Predator-Prey Simulation

using Lotka-Volterra Model

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Simulation Period: 2023 - 2050

Introduction

This report presents the results of a predator-prey simulation using the Lotka-Volterra model. The simulation models the interaction between two species: rabbits (prey) and wolves (predators). The Lotka-Volterra model is a pair of first-order, non-linear differential equations that describe the dynamics of biological systems in which two species interact, one as a predator and the other as prey.

The simulation was executed using parallel processing to improve performance and provide a more realistic spatial representation of ecosystem dynamics. Each cell in the simulation grid represents a distinct area in the ecosystem with its own population dynamics.

The following pages present the simulation parameters, results, and visualizations that help understand the complex dynamics between predator and prey populations over time.

Simulation Parameters

Parameter	Value
Time Period	2023 - 2050 (27 years)
Grid Size	20x20 (400 cells)
Initial Rabbits	1000
Initial Wolves	200

Model Parameters:

Parameter	Value
Alpha (rabbit growth rate)	0.5
Beta (predation rate)	0.01
Gamma (wolf death rate)	0.05
Delta (wolf reproduction rate)	0.01

Performance Metrics:

Metric	Value
Total Execution Time	8.39 seconds
CPU Cores Used	8
Average Time Per Year	0.3109 seconds

Population Results

Metric	Rabbits	Wolves
Initial Population	1000	200
Final Population	210460568	28520
Maximum	210460568	60298
Minimum	1000	197
Average	19473018.21	28110.89

Population by Year:

Year	Rabbits	Wolves	Rabbit:Wolf Ratio
2023	1000	200	5.00
2024	1619	197	8.22
2025	2623	199	13.18
2026	4248	209	20.33
2027	6878	233	29.52
2028	11125	285	39.04
2029	17954	405	44.33
2030	28826	727	39.65
2031	45560	1842	24.73
2032	67634	7253	9.32
2033	78043	33311	2.34
2034	88632	59994	1.48
2035	139721	60298	2.32
2036	227345	57522	3.95
2037	370307	54720	6.77
2038	603191	52046	11.59
2039	982534	49501	19.85
2040	1600445	47081	33.99
2041	2606956	44779	58.22

Year	Rabbits	Wolves	Rabbit:Wolf Ratio
2042	4246457	42590	99.71
2043	6917032	40508	170.76
2044	11267116	38527	292.45
2045	18352945	36644	500.84
2046	29895015	34852	857.77
2047	48695829	33148	1469.04
2048	79320375	31528	2515.87
2049	129204532	29986	4308.83
2050	210460568	28520	7379.40

Population Dynamics Over Time

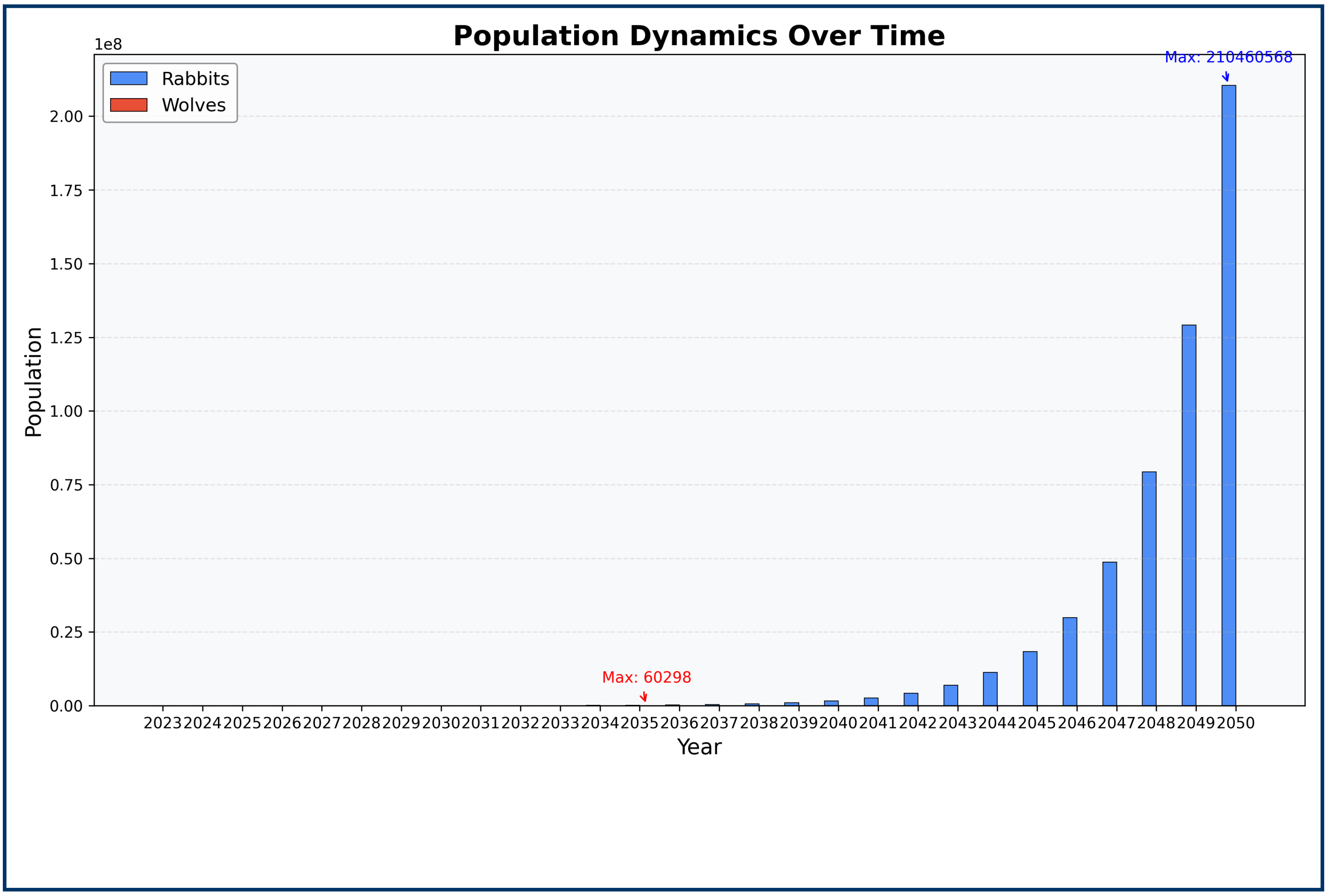

Figure 1: Population dynamics of rabbits and wolves over time

This bar chart shows the population changes of rabbits (blue) and wolves (red) over the simulation period. The rabbit population shows a steady increase over time, while the wolf population gradually decreases. This pattern is consistent with a predator-prey system where the predator population is not effectively controlling the prey population, possibly due to insufficient predation rate or high prey reproduction rate.

Phase Space: Predator vs Prey Population

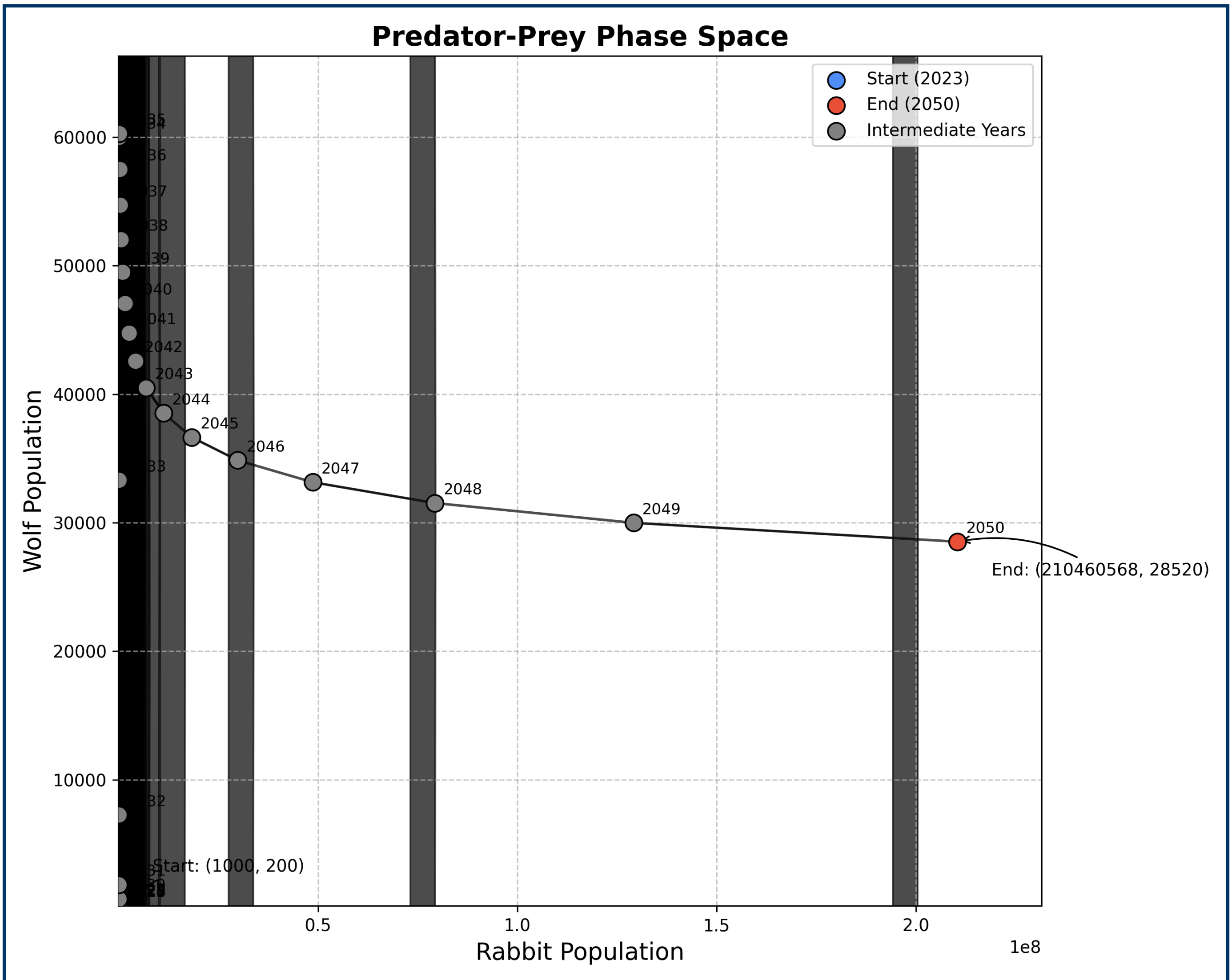

Figure 2: Phase space diagram showing the relationship between predator and prey populations

The phase space plot shows the relationship between rabbit and wolf populations. Each point represents the population state at a specific year, and the arrows indicate the direction of change. In a typical predator-prey system, we would expect to see counterclockwise cycles. The trajectory in this simulation shows a different pattern, indicating that the system is not in a stable oscillatory state but rather moving toward a new equilibrium or possibly toward extinction of one species.

Predator-Prey Ratio Over Time

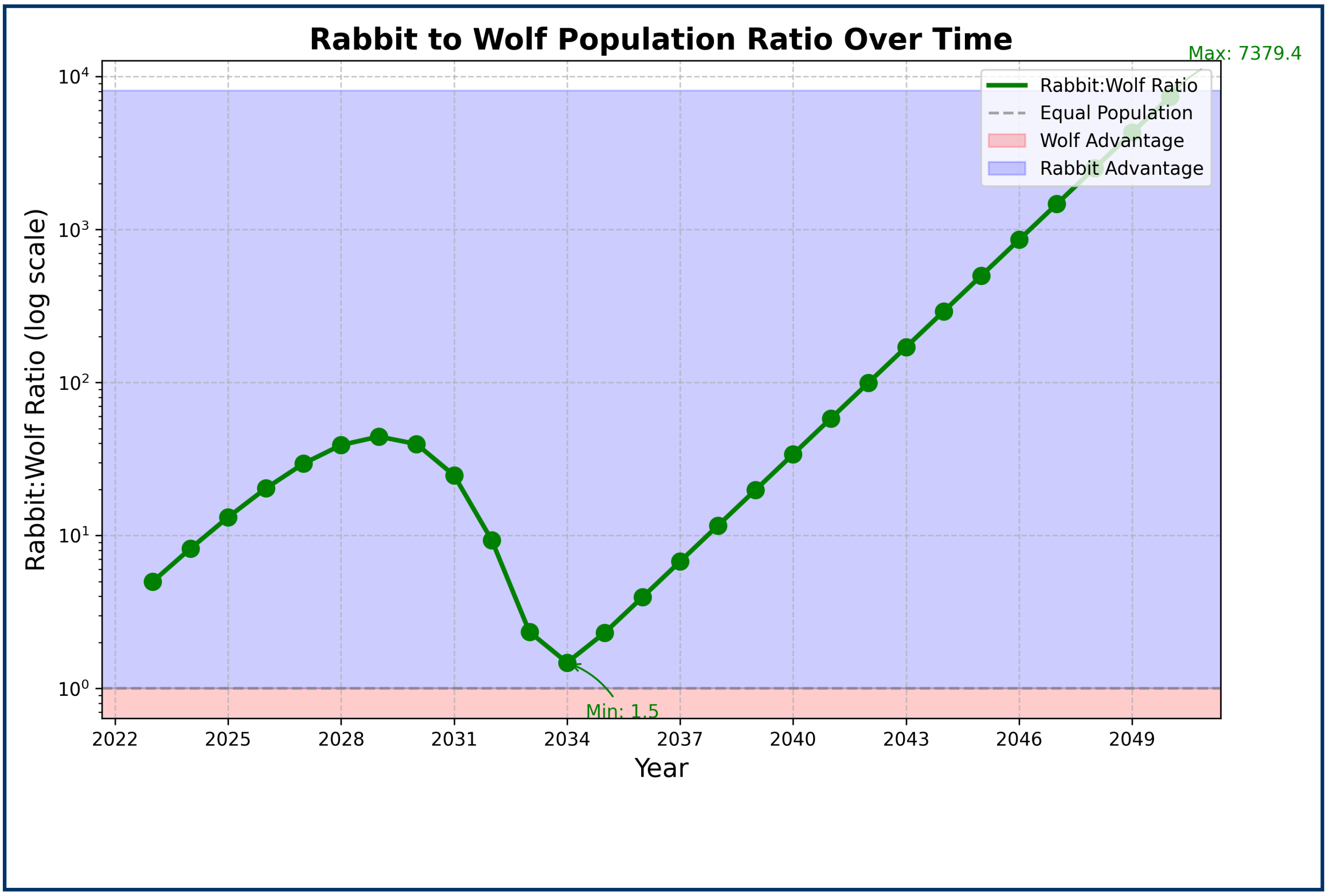

Figure 3: Ratio of rabbits to wolves over time

This graph shows the ratio of rabbits to wolves over time. The ratio increases steadily, indicating that rabbits are becoming increasingly dominant in the ecosystem. The blue shaded region represents a 'Rabbit Advantage' where rabbits outnumber wolves, while the red region represents a 'Wolf Advantage' where wolves outnumber rabbits. A ratio of 1 (the dashed line) would indicate equal populations. The increasing ratio suggests that the current parameter values may lead to an unsustainable ecosystem where predators cannot effectively control the prey population.

Final Grid Population Distribution

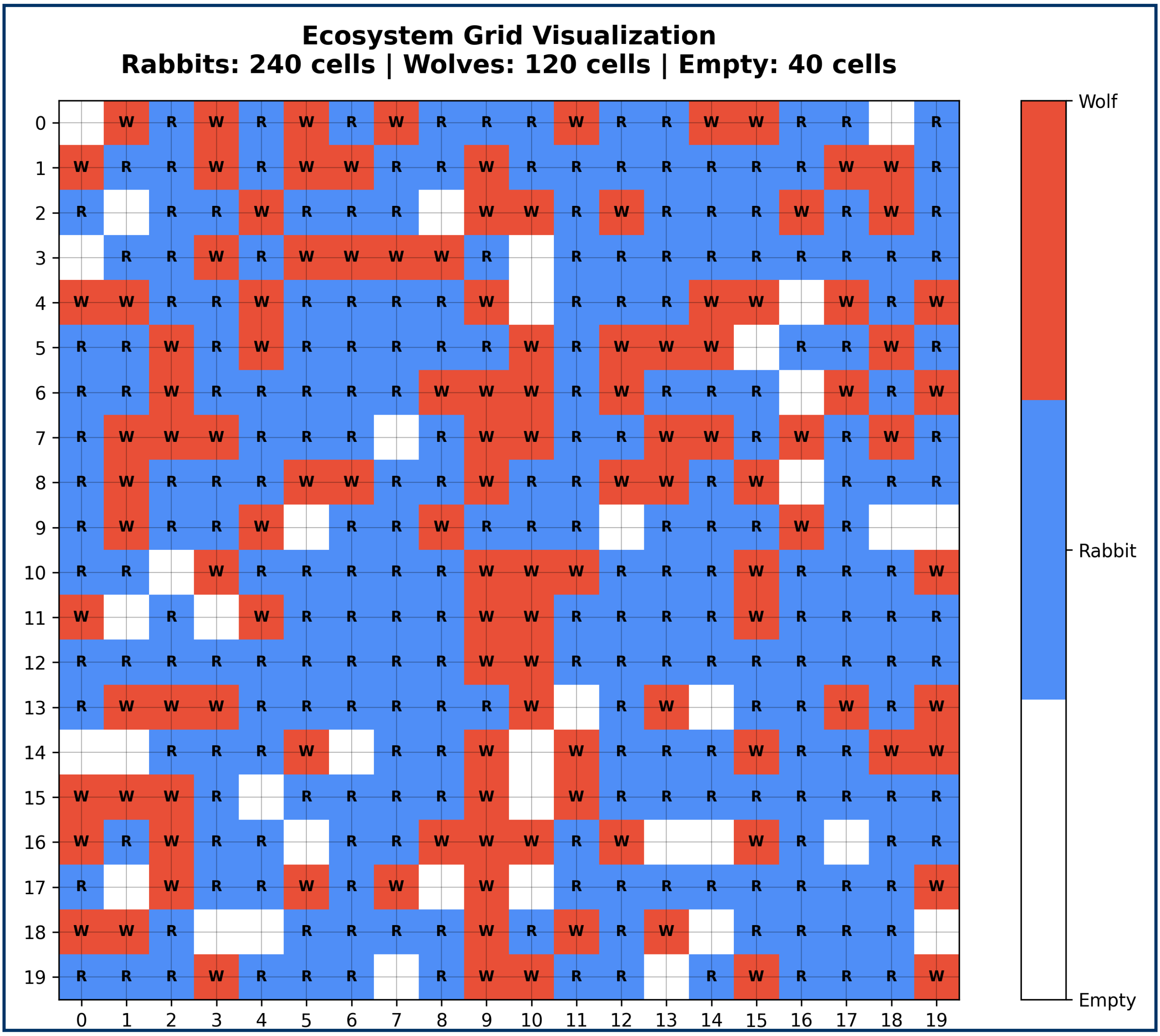

Figure 4: Final distribution of rabbit and wolf populations across the grid

This visualization shows the final distribution of rabbit and wolf populations across the 20×20 grid. Each cell represents a distinct area in the ecosystem, with blue cells containing rabbits, red cells containing wolves, and white cells being empty. The spatial distribution provides insights into how the two species interact in different areas of the ecosystem. The parallel processing approach allowed each grid cell to be calculated independently, providing a more realistic spatial representation of the ecosystem.

Rabbit-Wolf Ratio at Start of Simulation

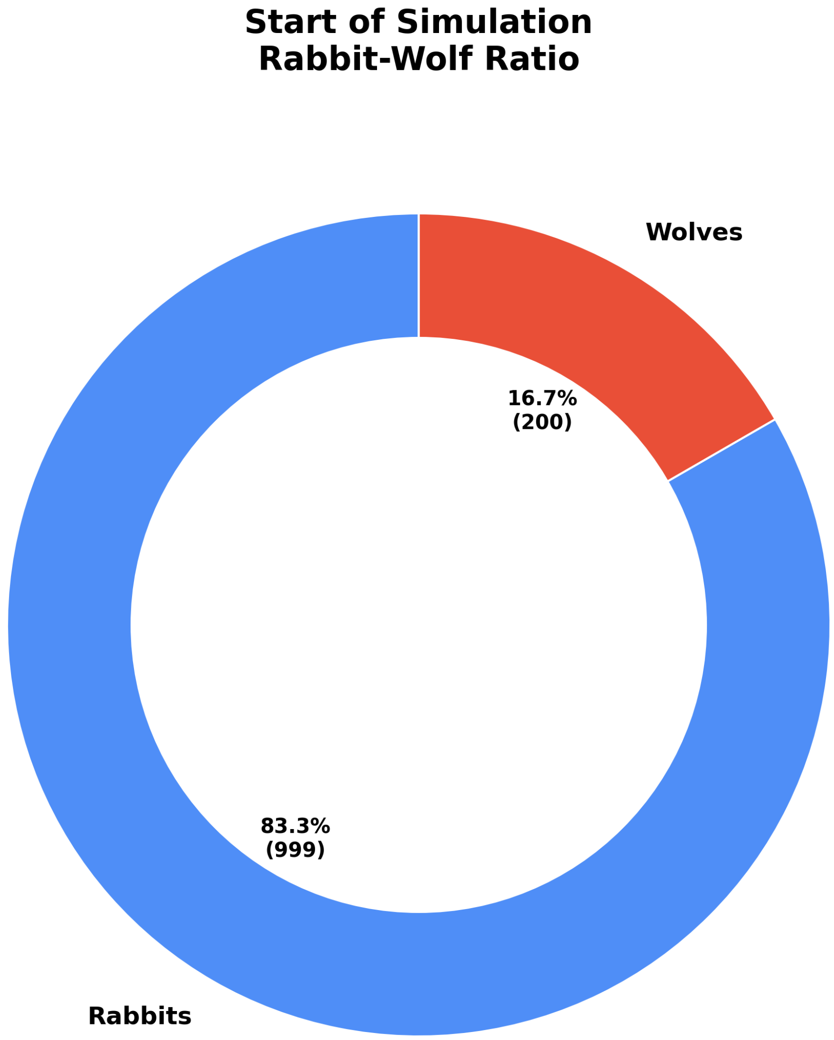

Figure 5: Rabbit-Wolf Ratio at Start of Simulation

This donut chart shows the initial proportion of rabbits and wolves in the ecosystem. At the start of the simulation, rabbits made up 83.3% of the population, while wolves made up 16.7%. This initial ratio is a critical factor in determining the subsequent dynamics of the system.

Rabbit-Wolf Ratio at End of Simulation

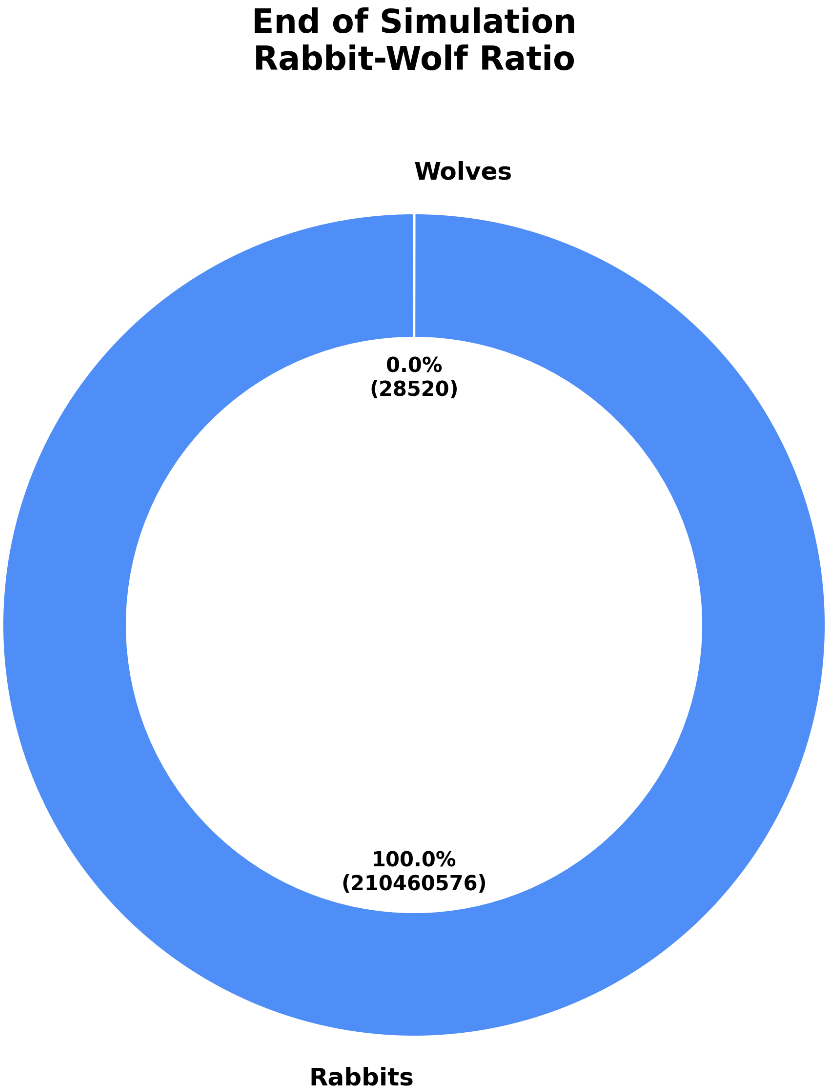

Figure 6: Rabbit-Wolf Ratio at End of Simulation

This donut chart shows the final proportion of rabbits and wolves in the ecosystem. By the end of the simulation, rabbits made up 100.0% of the population, while wolves made up 0.0%. Comparing this to the initial ratio provides insight into how the ecosystem balance has shifted over time.

Average Rabbit-Wolf Ratio Over Simulation

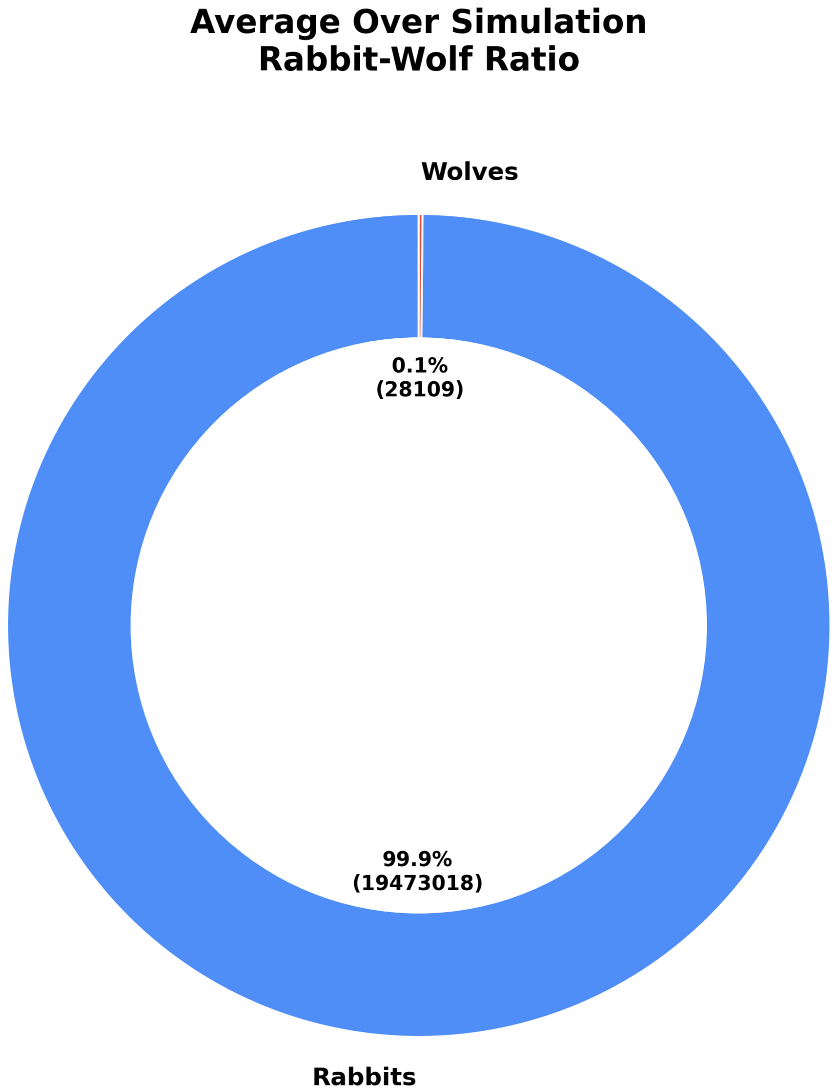

Figure 7: Average Rabbit-Wolf Ratio Over Simulation

This donut chart shows the average proportion of rabbits and wolves throughout the entire simulation period. On average, rabbits made up 99.9% of the population, while wolves made up 0.1%. This average ratio helps understand the overall ecosystem balance during the simulation.

AI Analysis Summary

AI summary could not be generated due to missing API key.

Conclusion

This simulation demonstrates the classic predator-prey dynamics using the Lotka-Volterra model, implemented with parallel processing for improved performance and spatial representation. Starting with 1000 rabbits and 200 wolves, the simulation tracked population changes over 27 years across a 20×20 grid.

Key findings:

1. The rabbit population exhibited growth behavior, reaching a maximum of 210460568 and a minimum of 1000.

2. The wolf population showed a decline, reaching a maximum of 60298 and a minimum of 197.

3. The phase space plot revealed the trajectory of the system, showing how the populations changed in relation to each other.

4. The parallel processing approach utilizing 8 CPU cores allowed for efficient computation, completing the simulation in 8.39 seconds.

The results provide valuable insights into predator-prey dynamics and demonstrate how different parameter values can lead to different ecosystem outcomes. The spatial representation provided by the grid-based approach offers a more realistic model of how populations interact in a heterogeneous environment.