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	100000
Initial Wolves	195

Model Parameters:

Parameter	Value
Alpha (rabbit growth rate)	0.1
Beta (predation rate)	0.01
Gamma (wolf death rate)	0.1
Delta (wolf reproduction rate)	0.01

Performance Metrics:

Metric	Value
Total Execution Time	12.57 seconds
CPU Cores Used	8
Average Time Per Year	0.4657 seconds

Population Results

Metric	Rabbits	Wolves
Initial Population	100000	195
Final Population	752427	5211
Maximum	752427	52205
Minimum	76284	195
Average	271603.29	20318.93

Population by Year:

Year	Rabbits	Wolves	Rabbit:Wolf Ratio
2023	100000	195	512.82
2024	108742	1803	60.31
2025	104548	16313	6.41
2026	76284	50356	1.51
2027	76657	52205	1.47
2028	84308	47536	1.77
2029	93107	43010	2.16
2030	102846	38898	2.64
2031	113606	35179	3.23
2032	125492	31815	3.94
2033	138621	28773	4.82
2034	153124	26022	5.88
2035	169144	23534	7.19
2036	186841	21283	8.78
2037	206388	19248	10.72
2038	227981	17408	13.10
2039	251833	15743	16.00
2040	278180	14238	19.54
2041	307284	12876	23.86

Year	Rabbits	Wolves	Rabbit:Wolf Ratio
2042	339433	11645	29.15
2043	374945	10532	35.60
2044	414173	9525	43.48
2045	457505	8614	53.11
2046	505370	7790	64.87
2047	558243	7045	79.24
2048	616647	6371	96.79
2049	681163	5762	118.22
2050	752427	5211	144.39

Population Dynamics Over Time

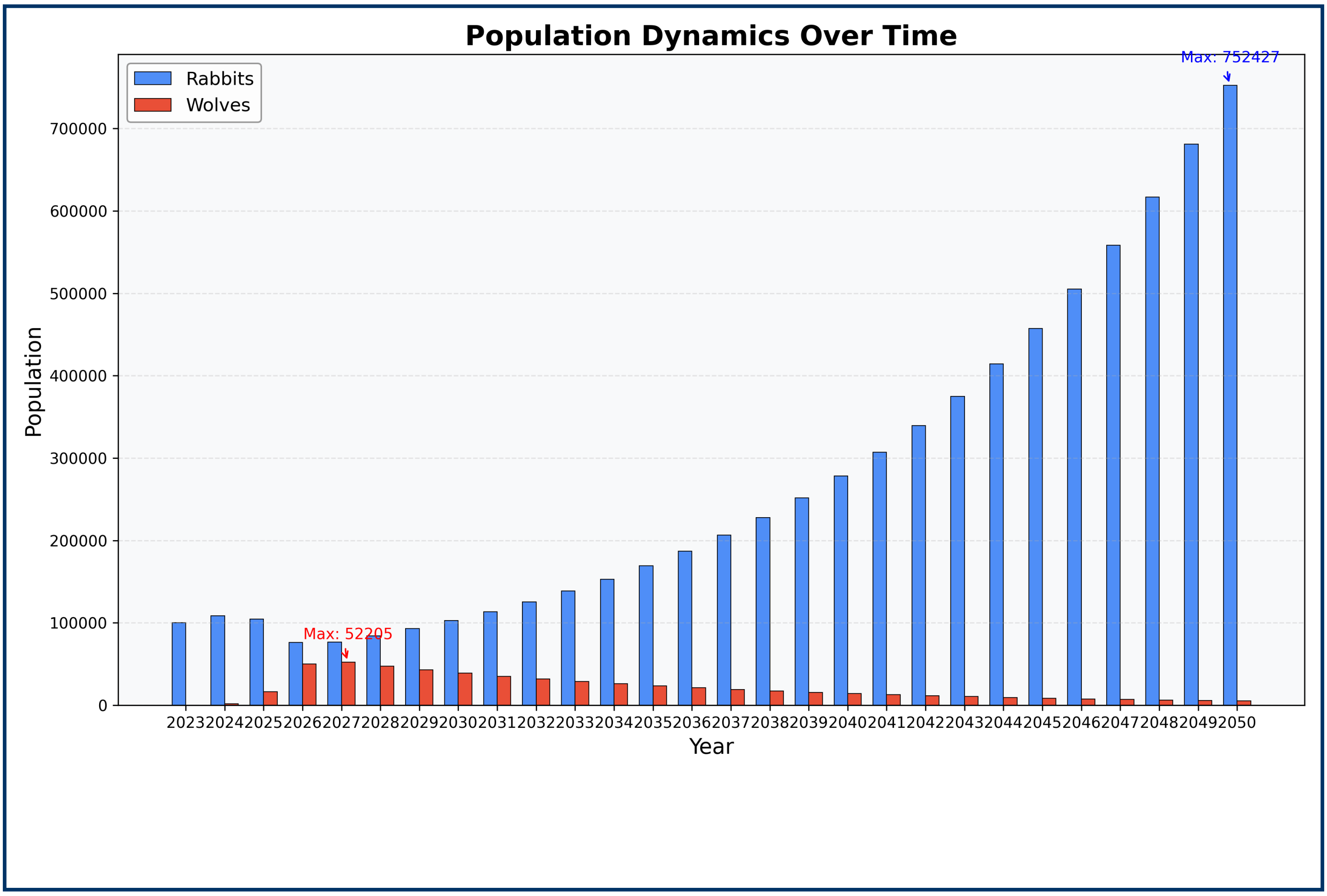

Figure 1: Population dynamics of rabbits and wolves over time

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

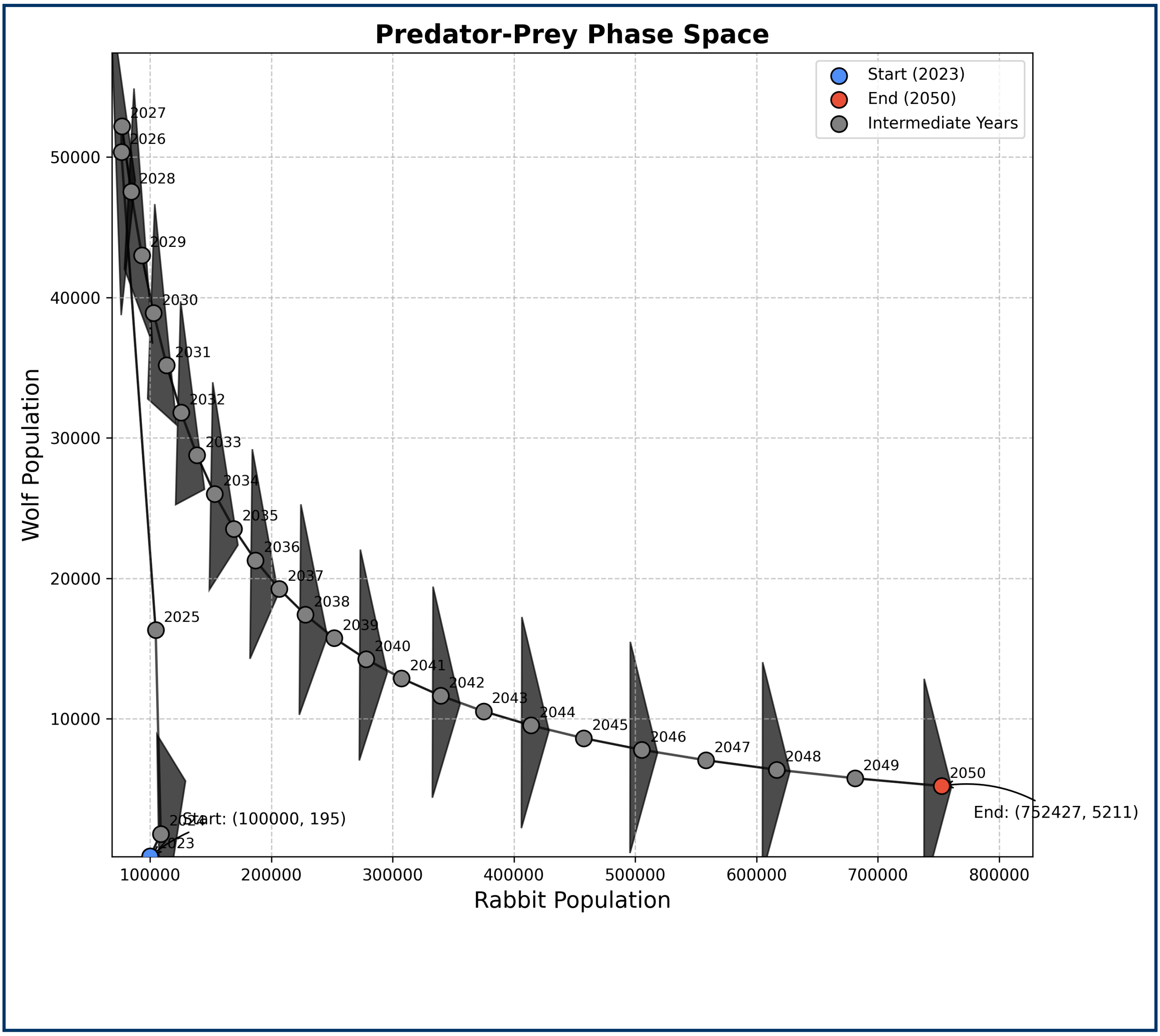

Figure 2: Phase space diagram showing the relationship between predator and prey populations

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

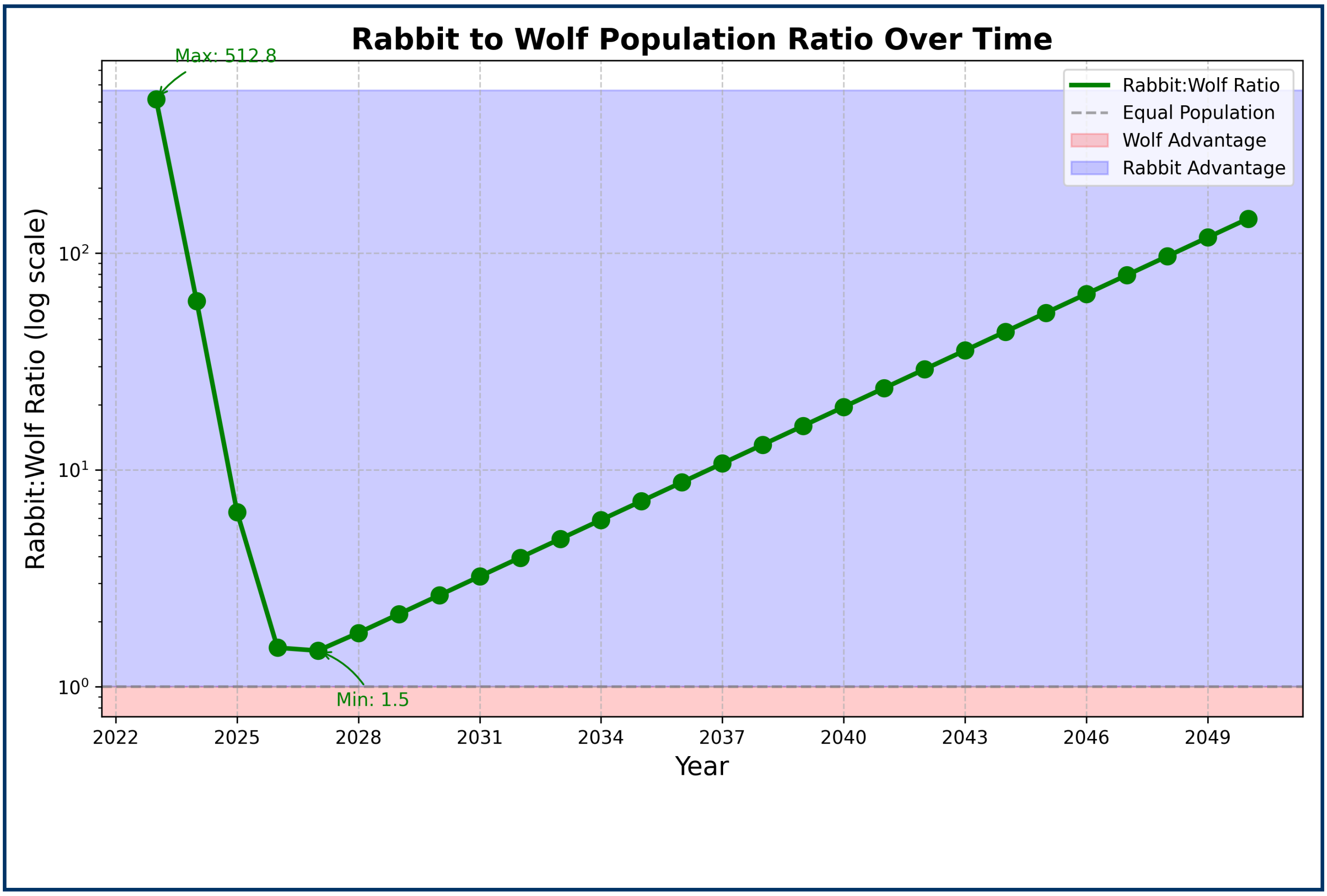

Figure 3: Ratio of rabbits to wolves over time

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

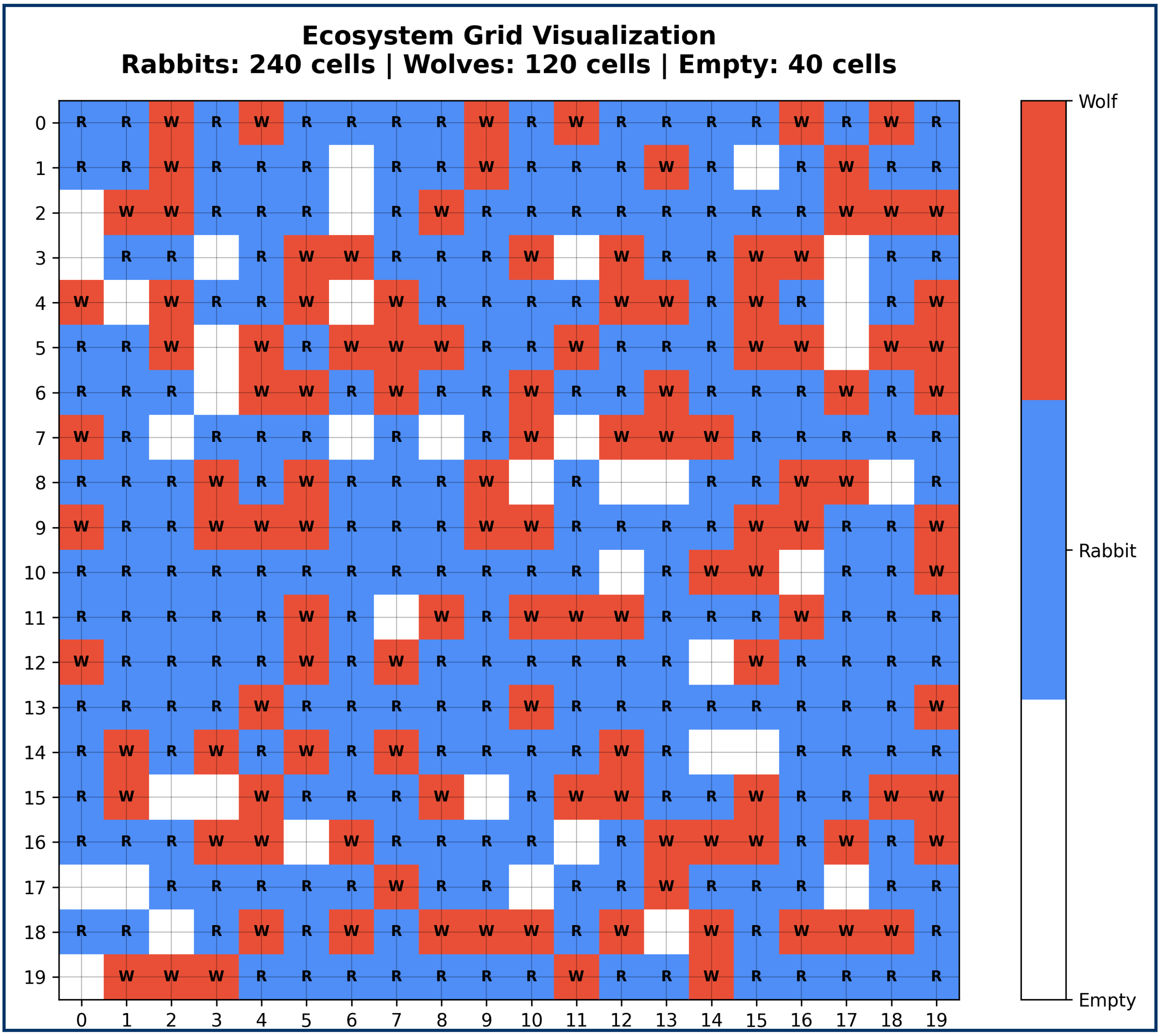

Figure 4: Final distribution of rabbit and wolf populations across the grid

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

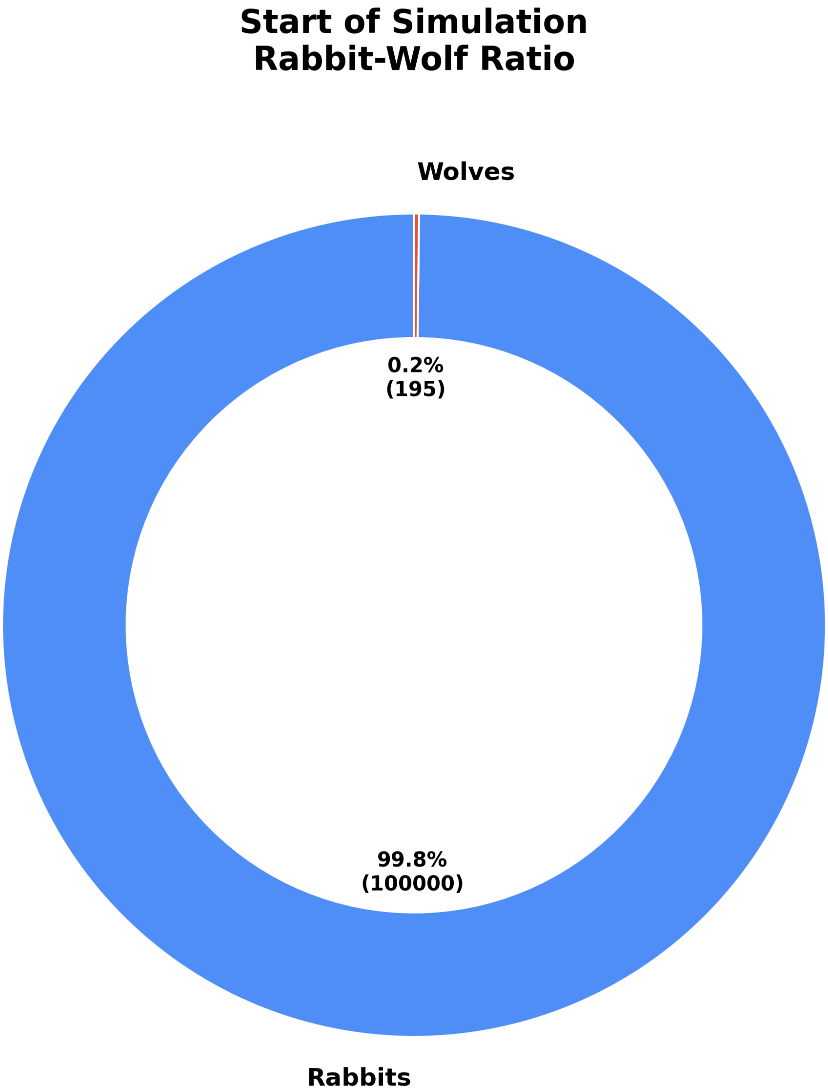

Figure 5: Rabbit-Wolf Ratio at Start of Simulation

This donut chart shows the initial proportion of rabbits and wolves in the ecosystem. At the start of the simulation, rabbits made up 99.8% of the population, while wolves made up 0.2%. This initial ratio is a critical factor in determining the subsequent dynamics of the system.

Rabbit-Wolf Ratio at End of Simulation

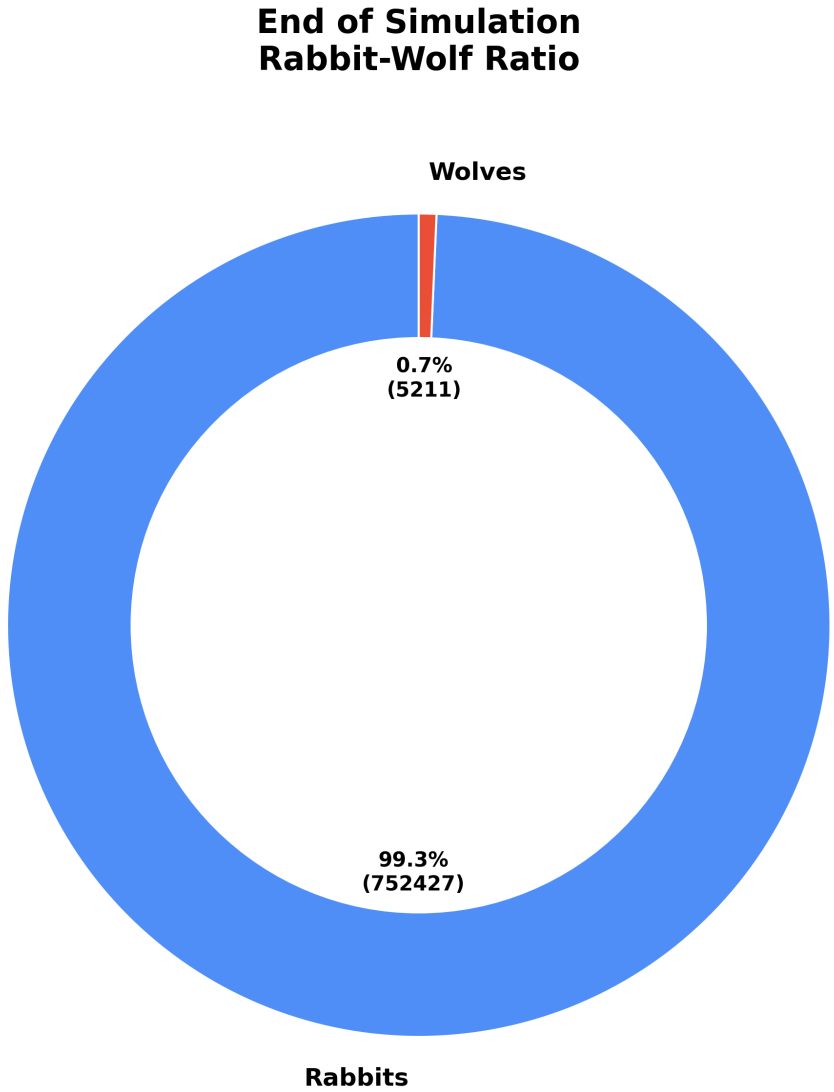

Figure 6: Rabbit-Wolf Ratio at End of Simulation

This donut chart shows the final proportion of rabbits and wolves in the ecosystem. By the end of the simulation, rabbits made up 99.3% of the population, while wolves made up 0.7%. Comparing this to the initial ratio provides insight into how the ecosystem balance has shifted over time.

Average Rabbit-Wolf Ratio Over Simulation

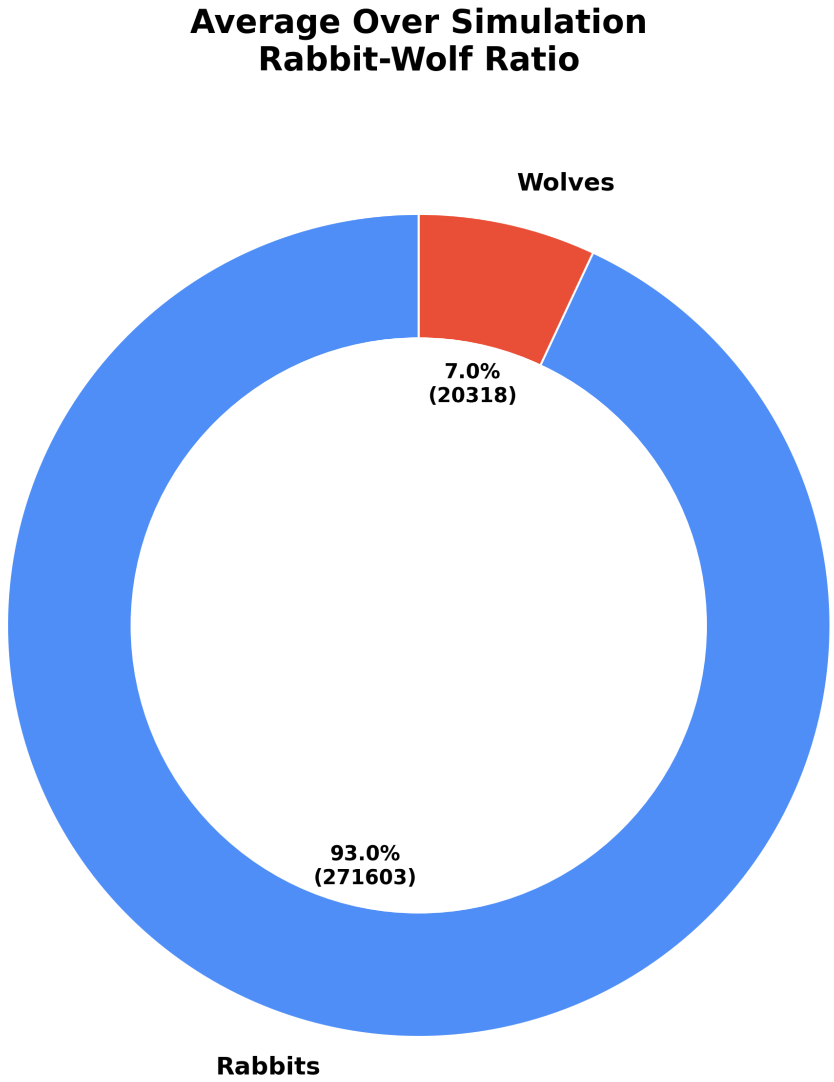

Figure 7: Average Rabbit-Wolf Ratio Over Simulation

This donut chart shows the average proportion of rabbits and wolves throughout the entire simulation period. On average, rabbits made up 93.0% of the population, while wolves made up 7.0%. 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 100000 rabbits and 195 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 752427 and a minimum of 76284.

2. The wolf population showed a decline, reaching a maximum of 52205 and a minimum of 195.

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 12.57 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.