Reintroduction of the Mexican Gray Wolf

New Mexico

Supercomputing Challenge

Final Report

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Team: 70

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Executive Summary

The Mexican Gray Wolf has been reintroduced in certain areas of the United States. The reintroduction is an attempt to undo the damage of the wolves not being in those areas.

The objective of this project was to use StarLogo TNG to model the wolf reintroduction. The original goal of the project was to find the number of wolves that would stabilize with the given number of elk and deer for the Blue Range Area. This model allowed the wolf to reproduce and die while the model was running. The results from running this model were too complicated to properly analyze. The team decided to modify the goal and build a model to find conditions in the StarLogo model that enabled a stable population with the number of wolves to remain constant during the simulation.

The model was run with three different scenarios. The first scenario did not have any wolves. The second and most stable scenario was when there were six wolves in the simulated run. The third scenario was when the simulation had ten wolves. The vegetation provided additional information for the results. The vegetation in the first scenario acually died out due to the elk and the deer being over populated and eating all the available vegetation. When there were too many wolves in the third scenario, the elk and the deer were completely killed off and the vegetation was overgrown. Scenario two shows how the elk, deer and vegetation can all coexist. These scenarios successfully illustrated how the number of wolves impacted the balance of the deer and elk in the model and helped show how fragile the balance of nature can be.

Introduction

The Mexican Gray Wolf population is very small and is in danger of becoming extinct. Previous reintroductions of the Mexican Gray Wolf have not succeeded due to many factors. First of all, the Mexican Gray Wolves were bred in captivity before being introduced into an environment. While in captivity the wolves were exposed to diseases that were introduced by domestic dogs, causing the pup mortality rate to increase. After being cared for in captivity they were introduced into an environment without humans where they may or may not have developed the wild instincts necessary to survive on their own. For example, if they were unable to hunt and obtain food on their own they would starve from lack of food or they would attack cattle which were the largest easy prey. But ranchers took matters in to their own hands to protect their cattle by shooting the wolves. Since the reintroductions started in 1982, when the first reintroduction plans were made, twenty three Mexican Gray Wolves have been shot and killed. As an example, in 2009, two wolves were found illegally shot. Because of diseases, lack of wild instincts due to being bred in captivity, and human predators, previous reintroductions have not produced the desired outcome of the reintroduction.

The original goal of the project was to find the number of wolves that would stabilize with the given number of elk and deer for the Blue Range Area. This model allowed the wolf to reproduce and die while the model was running. The results from running this model were too complicated to properly analyze. The team decided to modify the goal and build a model to find conditions in the StarLogo model that enable a stable population with the number of wolves to remain constant during the simulation. The question is how many wolves are needed to provide a stable environment with elk, deer, and vegetation.

Research was done on the wolves, elk and deer to understand their life cycle so that they could be modeled in StarLogo TNG. The Mexican Gray Wolf's scientific name is *Canis lupus baileyi*. It is an endangered animal. Wolves usually have four to six pups in a litter and they have a litter every one to two years. There are approximately six to nine wolves in each pack. Wolves only live about twelve years on a diet consisting of deer, elk, rabbits and other animals.

Elk is one of the main food sources for the gray wolf. Elk are herbivores and eat approximately twenty pounds of small grasses, seedlings and low lying brush every day. The Blue Range Area has an estimated population of 16,000 elk. Elk usually live between fourteen and seventeen years. The elk's scientific name is *Cervus elaphus.* The elk is the second largest family member of the deer species. Today, about one million elk live in the western United States, Wisconsin, Michigan, Minnesota, Pennsylvania, Arkansas, Kentucky, Tennessee, New Mexico, Arizona and North Carolina, and from Ontario west in Canada. Because elk are one of the main food sources for gray wolves, they are included as one of the agents in our model.

The White-tailed deer's scientific name is *Odocoileus Virginianus*. It is another significant source of food for wolves and a second agent in our model. Deer have a life span of about ten years and reproduce with an average of one offspring a year. Their diet mainly consists of woody vegetation and flowering plants, not including grasses, which make up only a small portion of their diet.

In Yellowstone National Park, the wolves were removed to make the park more enjoyable and safer for visitors. When wolves were taken out of Yellowstone National Park, the population of the elk spiked. The elk ate all of the vegetation they could find. This impacted the birds as well as the other animals at Yellowstone. This caused the entire ecosystem to be thrown off balance.

Method

Area

Wolf reintroduction programs have been piloted in several areas including the Blue Range Area, White Sands Missile Range, Apache-Sitgreaves National Forest, and Yellowstone National Park. The Blue Range Area as seen in Figure 1 was chosen for this study because of the large amount of data available on the area. To accommodate this study, the data was scaled down to model one wolf pack's impact on the potential reintroduction in their immediate area. A typical pack requires a range of approximately 100 square miles and our model was based upon this range size.

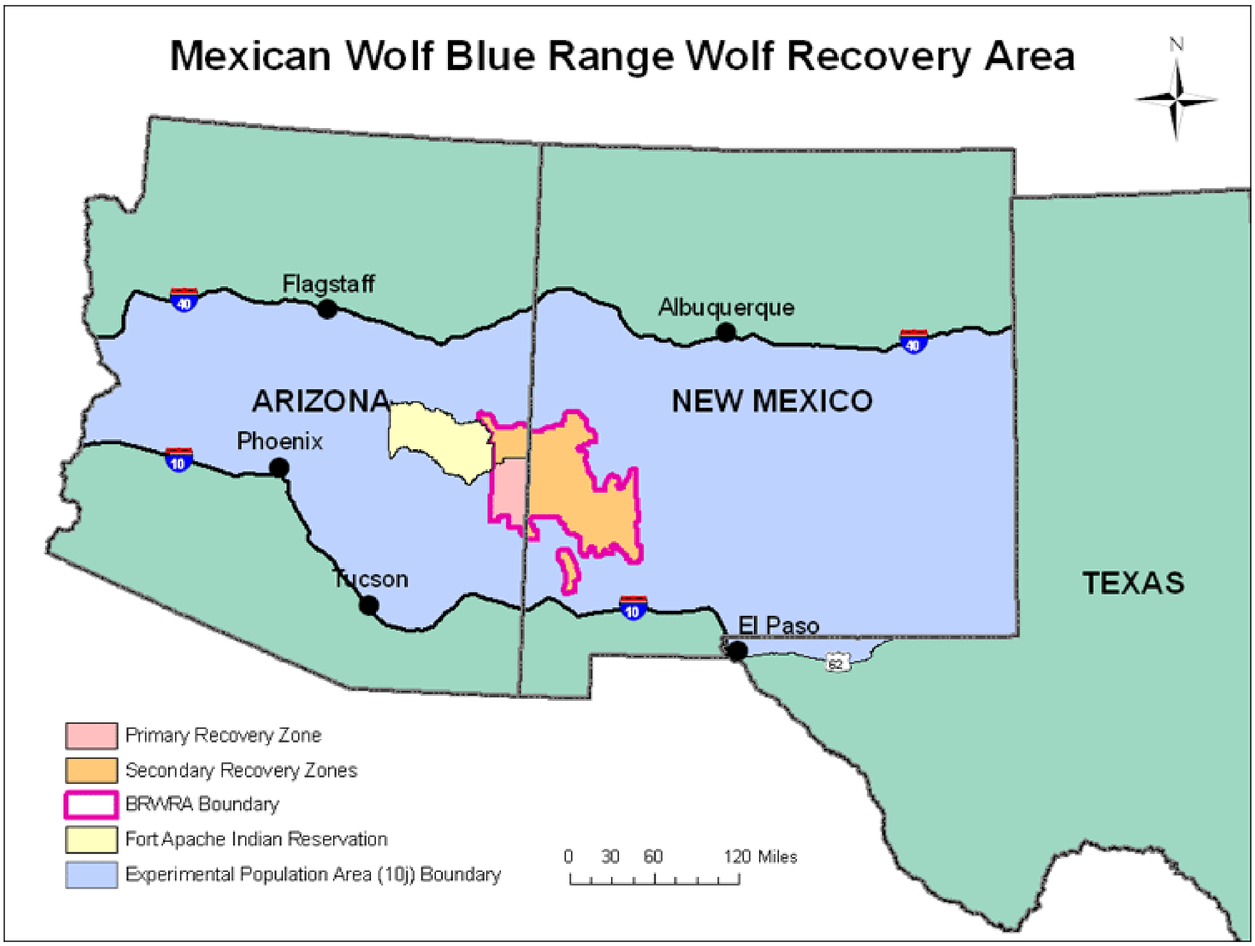

Figure 1: Mexican Wolf Blue Range Wolf Recovery Area

Predator-Prey Model

The computer model developed in StarLogo TNG was based upon a natural food chain as seen in Figure 2. The model was designed with the following agents: wolves, deer, elk, and vegetation. The sole predator in the model is the Mexican Gray Wolf. The wolf's population is controlled by a slider. This control allowed the model to be run with a set population for the wolves. The wolf eats deer and elk. Both elk and deer die if they are eaten by the wolf, become old, or starve. The elk and deer gain energy by eating vegetation. The vegetation grows at a steady rate and dies if it is eaten or grows old.

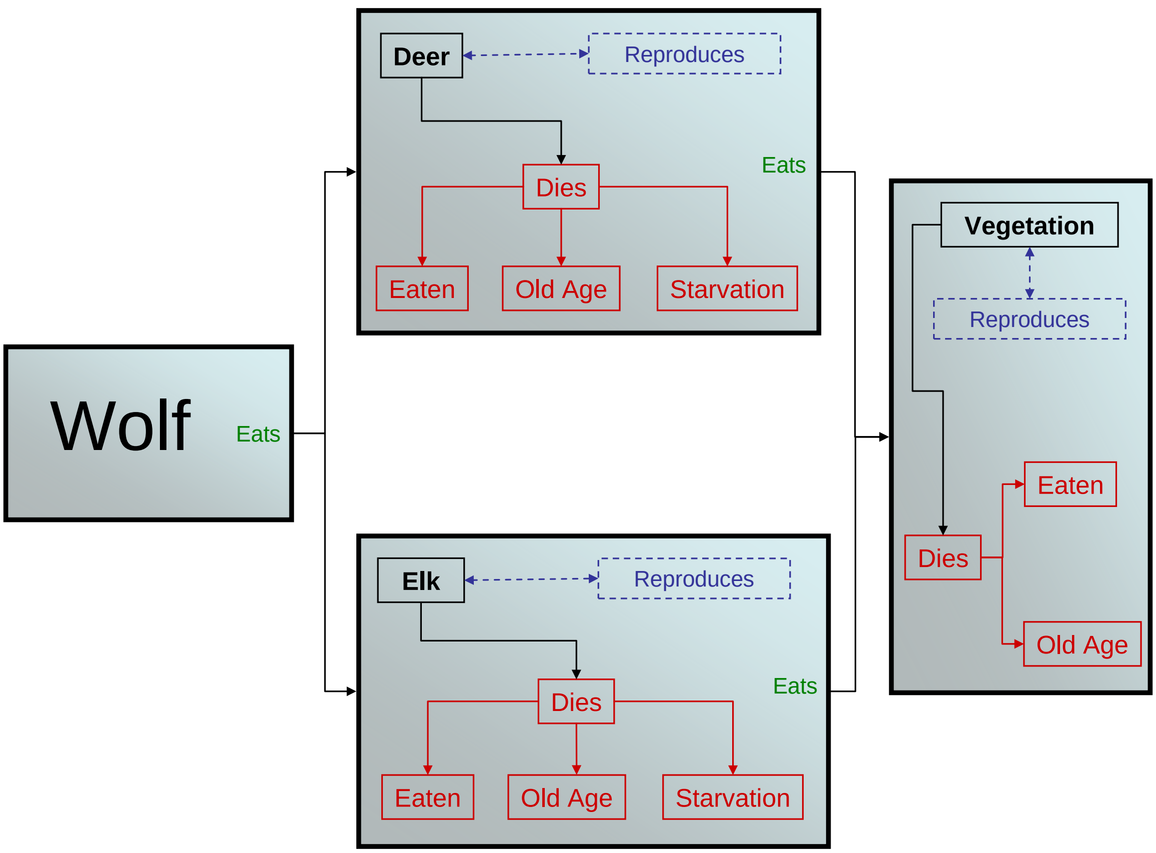

Figure 2: StarLogo Predator-Prey Model

The starting number of wolves is the manipulated variable in this model. The deer, elk, and vegetation are responding variables with fixed starting numbers based upon the numbers documented for the Blue Range Area and scaled down to representative numbers for an area of 100 square miles.

Scaling

In order to make our model as realistic as possible and to handle the limitations of StarLogo, we took real data from a reintroduction site, the Blue Range area, and scaled it down to fit our model as seen in Figure 3. Currently, there are approximately 16,000 elk and 32,000 deer in this area of 24,000 square miles. The model represents 100 square miles out of the total 24,000 square miles to simulate the average range size for a typical wolf pack. For every 240 deer in the Blue Range Area there is one deer in the model, making the deer population in the model 133. For every 240 elk in the Blue Range Area there is one elk in the model, making the elk population in the model 67. When StarLogo had over 1000 agents on the screen at one time, the program would run very slowly or even crash. The large amount of vegetation in this model had to be rescaled but kept in proportion to the other agents in the model so the system could run. To overcome this problem, the vegetation represented more than one piece of vegetation. The energy received from the vegetation represented the same as if the elk or deer had eaten 7 individual pieces of vegetation.

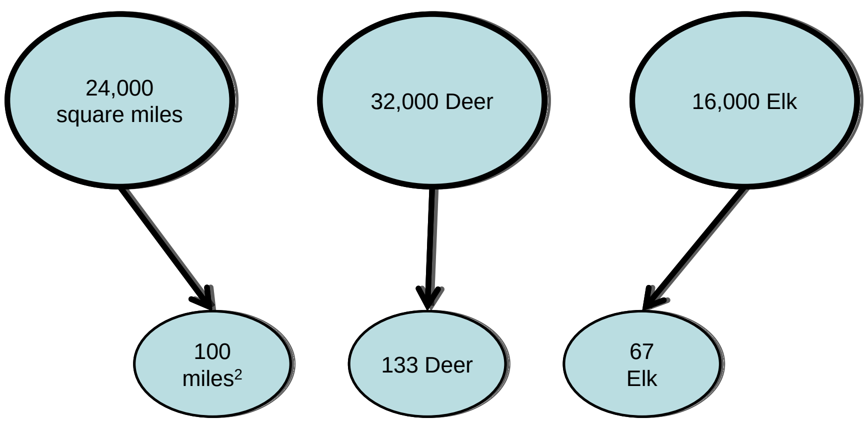

Figure 3: Model input scaling from the Blue Range Area data.

Programming Blocks

Many StarLogo models were studied to determine the best way to model the specific predator and prey for this project. Once the agents were created, the way they interact with each other was developed. This involved the use of several different programming blocks: the smell block, the life cycle block, and the collision block.

The smell block controls the sensitivity of the agents to other agents. If the smell has a large radius, the agent will react faster than if the smell radius is smaller. Basically, it controls how sensitive the agent is to its surroundings. This can be seen in Figure 4.

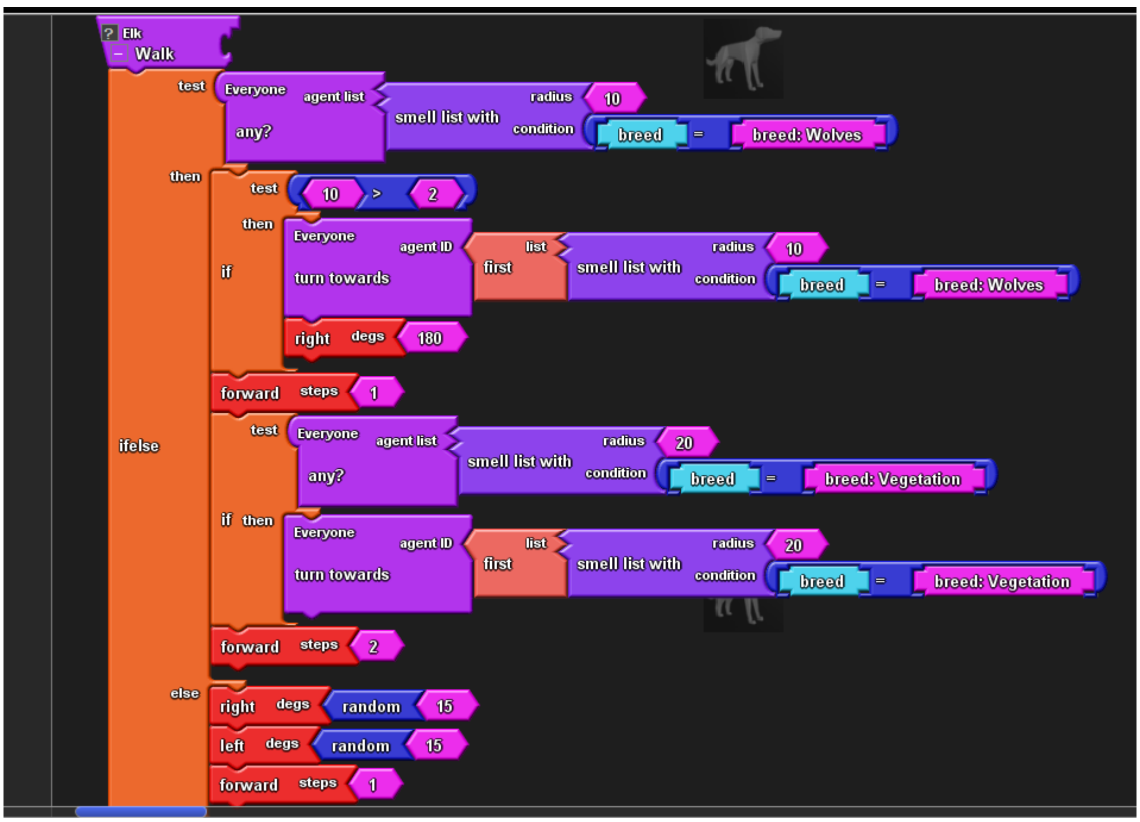

Figure 4: Example of Smell Programming

A crucial variable was created to represent the agent's energy. The energy will increase and decrease based on the amount of food the animal eats or the number of steps they have to take. When the animal eats, its energy level increases by a certain amount depending on the animal. In the model, an animal dies of starvation when its energy level reaches zero. The animal must eat to maintain its energy. Elk reproduce if their energy reaches thirty and the age reaches twenty eight. The deer reproduces when their energy reaches thirty and their age reaches twenty six. The screenshot of the life cycle block for the programming of this can be seen in Figure 5.

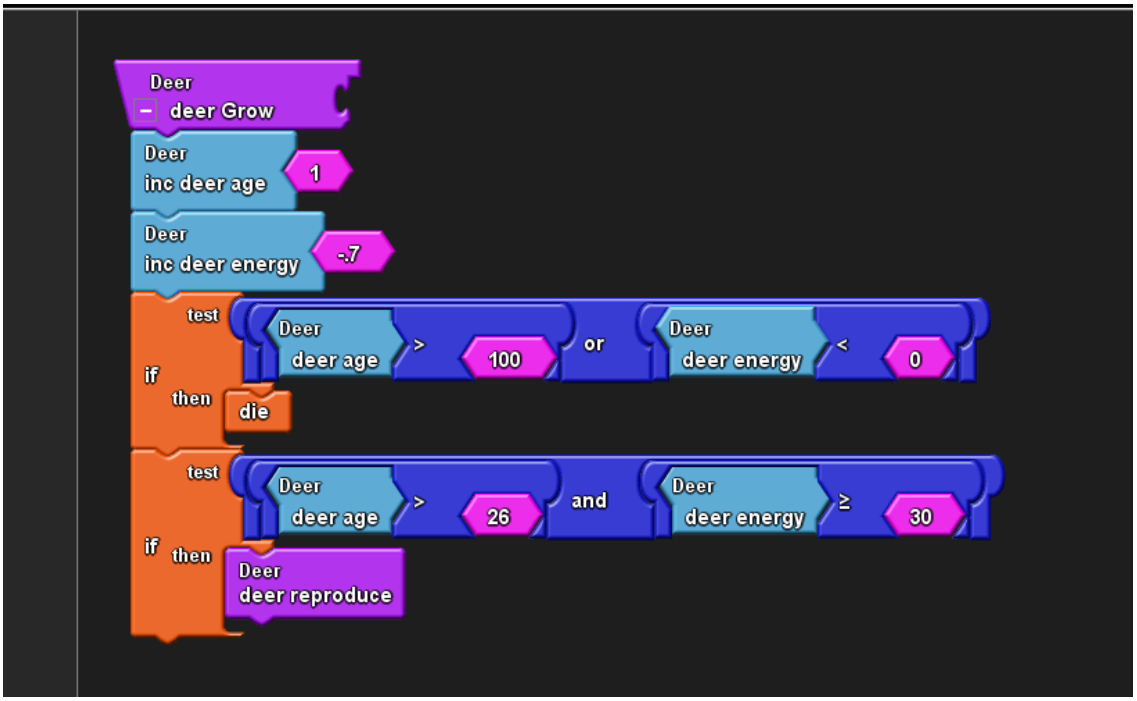

Figure 5: Example of Life Cycle Programming

Collisions are the next important piece of the programming. The collision block enabled the program to know what the outcome will be when one agent comes in contact with another agent. The result of the collision in this simulation results in the death of one of the agents. When a wolf collides with a deer or elk, also known as the prey, the prey will die. When the elk or the deer collide with vegetation something different happens. The vegetation will die, but energy will also be given to the animal that collided with the vegetation. The energy determines the life span of the animal. The programming for collisions can be found in Figure 6.

Figure 6: Collision Programming

A helpful feature in StarLogo is the ability to create a table or graph while the simulation is running. Figure 7 shows the programming block for creating a graph with defined variables. The tables generated can be viewed while the program is running. The user can also download a comma delimited file to be used in Excel to make a graph. The graphs were created in Excel so they were easier to read.

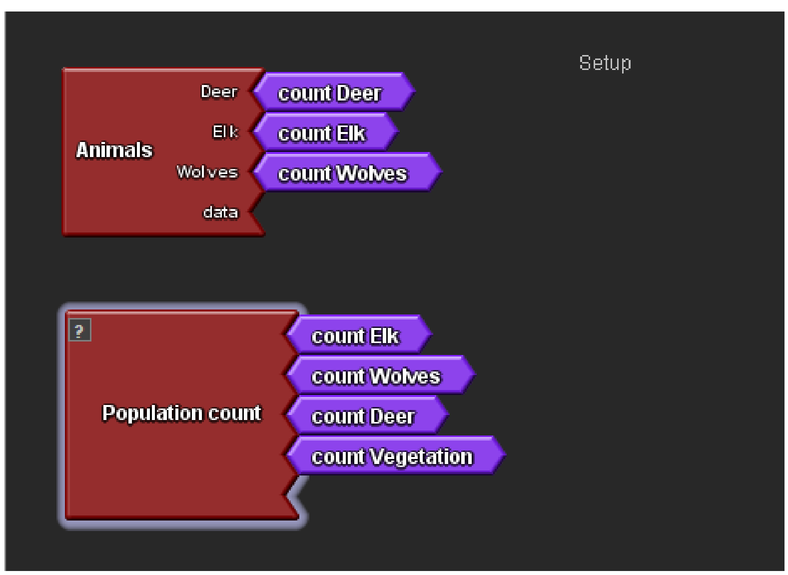

Figure 7: Programming for Charts in StarLogo

Figure 8 shows some of the many pieces that were used to make this model work and the overall complexity of this model.

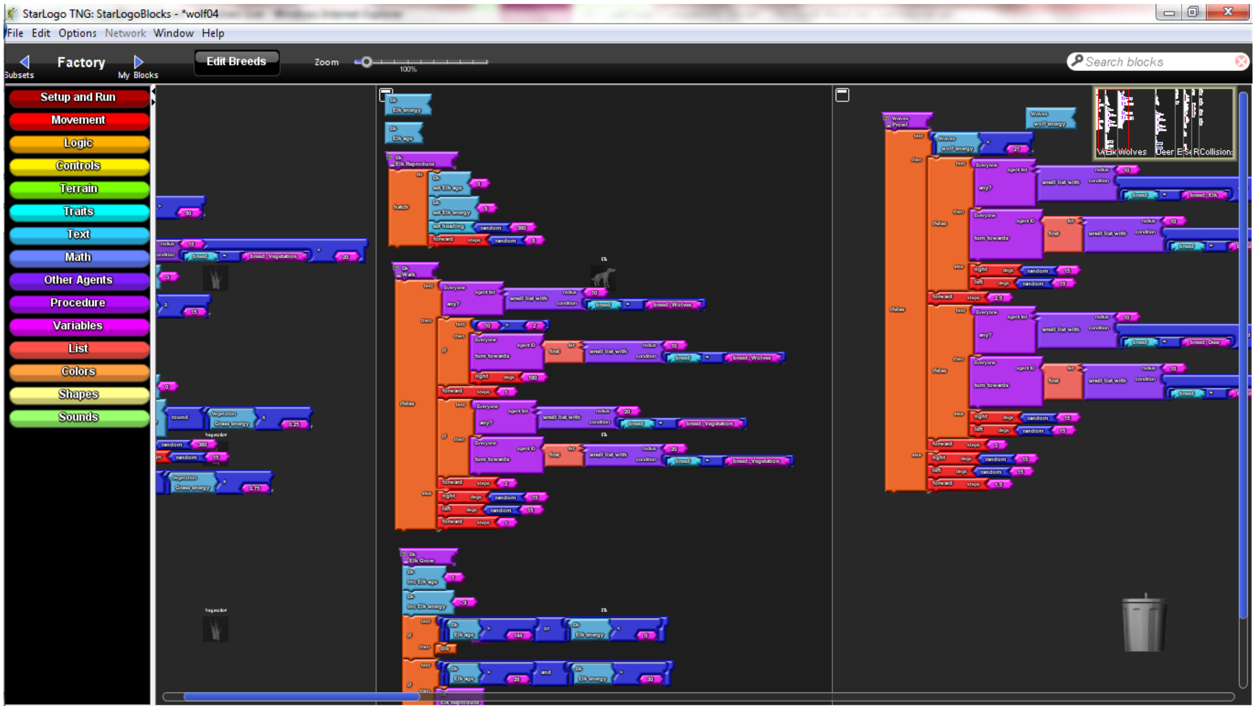

Figure 8: Sample Programming Screen Shot from StarLogo

Assumptions

The Lotka-Volterra equations are commonly used to model predator prey systems. Volterra made four assumptions for the use of these equations. First, the prey will grow unlimited if the predators cannot keep them under control. Second, the predators depend on the prey to survive. Third, the number of prey caught depends on the availability of the prey. Last, the growth rate of the predator is proportional to the food intake. These assumptions apply to the Starlogo TNG model described in this paper.

Several other assumptions were made:

Wolf

- No predators
- Food source is elk and deer

Elk

- Reproduce after energy reaches thirty and the age is twenty eight
- Wolf is the only predator
- Dies after energy equals zero or the age is equal to 144
- Dies if eaten by wolf
- Food source is vegetation

Deer

- Reproduce after energy reaches thirty and the age is twenty six
- Wolf is the only predator
- Dies after energy equals zero or the age reaches 100
- Dies if eaten by wolf
- Food source is vegetation

Vegetation

- Reproduces when the energy reaches fifteen
- Dies when eaten by elk or deer
- Dies when the energy reaches fifty

Results

The program was run to demonstrate how the agents interacted with each other. Figure 9 shows what a typical run would look like. Three different scenarios were run to test the impact the number of wolves had on the population of the deer and elk. The data was recorded in StarLogo as seen in the right column of Figure 9.

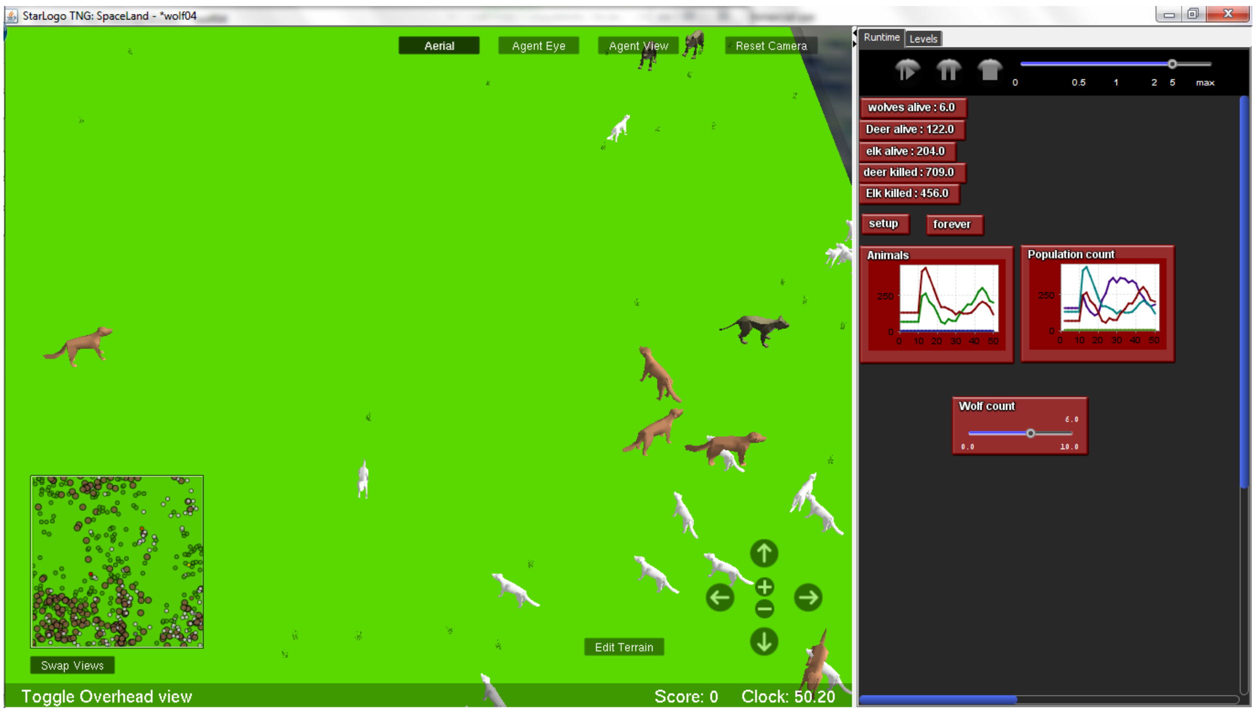

Figure 9: StarLogo Model with all agents.

Scenario One

The first scenario was to test what would happen if the wolves were removed from the ecosystem similar to what happened in Yellowstone as mentioned earlier. In the model the first run of this scenario consisted of only vegetation. During this run the vegetation population increased due to the absence of the deer and elk. When the program was run with deer and vegetation, the deer's population slowly increased with the vegetation until a certain point then they both decreased because the deer had depleted the vegetation. When the program was run with deer, elk, and vegetation all agents rapidly increased and then all agents suddenly decreased. The deer and elk became over populated and the vegetation was gone. The elk and the deer could not survive. Figure 10 shows the results of this scenario.

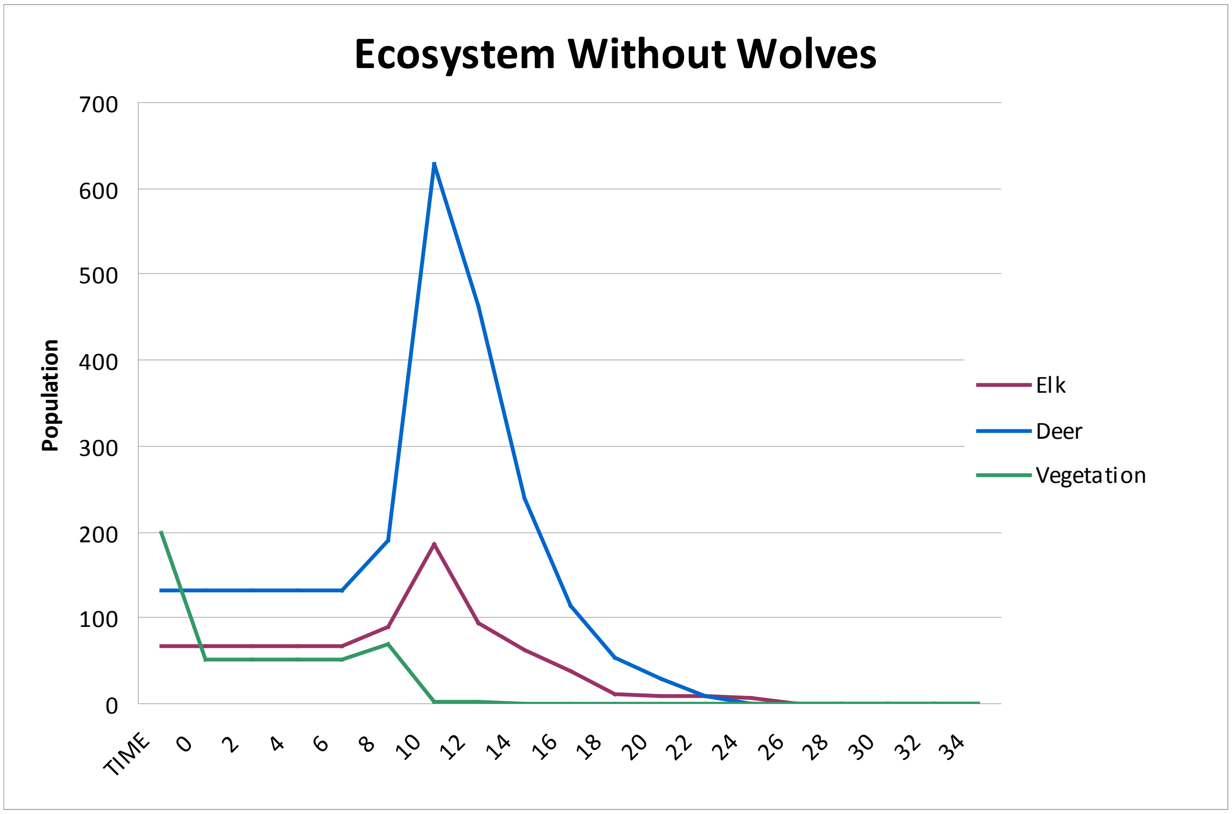

Figure 10: Ecosystem Without Wolves

Scenario Two

In the second scenario, six wolves were needed to maintain a stable environment. Figure 11 is a good example of a stable ecosystem where the wolves, elk and deer coexist. There was usually a rapid increase in the very beginning of the run due to the randomized feature in the program. Once the animal populations stabilized, the program would run for several minutes.

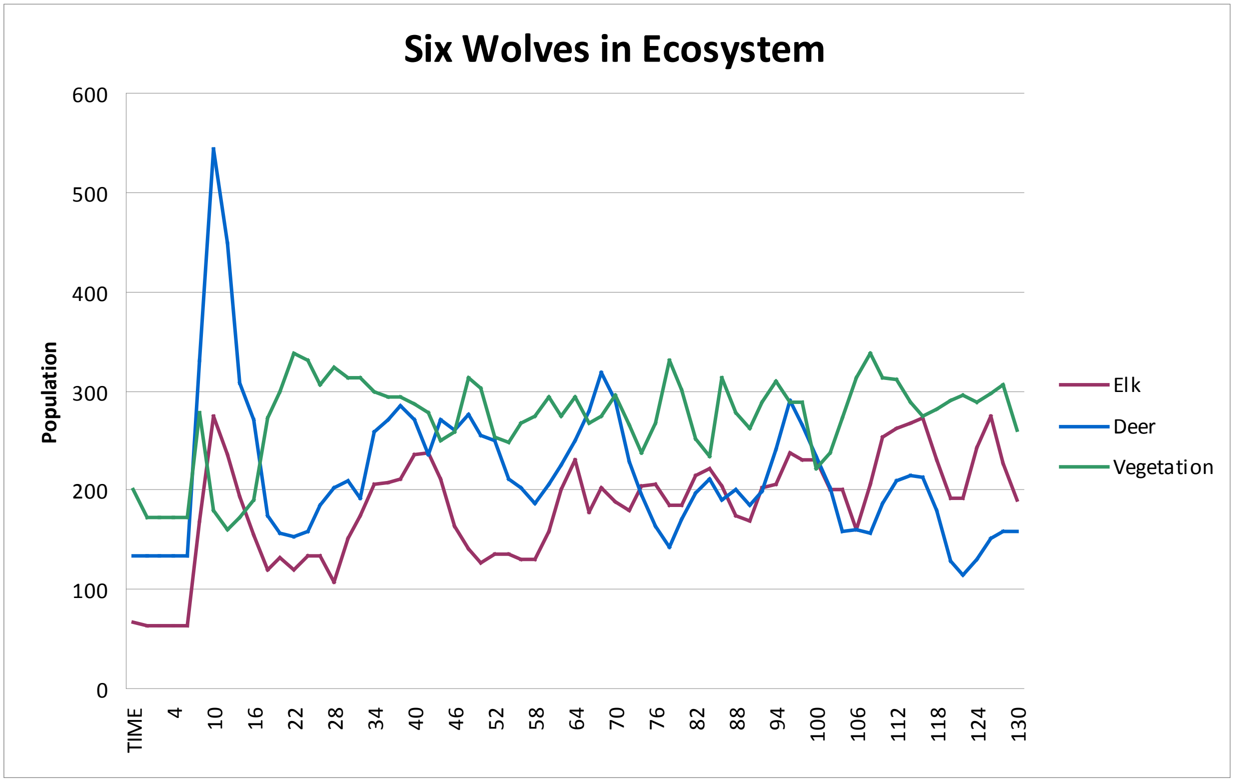

Figure 11: Six Wolves in Ecosystem

Scenario Three

For the third scenario, ten wolves were added. Figure 12 shows the results from this scenario which were a little suprising. After studing the chart it looks like the wolves ate too many deer and elk. The population decreased and the vegetation was plentiful.

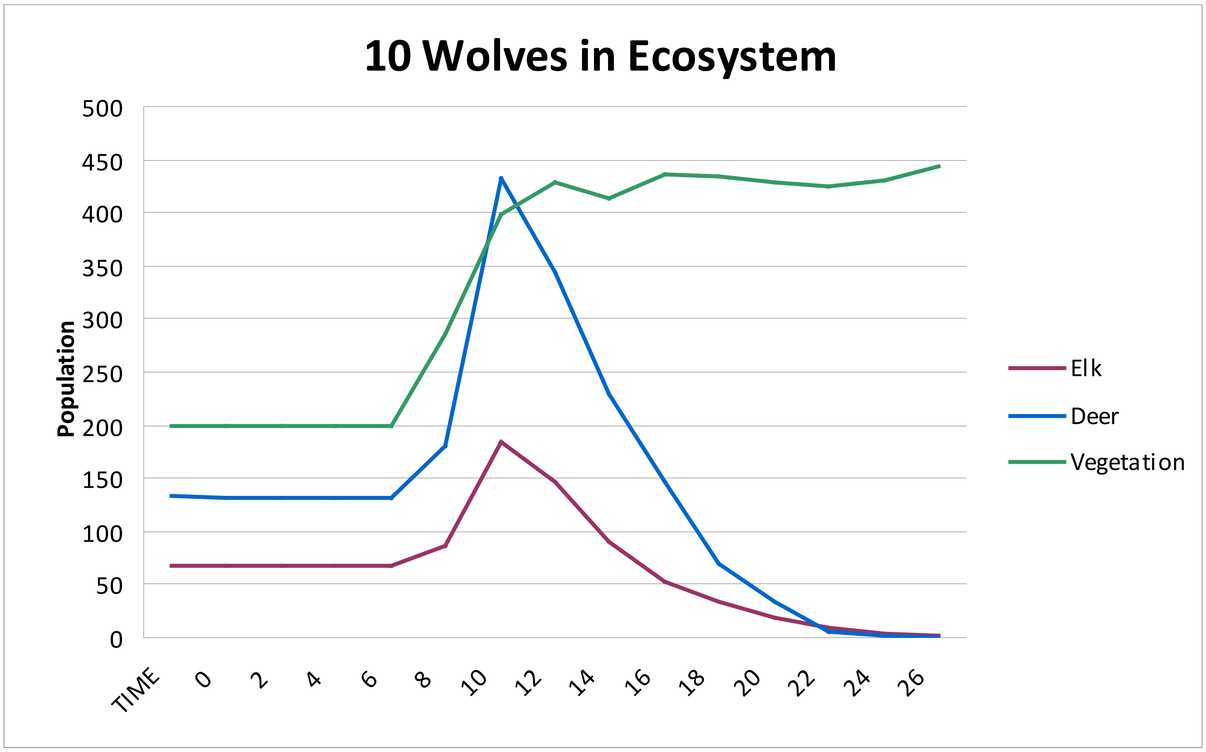

Figure 12: Ten Wolves in Ecosystem

The focus of this study was primarily on the population of the elk and deer based on the number of wolves introduced. The vegetation provided additional information for our result. The vegetation in the “no wolves” scenario acually died out due to the elk and the deer being over populated and eating all the available vegetation. When there were too many wolves in the ecosystem, the elk and the deer were completely killed off and the vegetation was overgrown. Figure 11 shows how the elk, deer and vegetation can all coexist.

Conclusion

Stabilizing an ecosystem in StarLogo is very challenging. Several techniques were used to try to stabilize the model. Several of our trials were run allowing the wolves to die and reproduce. This made the model very hard to analyze. The goal was to understand how the number of wolves impacted the balance of the deer and the elk. After studying the results, it was determined that the wolf numbers should not change in our model for the individual trials.

Six wolves turned out to be the correct amount in this model. The teaching point is that wolves may be introduced to an ecosystem where they once lived. The balance will be achieved after time. The problem is that the wolf's population must be controlled. Too many wolves are just as bad as too few. With the available land shrinking, the challenge will always be to find and manage the balance between predators and prey.

The most significant achievement in this project was realizing that the original goal was too complicated. The feedback from the scientists encouraged us to rethink our goal and simplify our model. The results of our revised model allowed us to understand the impact that the number of wolves had on the population of the deer and elk.

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Appendix

Table for Figure 10: No Wolves

Time	Elk	Deer	Vegetation
0	67	133	200
2	67	133	51
4	67	133	51
6	67	133	51
8	67	133	51
10	89	189	69
12	185	629	2
14	94	464	2
16	63	239	0
18	39	115	0
20	12	53	0
22	10	28	0
24	9	8	0
26	7	1	0
28	1	0	0
30	1	0	0
32	1	0	0
34	0	0	0

Table for Figure 11: Six Wolves

Time	Elk	Deer	Vegetation
0	67	133	200
2	63	133	172
4	63	133	172
6	63	133	172
8	63	133	172
10	169	330	278
12	275	543	180
14	236	448	160
16	194	308	172
18	154	271	190
20	120	175	272
22	132	157	300
24	119	153	338
26	134	159	330
28	133	185	307
30	108	203	323
32	152	209	314
34	175	191	313
36	205	259	300
38	208	271	293
40	211	285	293
42	236	271	286
44	238	236	278
46	212	271	249
48	163	260	258
50	141	276	313
52	127	256	303
54	136	250	254
56	135	211	248
58	130	203	267
60	130	187	275
62	158	205	294
64	200	226	275
66	231	249	293

Time	Elk	Deer	Vegetation
68	178	279	268
70	202	319	274
72	189	290	296
74	180	228	266
76	204	195	238
78	206	163	268
80	184	142	331
82	185	171	301
84	215	197	252
86	221	212	234
88	204	190	313
90	174	200	278
92	169	185	263
94	203	198	289
96	206	241	309
98	238	290	288
100	230	266	288
102	230	234	221
104	201	203	237
106	201	158	273
108	160	160	314
110	206	157	338
112	253	187	314
114	263	209	312
116	268	215	289
118	273	213	274
120	231	179	281
122	192	128	290
124	191	115	295
126	242	130	288
128	275	151	297
130	227	159	306
132	190	158	260

Table for Figure 12: Ten Wolves

Time	Elk	Deer	Vegetation
0	67	133	200
2	67	131	199
4	67	131	199
6	67	131	199
8	67	131	199
10	86	181	286
12	184	433	398
14	147	344	428
16	90	230	414
18	52	147	437
20	33	69	434
22	18	34	429
24	9	6	424
26	3	1	430
28	1	0	443

Glossary

Agent - An animal or object in StarLogo that can be programmed to follow a set of commands.

Collision - In the programming, describes what happens when to animals collide, run into each other (gains energy, dies)

Constant - An agent whose starting amount is always the same, but changes over time (ex: deer, elk, vegetation)

Ecosystem - A system formed by the interactions of organisms and their environment

Elk - prey for the Mexican Gray Wolf, an agent, eats vegetation

Energy - A variable given to an agent to track and adjust the amount stored based on the action of the Agent. An example would be that for every step the agent takes it loses energy. The energy will increase when the agent eats. It also controls reproduction and starvation.

Lotka-Volterra Equation - Two equations used to describe predator-prey models

Mexican Gray Wolf - predator eats deer and elk, an agent

Predator - An organism that exists by feeding on other organisms

Prey - An animal that is hunted or seized for food

Starlogo TNG - modeling and simulation software

Variable - An agent whose starting amount is different but stays at that same number during the course of the model (wolf)

Vegetation - Food source and energy source for deer and elk

White-tailed Deer - prey for the Mexican Gray Wolf, an agent, eats vegetation

Project Achievements

Learning how to work with StarLogo was the most challenging part of this project. It was also a challenge to incorporate team meetings around each team member's full schedules. The team found a way to bring out the best in each team member. Each person had at least one major contribution to this team effort. Everyone has improved their presentation skills. The process of doing this project has been a positive experience for everyone.

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