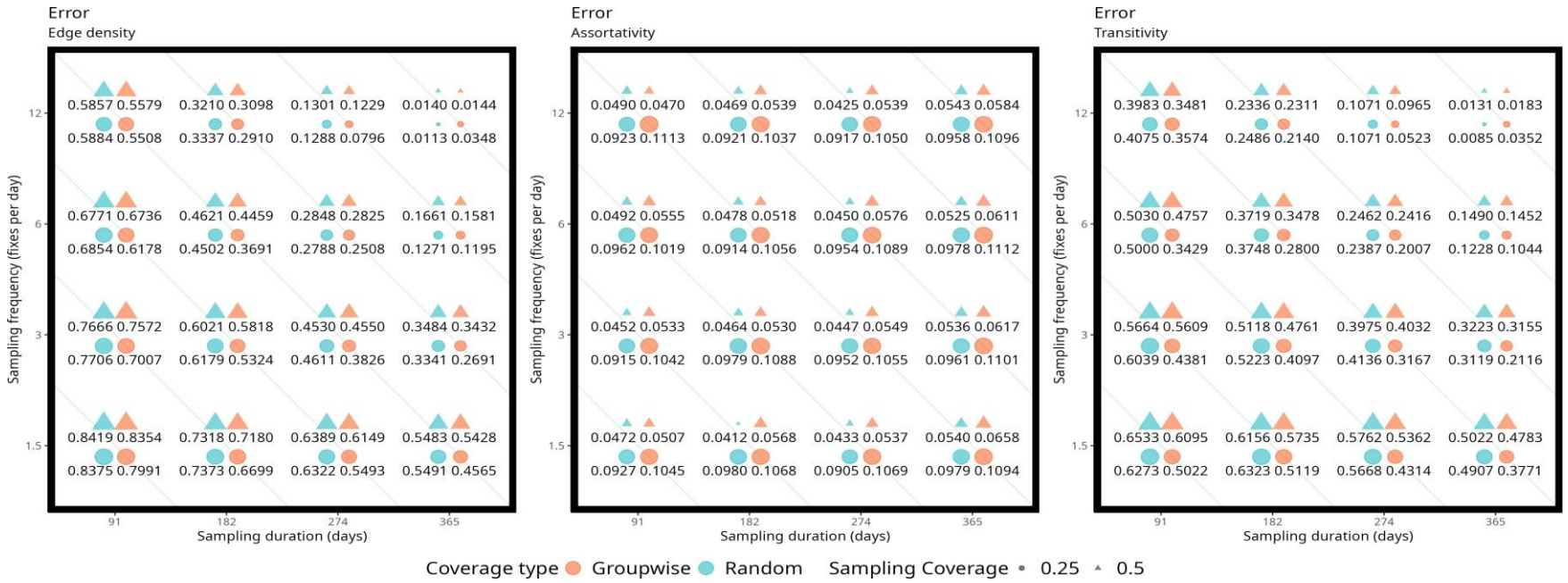


Fig. D Error comparison between networks resulting from random and groupwise sampling procedures. In each plot, the x- axis represents the sampling duration in days, while the y-axis represents frequency in fixes per day. Corresponding to each value of the duration and frequency, the sets of four points reflect the error in network metric values, with the size of each point corresponding to the magnitude of the error. The circular and triangle points indicate the sampling coverage of 25% and 50%, respectively. The black and red coloured points indicate random and groupwise sampling, respectively

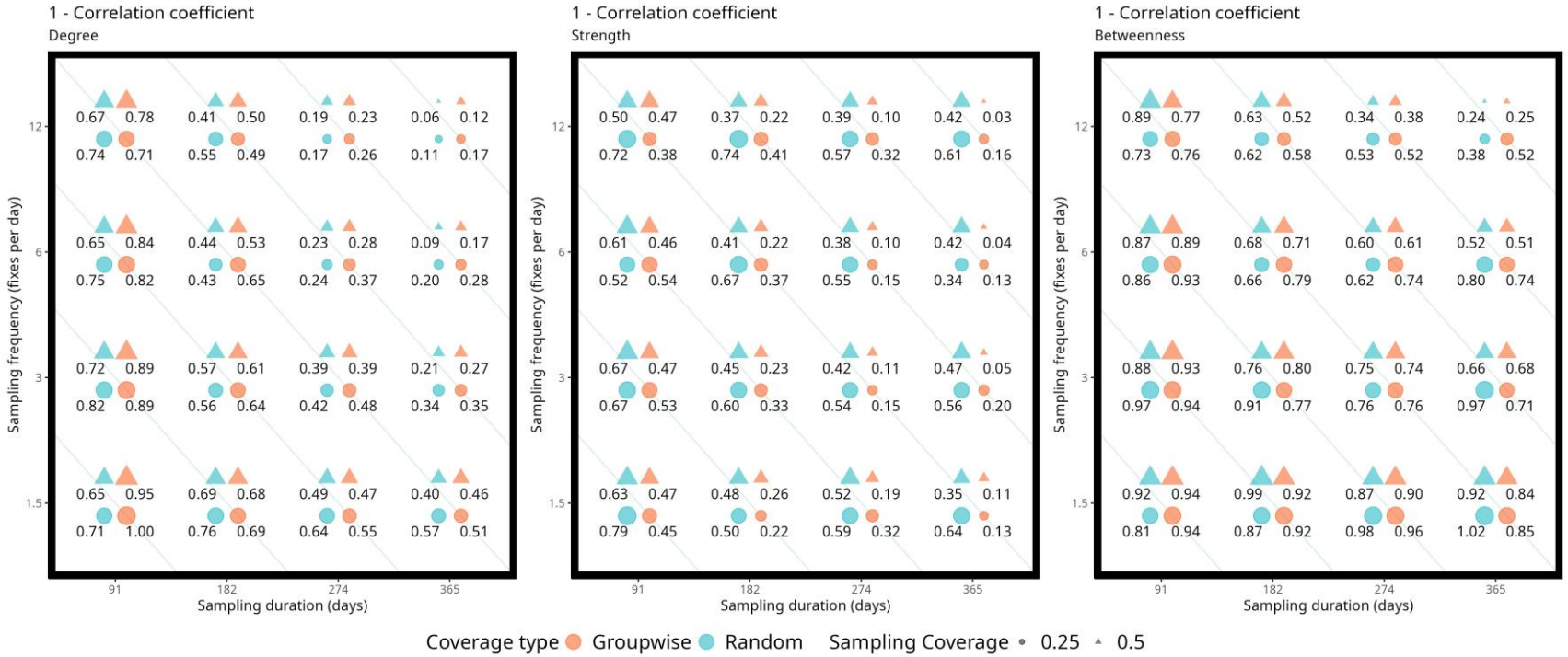


Fig. E Comparison of correlation coefficient values between networks resulting from random and groupwise sampling procedures. In each plot, the x-axis represents the sampling duration in days and the y-axis represents frequency in fixes per day. Corresponding to each value of the duration and frequency, the sets of four points represent 1 minus the correlation coefficient in network metric values, with the size of each point proportional to this value. Higher correlations indicate better agreement with the full dataset, hence low values depicted here (1-correlation) indicate good agreement. The circular and triangle points indicate the sampling coverage of 25% and 50%, respectively. The black and red coloured points indicate random and groupwise sampling, respectively