# Particle Methods Homework 2 – Metehan Dündar

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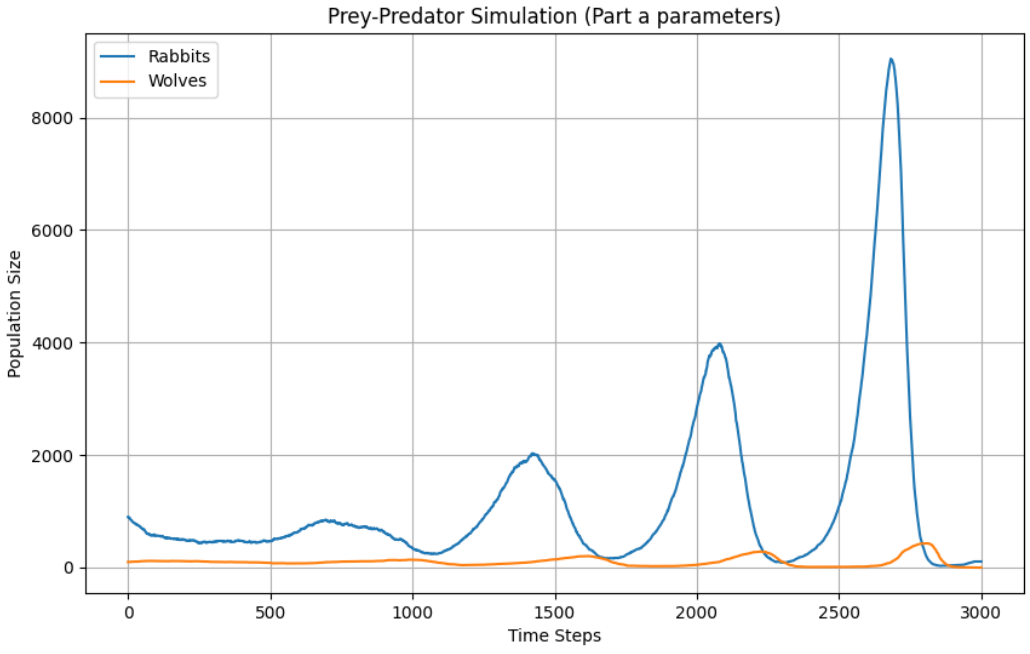
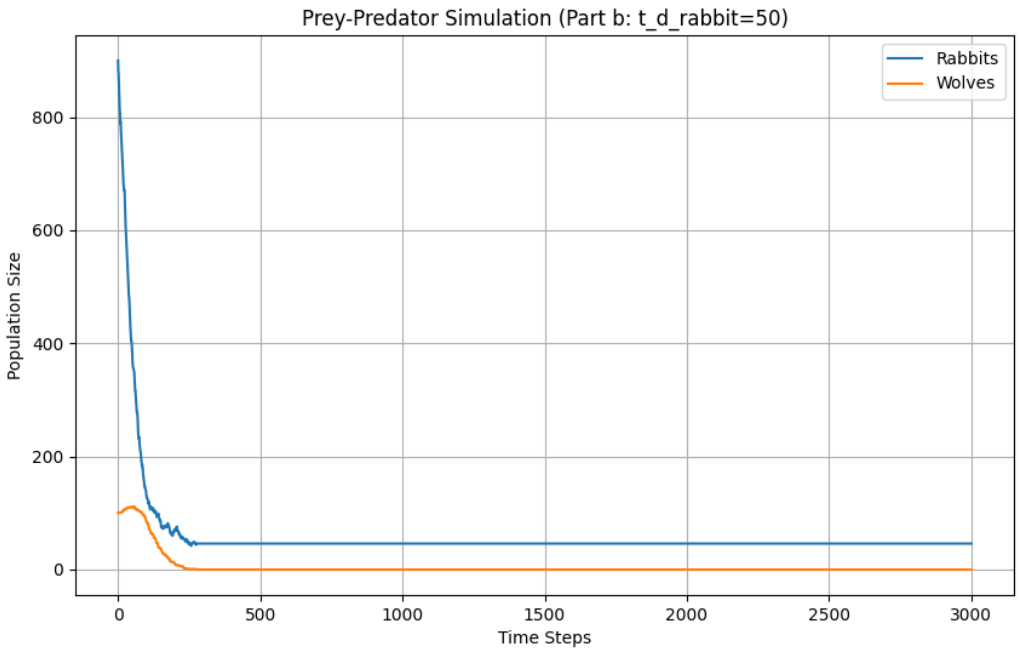
## A) Baseline Simulation (sigma=0.5, t_d^r=100)

- **Observations:** The simulation showed cyclical oscillations in rabbit and wolf populations, characteristic of predator-prey dynamics. Rabbit population peaks were generally followed by wolf population peaks, which then led to a decline in rabbits, followed by a decline in wolves. In the specific run analyzed, the wolf population eventually went extinct around step 2978 due to a preceding crash in the rabbit population.
- **Comparison to Lotka-Volterra:**
    - *Similarities:* The observed phase-lagged oscillations are qualitatively similar to those predicted by the deterministic Lotka-Volterra equations.
    - *Differences:* Unlike the stable cycles of the basic L-V model, the simulation exhibited stochastic fluctuations in amplitude and period length. Key differences arise from:
        - *Stochasticity:* Random events (movement, replication, death, eating) introduce noise.
        - *Discrete Agents/Time:* The model uses discrete units, not continuous densities.
        - *Spatial Dynamics:* Explicit space and proximity-based predation (r_c) differ from the L-V well-mixed assumption.
        - *Specific Rules:* Fixed rabbit lifespan and wolf starvation timer add biological details absent in basic L-V.
        - *Extinction:* Stochasticity allows for population extinction, which occurred for wolves in this run.



# B) Reduced Rabbit Lifespan (t_d^r=50)

- **Observations:** The simulation results changed drastically. Both populations declined rapidly, and the wolf population went extinct very early (around step 276). Sustained oscillations were not observed.
- **Explanation:** Halving the rabbit lifespan significantly increased their natural mortality rate. This heavily suppressed the rabbit population's ability to recover from predation and natural deaths, making the prey base unsustainable. The rapid decline in rabbits led directly to the swift starvation and extinction of the wolf population, as their food source disappeared too quickly for them to survive the t_d^w = 50 step starvation period.

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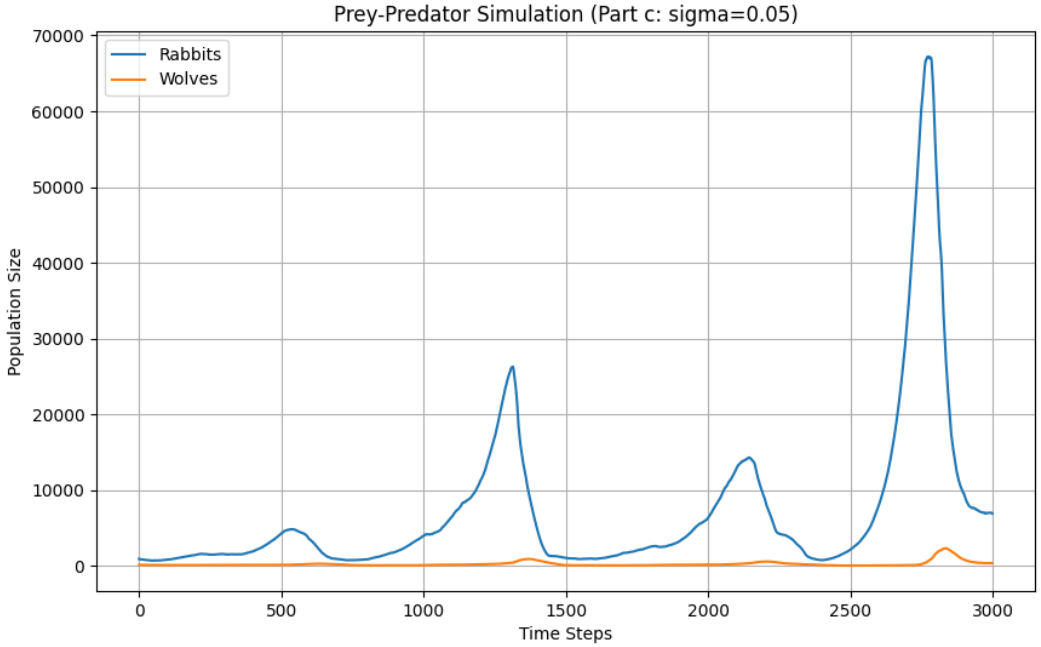
# C) Reduced Mobility (sigma=0.05, L=8)

- **Observations:** This scenario yielded results distinct from both (a) and (b). Both populations persisted for the full 3000 steps. Population numbers reached much higher peaks (e.g., rabbits > 50,000, wolves > 1,500) compared to part (a). Oscillations were still present but appeared slower and more extreme or 'spiky'.
- **Comparison to Part (a):** The key difference is the drastically reduced agent mobility. This led to:
    - **Spatial Clustering:** Agents move very little, promoting the formation of dense local rabbit clusters and patchy distributions.
    - **Altered Dynamics:** Reduced encounter rates likely allowed rabbit clusters to grow much larger before significant predation occurred, contributing to higher peaks. Dynamics are dominated by these spatial effects rather than a well-mixed interaction.

- **Lotka-Volterra Approximation:** L-V is an even worse approximation here than in part (a). The strong spatial structuring violates the fundamental well-mixed assumption of L-V far more significantly.
- **What Makes the Difference:** The agent mobility (sigma) is the crucial factor. Low mobility transforms the system dynamics from quasi-mixed to spatially dominated, altering interaction rates, population scales, and stability.

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# Conclusion

This agent-based simulation demonstrated classic predator-prey oscillations but also highlighted significant deviations from the idealized Lotka-Volterra model due to stochasticity, spatial dynamics, and specific biological rules (lifespan, starvation). The results showed high sensitivity to parameter changes: reducing prey lifespan led to rapid system collapse (Part b), while reducing agent mobility led to spatially structured dynamics with larger populations and greater persistence (Part c). These findings emphasize the importance of considering individual behaviors, spatial effects, and stochasticity when modeling ecological systems.