Background Information on Simulation Created for

Lesson 3: Rabbits, Rabbits and More Rabbits: Logistic Growth in Animal Populations

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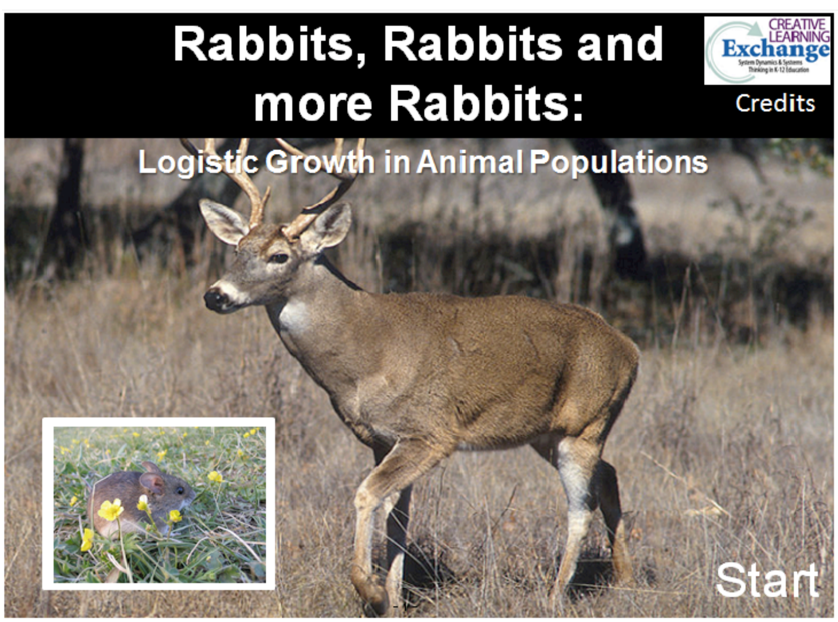
in collaboration with the Creative Learning Exchange



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Lesson 3: Rabbits, Rabbits and More Rabbits: Logistic Growth in Animal Populations

Note: Lesson 3 is an important precursor to Lesson 4: Waves of Change: Predator and Prey Dynamics. Population dynamics are taught in a mini-series of three lessons. We recommend starting with this lesson, logistic growth, and teaching these lessons in order because they clearly show the progression of structure needed to simulate S-shaped and cyclic behavior patterns.

Contents

Introduction

This lesson illustrates how a single population of animals can exhibit logistic growth or decline. Logistic growth (also called S-shaped growth) can occur as a result of density pressures when a population expands to reach its carrying capacity. The first phase of a logistic growth pattern features exponential growth. Plenty of resources are available for each member of the population because the overall population density (animals compared to land area) is low. Animals are able to live long lives, on average, and reproduce abundantly. Eventually, growth slows and levels off when the animals experience the ill effects of high density, such as stress from crowding and competition for food resources.

Overview of Model Behavior

Run the Model with the Default Settings

Four populations of animals are offered in a table on the Control Panel of the simulation (Figure 1). The default values simulate a deer population for a period of 20 years. Click "Run" to generate the behavior in the screen shown below.

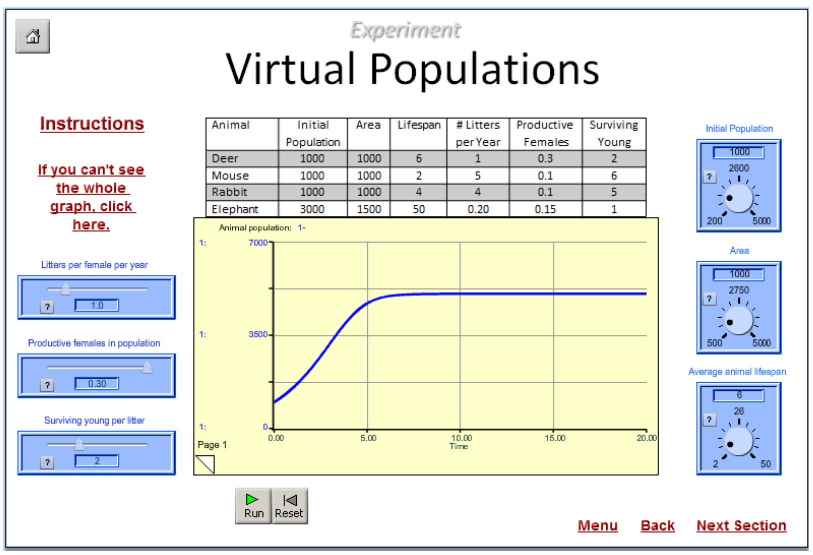

Figure 1: The Control Panel of the simulation, showing logistic growth for a population of deer.

Note that while the time unit of this model is years, a population of cells in a culture dish might experience this same growth pattern in days. On your screen, click the white triangle in the lower left of the graph to see graphs of other variables. In Figure 2, you will see a variable called "Real animal lifespan." This variable is the result of modifying the average lifespan (set in the Control Panel) to reflect density pressures on the population. In other words, as density increases, we should expect to see animals living shorter lives. See the graph below for an example showing the default run for deer. As too many deer crowd into the same space, on average, they live much shorter lives.

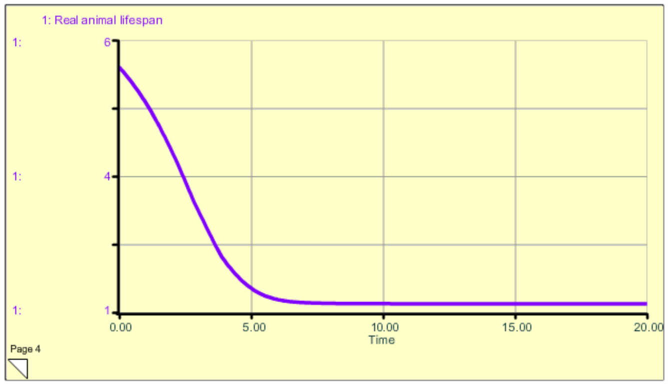

Figure 2: Real lifespan (on average) is much shorter in a population of crowded animals.

Compare and Contrast Animals

The simulation can be used to supplement learning about various types of animals and their habitats. For example, in Figure 3, run 1 shows the trajectory for deer, while run 2 shows the growth of a population of mice.

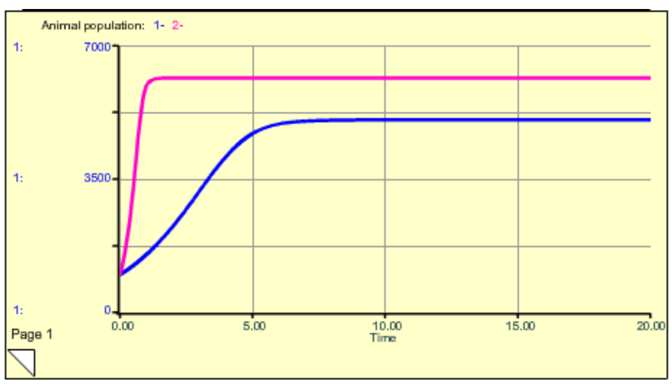

Figure 3: A comparative graph showing logistic growth in deer and mice populations.

Logistic growth occurs when a population reaches the limits of its environment. The population is squeezed due to density-dependent pressures. Mice, being smaller and needing much less space than larger animals such as deer, will attain a much higher level of population before reaching the limits of the environment.

The settings for births and deaths for each of the populations reveal something about the animal and how it fits into its environment. Mice are prey for many species and need a relatively high birth rate to replace the members that are eaten. Absent predation (the model does not include predators), mice will reach their carrying capacity more quickly than animals that reproduce at a slower rate. At the other extreme, elephants have few predators. They have evolved to live long lives, use many years to raise their young to independence, and therefore reproduce very slowly.

Examine Influences on a Single Population

The model can also be used to show how the logistic growth process can proceed faster or more slowly according to factors that affect births and deaths in the population. In Figure 4, below, run 1 shows the default behavior of a deer population. The second simulation run sets “Litters per year” to 2 (from the default value of 1) and the third gives the animals twice as much space (2000 square miles instead of 1000 square miles).

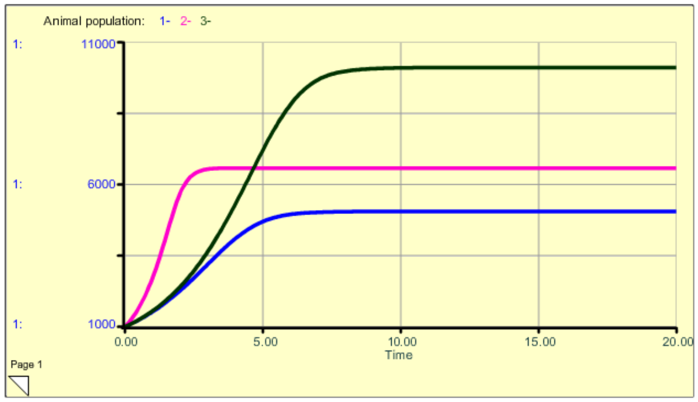

Figure 4: A population of deer may grow more quickly and to greater heights, depending on changes in the model settings.

Note that students may observe that certain animals are unable to give birth more than once a year, or they may make some other observation that seems to contradict the numbers in the table. Such critical thinking skills are very important; simulation models allow us to test our assumptions and ask “what if” questions. “What if deer could give birth more than once every year?” is a valid question to test with a model if the intention is to learn how that setting would affect the population growth of the herd. Students may also wish to use other resources, such as textbooks and the internet, to research the range of plausible numbers for the model’s parameters.

Model Structure and Assumptions

The model structure is presented in Figure 5. This screen is accessed via the menu by clicking the link “Explore the Model.” Variables colored green are changed via sliders and knobs in the Control Panel.

The links “Tour the Model Structure” and “Tour the Loops” give an overview of the model structure and the feedback loops governing its behavior. The loop labeled “R” for “reinforcing” is the dominant loop when the population is growing exponentially. Exponential growth is limited through the action of the balancing loop labeled “B2.” This loop increases deaths when population density gets high, causing deaths to eventually balance births. The result is dynamic equilibrium (also called steady state) when the population is neither growing nor declining.

An assumption embedded in the model structure is that a single density relationship represents “crowding” for four different animal species. As a general model of logistic growth, such an assumption is fine. Numbers given in the table on the Control Panel are reasonable estimates for the given species, but the density relationship that relates the amount of space available to the death rates of the animals is not based on real data. This model is not intended to represent any real animal species.

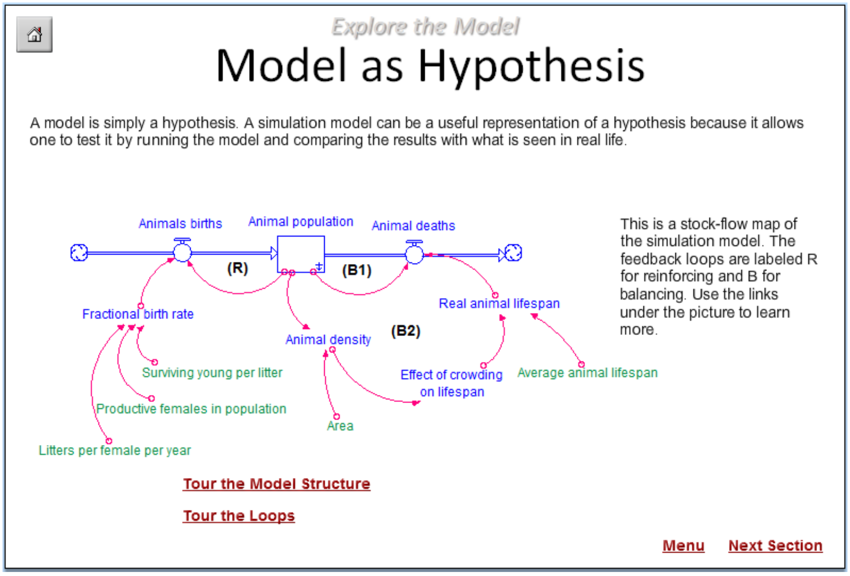

Figure 5: The structure of the model; green variables are changed in the Control Panel.

Limitations of the Model

As a general model of logistic growth, this model shows reasonable trajectories for the four species of mammals in the table on the Control Panel. Values for other, similar animals may also produce logistic growth patterns. However, the model has not been tested for specific species of birds, reptiles or insects. In principle, the model can be used for any species that experiences density-dependent limitations to its growth trajectory. The caveat is that all parameters of the model, including the density relationship defined in the variable “Effect of crowding on lifespan,” would have to be defined for that particular species. This can be done using the STELLA model that is available for download from the Creative Learning Exchange.

Also, please note that it is possible to produce invalid behavior with this model. One such example is shown in Figure 6, below.

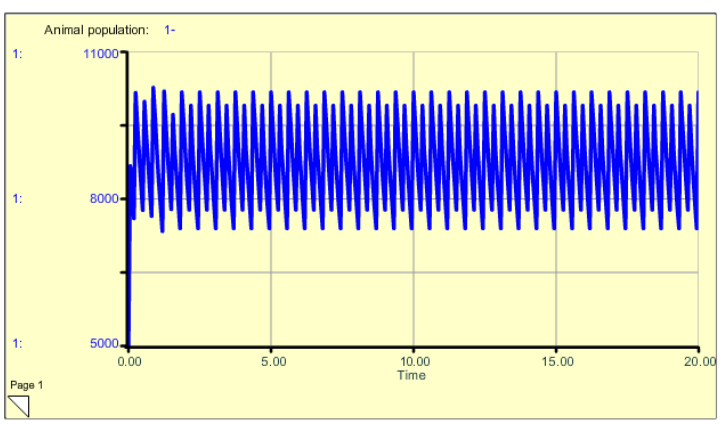

Figure 6: This is integration error, not true oscillation.

This graph is showing integration error, which is the result of the model being pushed to the boundaries of what the simulation software can compute given the internal settings of the model. It may look like the population is oscillating, but it is not.[1] This graph is created by setting all the sliders and knobs to their maximum values. This would correspond to an animal that has a very high birth rate (many young surviving to reproduce) and also a very long lifespan. While such an animal may exist (a good topic for investigation), the model is not able to handle such values given the internal definition of the density relationship. If students produce a graph that looks like a jagged oscillation, ask them to experiment with slowing the birth rate and death rate until an S-shaped pattern emerges again.

Talking Points – Linking the Simulation to Real Life

Some useful questions for discussion with students include the following:

- What pattern can be observed in human population growth – exponential, logistic or something else? Is human population growth limited? What could happen if/when we reach our limits?
- Is the carrying capacity of an environment or ecosystem a hard and fast limit, or more of a fuzzy danger zone?
- As human population grows, what are possible consequences for large animal species that need a lot of space to live?
- For animals that reproduce slowly, what can happen when their populations drop to very low numbers? What does it mean for a population to be "viable" or "sustainable" over the long term?

The Cause of the Problem is Within the System

The overall goal of the Oscillation curriculum is to teach a principle of complex systems: The cause of the problem is within the system. Socioeconomic systems that oscillate are often not recognized as oscillating due to their intrinsic structure. Explanations often point to outside influences that are themselves oscillating, or to a particular combination of outside factors believed to "drive" the oscillation. Yet by learning about a physical system such as a spring, we can clearly see that a spring oscillates because it is made to do so. It does not oscillate because a hand or other force continually pushes it in an up-and-down or back-and-forth motion. A spring gets set into motion with a push or a pull, and it oscillates due to its own structure.

The model in this lesson produces a logistic growth pattern, not oscillation. It is a stepping stone in understanding how two populations can be linked in such a way that they influence each other in a cyclic pattern over time. The next model builds on the model presented in this lesson, and Lesson 5 adds yet another component of predator-prey dynamics, a food supply for the prey species.

[1] The model does not generate true oscillation. Cyclic population dynamics are presented in Lessons 4 and 5.