Predator-Prey Simulation

using Lotka-Volterra Model

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Simulation Period: 2023 - 2033

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 - 2033 (10 years)
Grid Size	5x5 (25 cells)
Initial Rabbits	100
Initial Wolves	20

Model Parameters:

Parameter	Value
Alpha (rabbit growth rate)	0.1
Beta (predation rate)	0.01
Gamma (wolf death rate)	0.05
Delta (wolf reproduction rate)	0.001

Performance Metrics:

Metric	Value
Total Execution Time	8.96 seconds
CPU Cores Used	8
Average Time Per Year	0.8963 seconds

Population Results

Metric	Rabbits	Wolves
Initial Population	100	20
Final Population	253	12
Maximum	253	20
Minimum	100	12
Average	165.45	15.73

Population by Year:

Year	Rabbits	Wolves	Rabbit:Wolf Ratio
2023	100	20	5.00
2024	109	19	5.74
2025	120	18	6.67
2026	131	17	7.71
2027	144	16	9.00
2028	158	15	10.53
2029	174	15	11.60
2030	191	14	13.64
2031	210	14	15.00
2032	230	13	17.69
2033	253	12	21.08

Population Dynamics Over Time

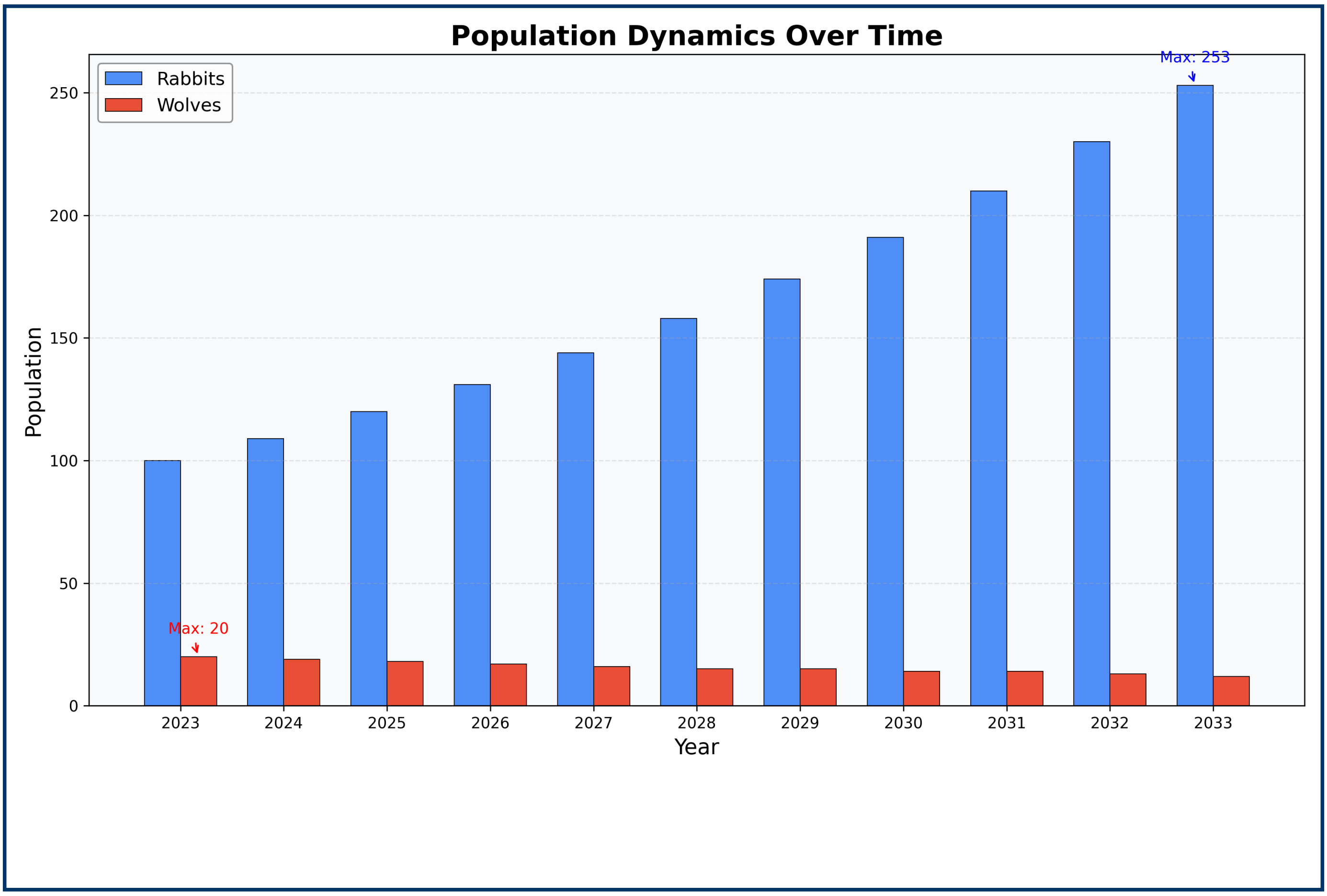

Figure 1: Population dynamics of rabbits and wolves over time

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

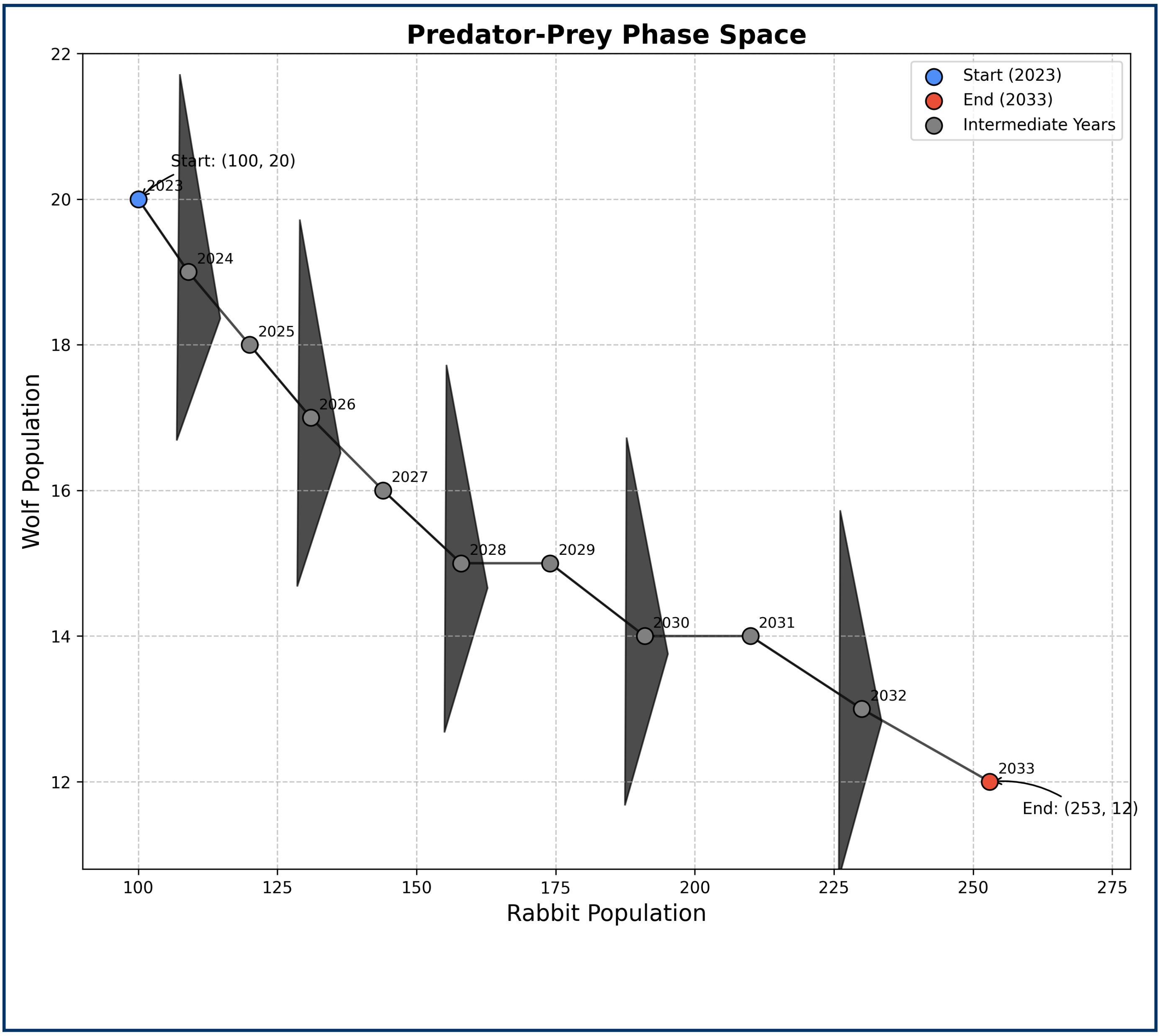

Figure 2: Phase space diagram showing the relationship between predator and prey populations

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

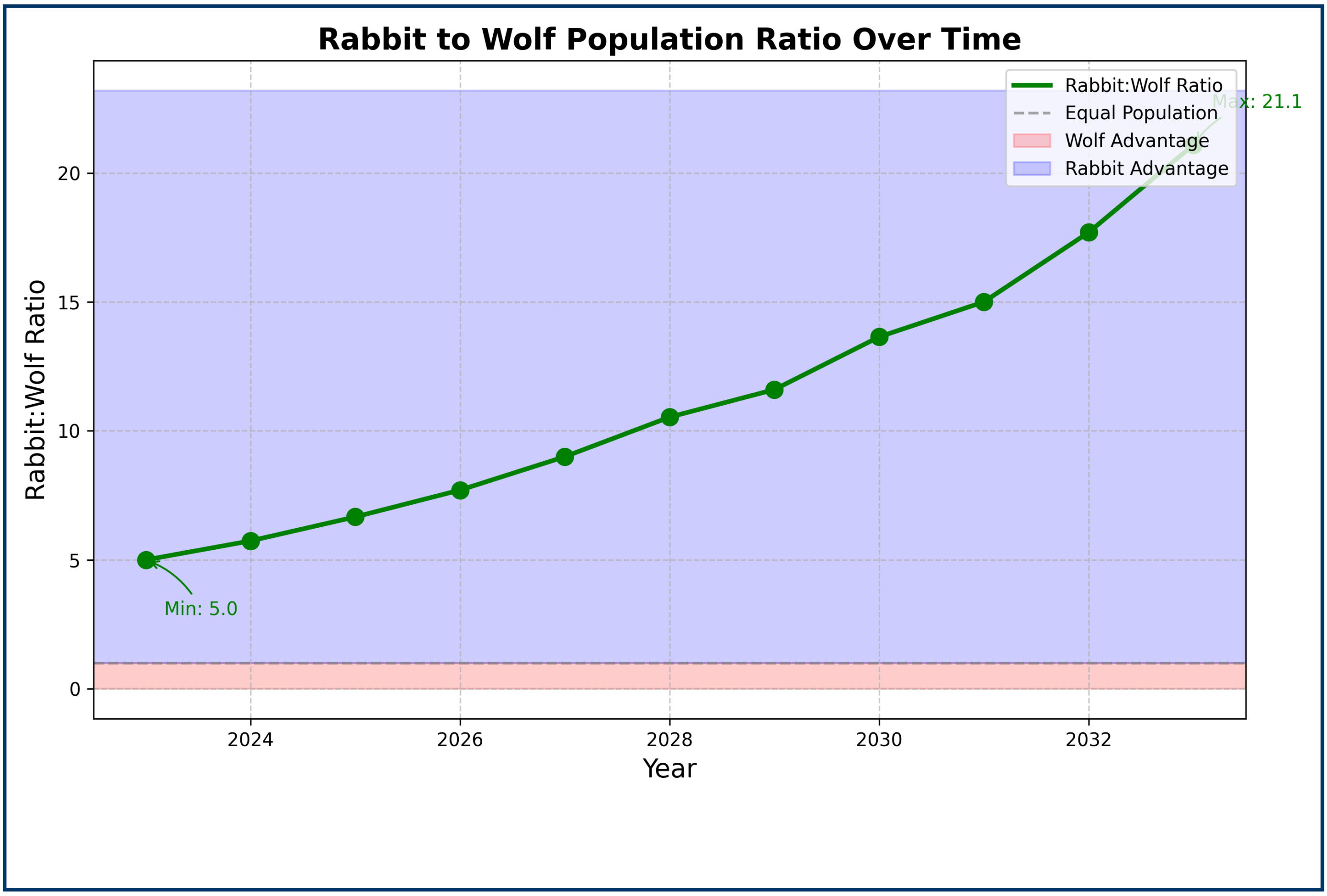

Figure 3: Ratio of rabbits to wolves over time

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

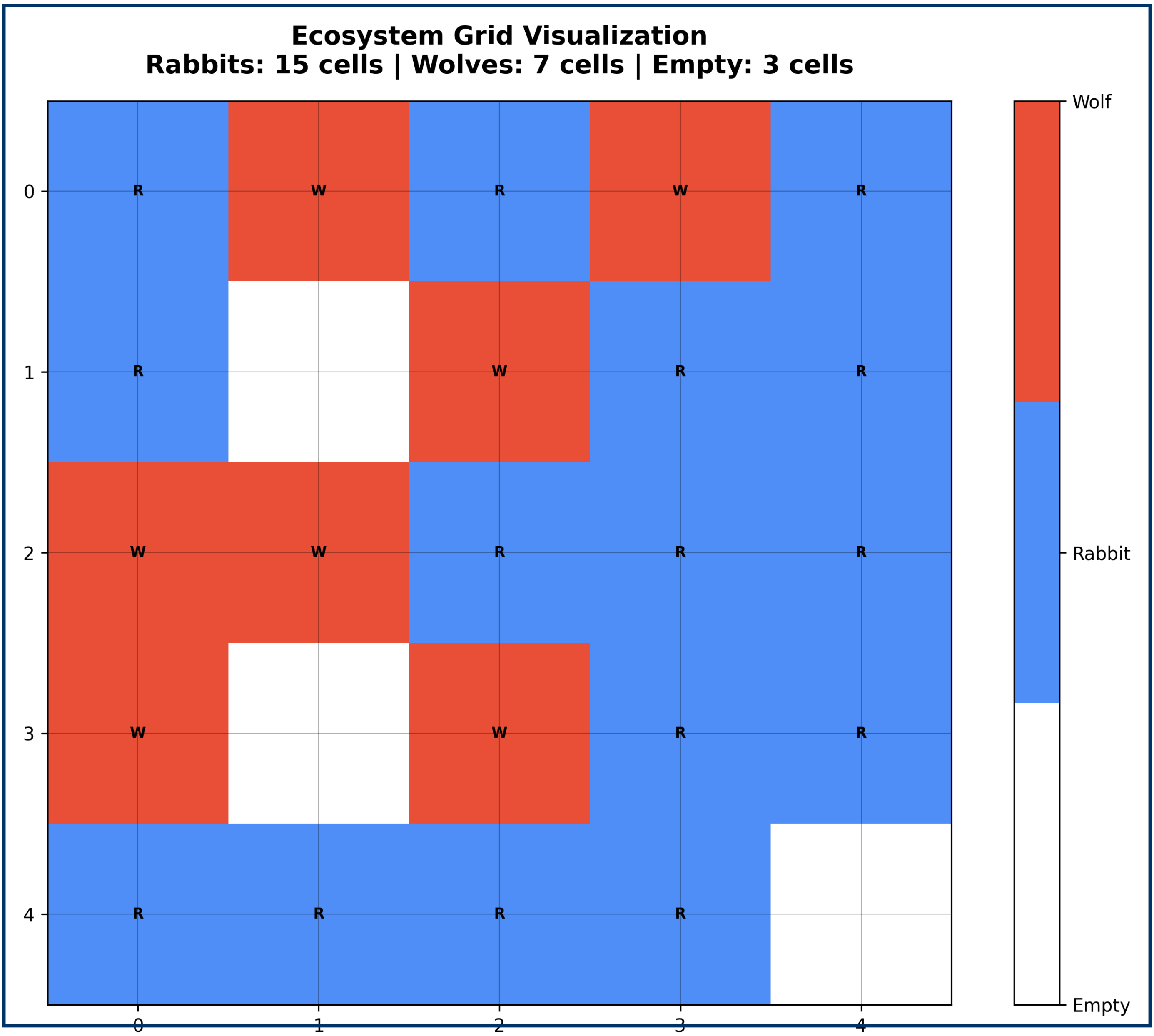

Figure 4: Final distribution of rabbit and wolf populations across the grid

This visualization shows the final distribution of rabbit and wolf populations across the 5×5 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

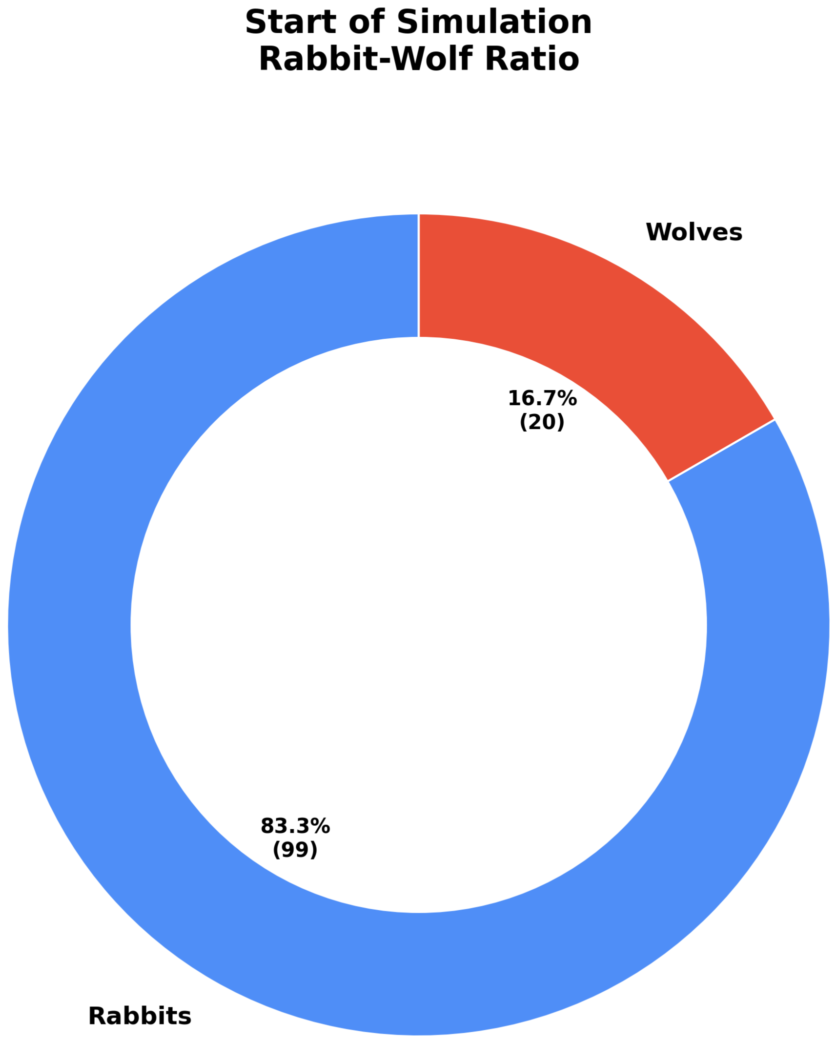

Figure 5: Rabbit-Wolf Ratio at Start of Simulation

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

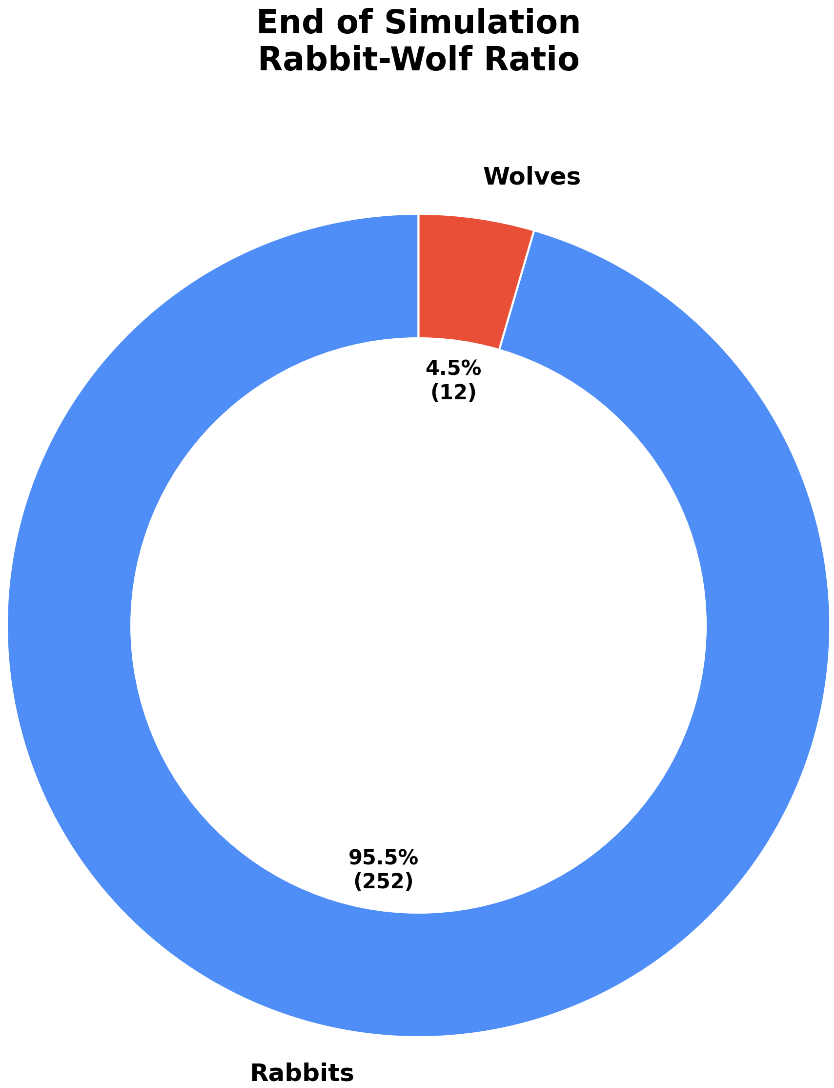

Figure 6: Rabbit-Wolf Ratio at End of Simulation

This donut chart shows the final proportion of rabbits and wolves in the ecosystem. By the end of the simulation, rabbits made up 95.5% of the population, while wolves made up 4.5%. Comparing this to the initial ratio provides insight into how the ecosystem balance has shifted over time.

Average Rabbit-Wolf Ratio Over Simulation

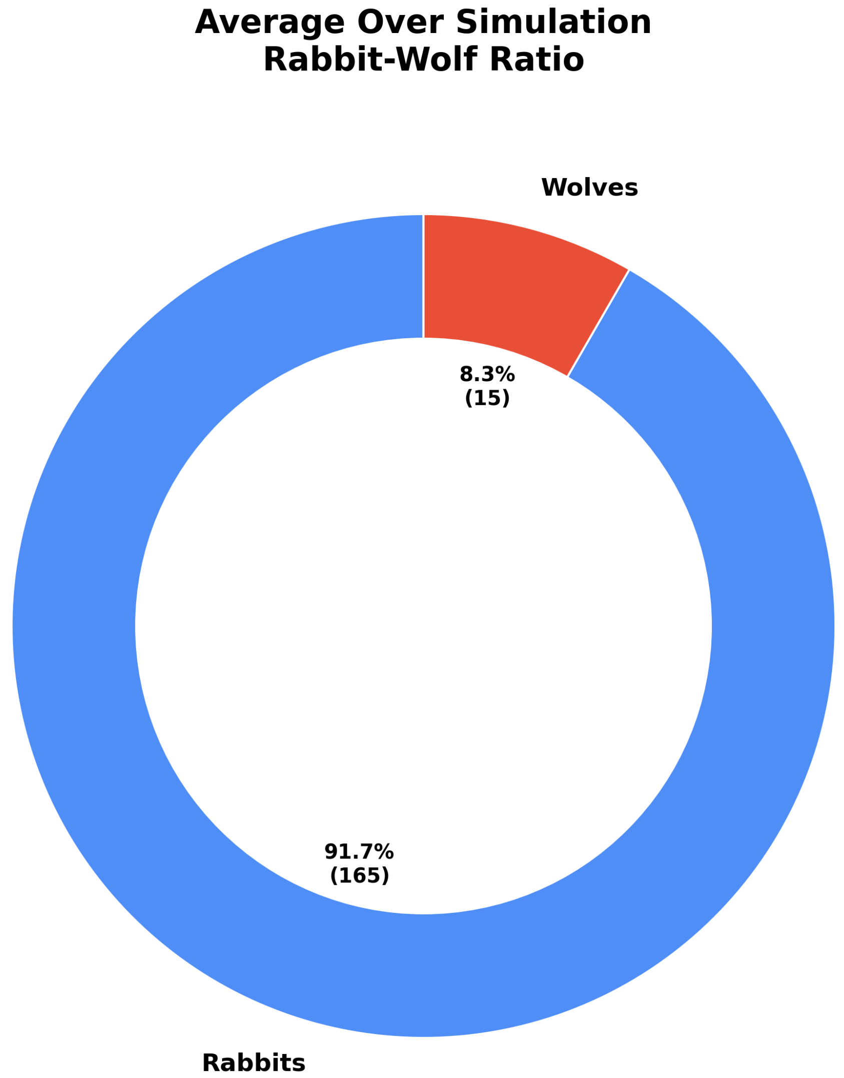

Figure 7: Average Rabbit-Wolf Ratio Over Simulation

This donut chart shows the average proportion of rabbits and wolves throughout the entire simulation period. On average, rabbits made up 91.3% of the population, while wolves made up 8.7%. This average ratio helps understand the overall ecosystem balance during the simulation.

AI Analysis Summary

This predator-prey simulation, modeled after the Lotka-Volterra equations, examined rabbit and wolf populations across a 5x5 grid from 2023 to 2033. Initial conditions of 4 rabbits and 1 wolf per grid cell (except for the last row with zero wolves), resulted in a complete collapse of the wolf population by 2024. Subsequently, the rabbit population exhibited exponential growth, reaching a total of 253 by 2033. The absence of wolves eliminated the top-down control on the rabbit population, leading to unchecked growth. The simulation highlights the critical role of predators in regulating prey populations and maintaining ecological balance. Future simulations should explore alternative initial conditions and environmental factors to further investigate predator-prey dynamics.

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 100 rabbits and 20 wolves, the simulation tracked population changes over 10 years across a 5×5 grid.

Key findings:

1. The rabbit population exhibited growth behavior, reaching a maximum of 253 and a minimum of 100.

2. The wolf population showed a decline, reaching a maximum of 20 and a minimum of 12.

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 8.96 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.