CSS 458

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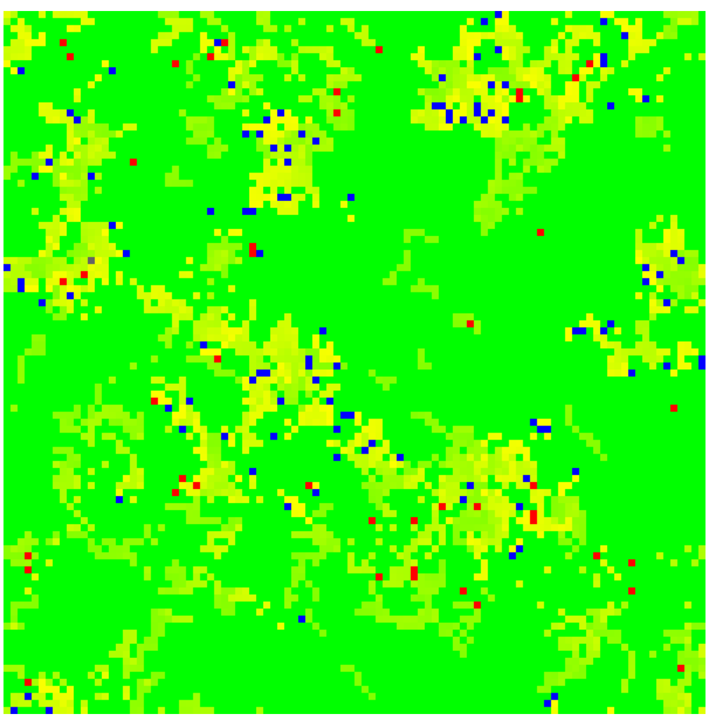
Population Playground Analysis Report

Introduction

The Lotka-Volterra set of equations describe the behavior of the populations of predators and prey as an effect of the opposite parameters. This means that changing the parameters to benefit the prey, would result in an increase in the amount of predators that the simulation can support. The model describes the prey population being dependent on the prey growth rate and the effect of the presence of predators on the prey growth rate, while the predator population is dependent upon the predator's death rate and the effect of the presence of prey on the predator's growth rate. This model also describes the tendency for the populations to oscillate as they interact with each other.

Our model differs from this set of equations because our populations have spatial factors as well as food limitations for the prey. In our analysis of changing the parameters we were looking for these behaviors and also any way that our simulation might behave differently.

Graphs created by our simulation have significant spikes and variance due to the randomness within a simulation as well as randomness from one simulation to another.



This is an example of our simulation. The red pixels represent predators, blue are prey, and green and yellow are plants. Predators chase the prey around the map, while the slower prey attempt to escape. Prey eat plants, which regrow over time.

If predators or prey run out of energy, they die. They can reproduce if they have enough energy and enough time has passed since their last reproduction.

When attacked, prey have a small chance to stun or kill predators instead of being eaten.

Lag Cross-Correlation Plot

Graphing the lag cross-correlation between the prey populations and predator populations, as shown in Figure 1, illustrates the delayed impact that each population has on the other. The first and highest peak is at around -200 timesteps. This shows that when the prey population increases (or decreases), the predator population typically increases (or decreases) around 200 timesteps later. This is because the increased number of prey allows the predators to gain energy and reproduce. More predators then eat the prey and reduce their population, as shown in Figure 2. A smaller local maximum occurs in Figure 1 at around 450 timesteps. This suggests that while after the predator population increases, the prey population decreases, which causes the predator population to decrease, which finally causes the prey population to increase around 450 timesteps after the increase in the predator population. Similar peaks occur throughout the simulation.

Figure 1 - Lag Cross-Correlation Plot Between preyPopulations[t + lag] and predatorPopulations[t]

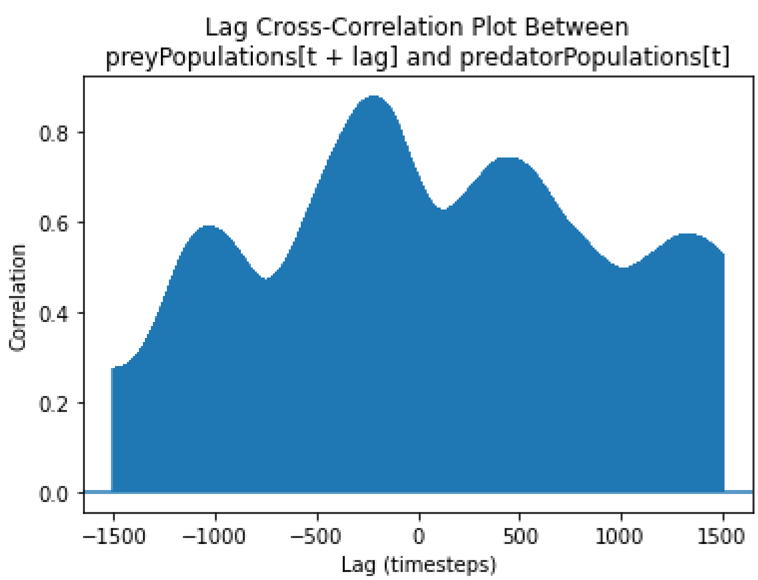
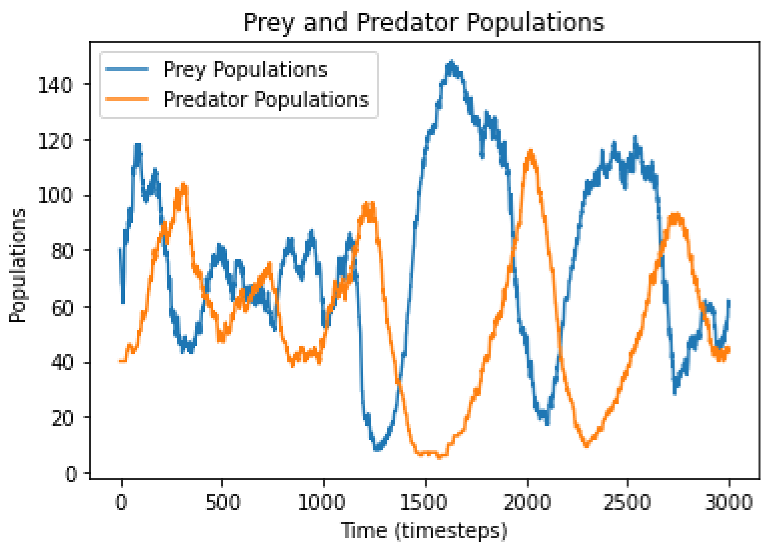


Figure 2 - Plot of preyPopulations and predatorPopulations over time



Changing Parameters Effect on Average Populations

Our approach to trying to make changes to our simulation and measure the effects on the populations was to make changes to a single parameter at a time. For our model we found that 3000 timesteps gave us a good amount of interactions between the population and allowed them to oscillate several times. After selecting a parameter we ran the simulation for the selected amount of timesteps 10 times, then slightly adjusted the chosen parameter and ran the simulation another 10 times. We did this for a total of 20 sets of changes done, with 10 simulations run for each change. Because our model has a great deal of variance between each model run due to randomness across multiple different parts of the simulation, we hoped these 10 simulation runs for each change would give us a good idea of what the average populations would look like for each set.

Figure 3 shows us the average populations of both the predators and the prey. For this set of simulations we had the amount of time it takes before the plant cells regrow decrease by 10 timesteps from the initial 250 timesteps. Based on intuition, what we would expect from this change is to see the average prey populations increase as the regrowth time decreases and availability of their food supply increases between each set of simulations. Based on the effect described in the Lotka-Volterra model, we would expect to see the average predator populations increase as the prey's food supply increases. Figure 3 appears to show us a minor change in the average prey populations, but a much more significant change in the average predator populations.

Figure 3 - Plot of Average Populations vs Plant Regrowth Times

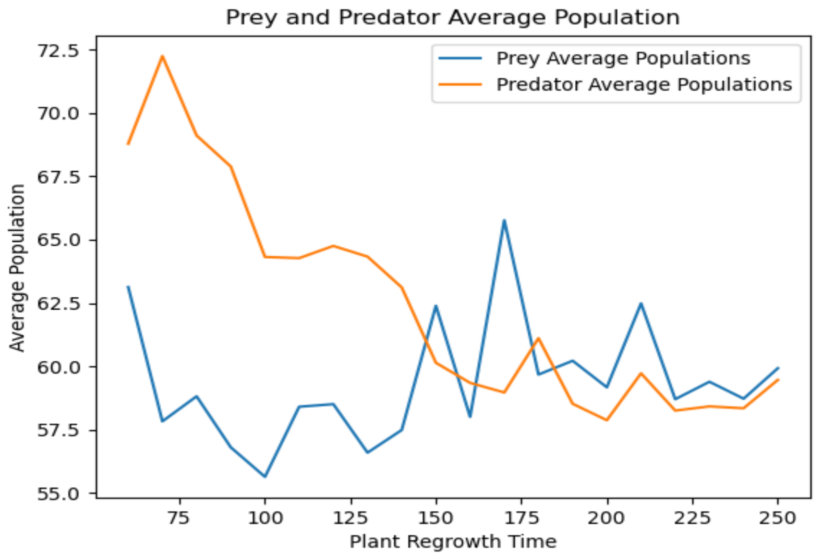


Figure 4 shows us the set of the simulations where the change being made between sets is the predator reproduction energy threshold being increased by 2. Figure 5 shows us the set of the simulations where the change being made between sets is the predator reproduction time being increased by 2. This parameter is a tuple, so while our graph is only showing us the lower bound of the threshold, the change is being made to the upper bound too. The effect in the Lotka-Volterra model would make us expect to see the average population of the prey increase but the average predator population stay the same for both of these changes. Figure 4 and 5 shows our simulation having this effect with the average prey population increasing as the predator reproduction energy threshold/predator reproduction time increases, but we also see our model showing the average predator population decreasing. This makes our model differ from the Lotka-Volterra model and we suspect this is due to the spatial factors having an effect on how the populations interact. It offers improved insight into real-world interactions between prey and predators.

Figure 4 - Plot of Average Populations vs Predator Reproduction Energy Thresholds

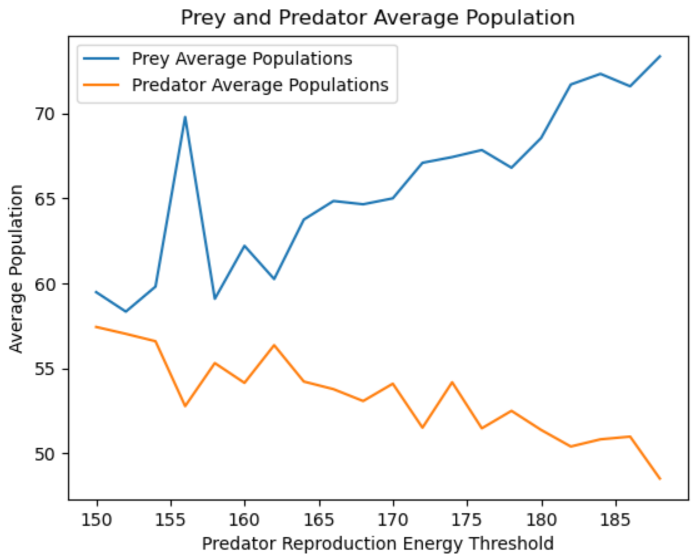


Figure 5 - Plot of average Populations vs Predator Reproduction Time

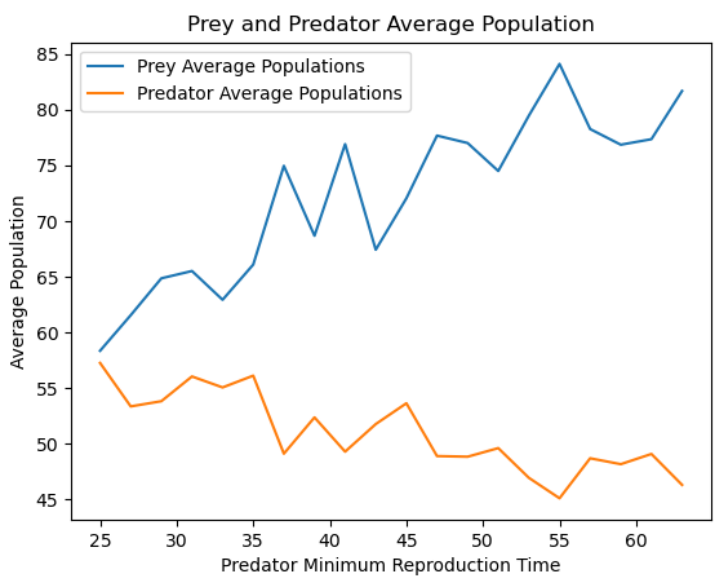
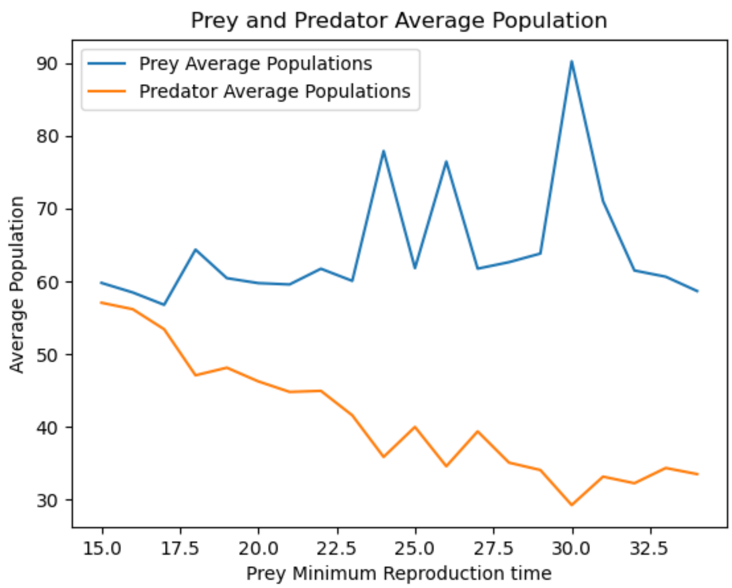


Figure 6 shows us the average populations against changing the prey minimum reproduction time by an increase of 1 between each set of simulations. This parameter is a tuple, so while our graph is only showing us the lower bound of the threshold, the change is being made to the upper bound too. The effect in the Lotka-Volterra model would make us expect that changing this parameter would make the average predator population decrease, and the average prey population stay the same. Figure 6 appears to show us that the average predator population does indeed decrease as the prey reproduction time increases, as well as that the prey population does not appear to change very much if at all.

Figure 6 - Plot of Average Populations vs Prey Minimum Reproduction Time



Conclusions

From the implementation and analysis of our predator vs prey model, we have noticed similarities and differences while trying to observe the same effects described in the Lotka-Volterra model. While our model predator and prey populations interact very differently through the added dimension of spatial interaction, we still have been able to observe some of the same effects.

Our simulation was able to demonstrate the oscillation described in the Lotka-Volterra model. While their model has explicit relationships defined between the two population numbers, our simulation shows a very similar relationship. We believe this is because the spatial interactions between the two populations and their parameters enables oscillation between both populations.

Changing the predator parameters (predator reproduction time, predator reproduction threshold) did show changes in the average prey populations but also appeared as changes in the average predator population. This aspect of our simulation analysis shows a divergence from expected observations described in the Lotka-Volterra model. Their model describes the predator population being dependent upon the predator's death rate and changing the predator parameters ends up having an effect on the predator's death rate.

Changing the prey parameters (plant regrowth time, prey reproduction time) did show us changes in the average predator populations but had little effect on the average prey populations. This lines up with the observed effects in the Lotka-Volterra model and our simulation could be displaying this for the same reason the Lotka-Volterra does. We theorize that the reason for this, however, is because the predators set a sort of "spatial maximum" for the number of possible living prey. By increasing the rate of reproduction for the prey, we are simply creating excess prey that predators will then eat. The only way to change the maximum number of prey is by altering the predators and their interactions with prey.

These more realistic agent-based simulations offer improved insight into the workings of real-life predator-prey dynamics. It shows how newly introduced species may interact and affect each other. Using this information, ecologists can better understand how to alter and preserve their environments.