CoreModels

DEER POPULATION

A CORE LEARNING GOALS ACTIVITY FOR SCIENCE AND MATHEMATICS

Summary
Students use STELLA® to build a simple model of changes in deer population. They add to the model factors that affect population size. They interpret graphs induced by their inputs in terms of population change.

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Overview:

In this activity, students will construct a STELLA® model to illustrate population growth in deer. They will initially build a model that involves a given population growing in size due to births. Students will then add to this model by including deaths followed by limiting factors such as food supply and habitat size. Students are then given the opportunity to build upon their model by adding improvements suggested by them.

Activities at a Glance:

Activity	Title	Materials	Estimated Time
1	Basic Model with Births and Deaths	STELLA, computers	45 minutes
2, 3	Adding limiting factors	STELLA, computers	30 minutes
4	Extensions	STELLA, computers	30 minutes

Prior Knowledge:

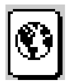
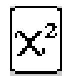
Students should be familiar with the characteristics of a population, emigration and immigration, limiting factors, and carrying capacity. They should also be familiar with exponential growth (J-curves) and logistic growth (S-curves). They should be familiar with reading and interpreting a graph. They should have basic computer skills. If students have not previously worked with pre-built STELLA® models, an introduction to the interface would be appropriate.

Deer Population
Answer Guide

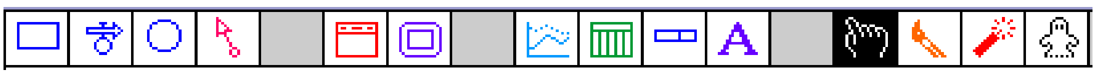
In many places, deer have become nuisance animals because they are so numerous. In some areas, a hunting season has been introduced or lengthened to reduce the number of deer. In other areas, animals that prey on deer—like wolves—have been brought back. You can use a STELLA® model to simulate how a deer population changes over time as different factors affect birth and death rates.

Building the Model:

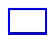
1. **Double-click** on the **STELLA** icon.

2.**Click once** on the icon of the world  . It should change to  .

3. The tool bar looks like this:



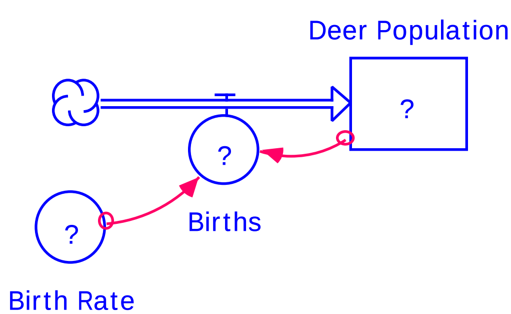
This is the source of the icons you will use to build your model.

4. **Click once** on the stock icon  . Slide your pointer out into the open field and click again. A large stock should appear with the word **Noname 1** highlighted. Before doing anything else, **type** the words **Deer Population.**

5. **Click once** on the flow icon  . Position your pointer to the left of the stock, then **click and drag** until the stock becomes shaded. Let go of the mouse button. Type the word **Births.**

6. **Click** on the **converter** icon which looks like this:  . Move your pointer near the Births flow and click again. Label this converter **Birth Rate**.

7. **Click** on the **connector** icon  . Place the icon inside the Deer Population stock. Hold the mouse down and drag the pointer inside the **Births** flow. Put another connector going from the **Birth Rate** converter into the **Births** flow. Your diagram should look like this:



By replacing the question marks in your model with numbers or equations, you tell the model how many deer are now in the population, how fast deer reproduce, and how to calculate the number of births. The assumptions are that females are half the population and that half of the does produce one fawn each year to add to the population.

8. **Double-click** on the Deer Population stock and enter **10** in the text box. **Click OK.**
9. **Double-click** on the Birth Rate converter and enter **0.25** in the text box. **Click OK.**
10. **Double-click** on the Births flow. To enter the expression **Deer_Population*Birth_Rate**, use the mouse to click on Deer_Population and Birth_Rate in the Required Inputs box and the asterisk (for multiplication) in the numeric keypad displayed**.**

Q1. At a birth rate of 0.25, the population should increase by what percent each year?

25%

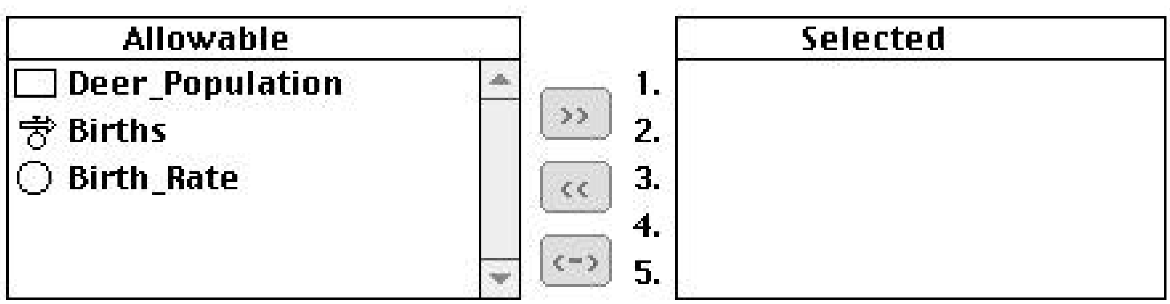
Setting Time Specs:

11. Go the the **Run** menu and drag down to select **Time Specs...**
12. In the boxes under **Length of Simulation**, set **DT: to 1**. (DT is 1 year, the unit of change in time.) Under **Unit of Time**, click the **Years** button. Click OK.

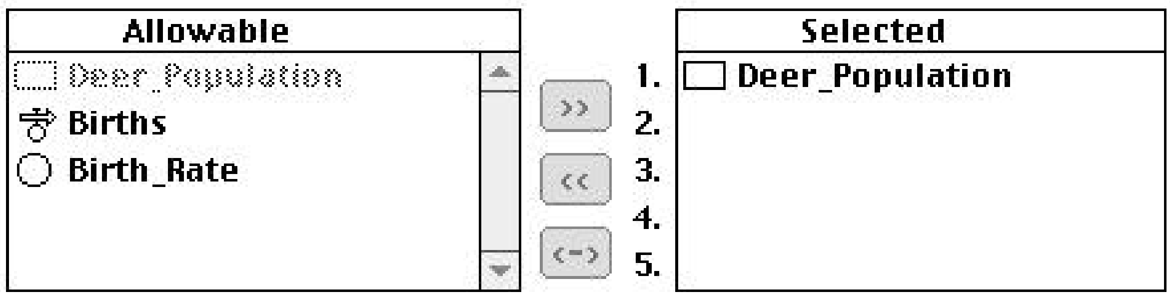
Setting up a Graph:

13. You need to specify which variable you want STELLA® to show in a graph.

- **Click** on the graph icon  .
- Slide the icon to an open spot in the window and **click** again.
- **Double-click** on the large blank graph that appears. A new window will open. You will see two boxes, which look like this:



To select the deer population as the variable to graph, **click** on Deer_Population, then **click** on the >> symbol (or **double-click** on Deer_Population).
The boxes now look like this:



Click OK to close the window.

14. To prevent the graph box from disappearing every time you run the model, you should pin down the graph window.

- Move your pointer to the horizontal bar at the top of the graph window.
- Drag the graph so it fits on the white space below the model.
- **Click** once on the black circle (looks like a push pin) in the upper corner of the graph.

Using the Model:

15. To run the model, **click and hold** the **Run** option on the menu bar and **drag down to Run**.

Q2. Sketch the graph on the axes provided. Label each axis with the scale and units.

See Appendix A

Q3. Describe in full the curve. What does the curve show about the rate of growth?

The deer population starts at 10 and increases at an ever increasing rate, showing exponential growth.

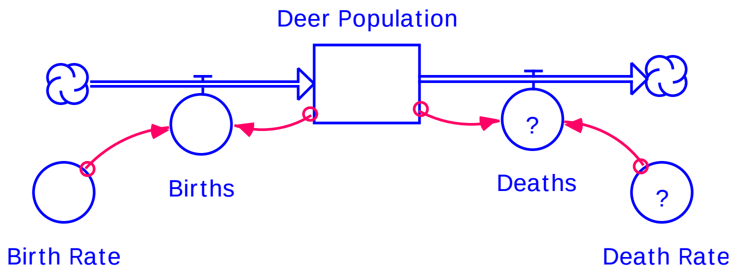
Adding Deaths:

To make the model more realistic, you should add deaths. Just as births in the model are represented by a flow that affects the deer population stock, deaths will be represented by a flow.

16. Add the deaths flow to the model. (HINT: To make a flow point out of a stock, start inside the stock box and drag the flow out.)

17. The number of deaths depends on the size of the deer population and the death rate. To establish these relationships, create a death rate converter and install connectors from the stock to the deaths flow and from the death rate converter to the deaths flow.

Your model should look like this:



Q6. If you assume that the death rate is equal to the birth rate, how do you think the deer population will change over 12 years?

The deer population will remain constant.

18. Double-click on the question marks in Death Rate and Deaths and enter this information:

Death Rate	**0.25**
Deaths	**Deer_Population*Death_Rate**

19. Run the model to observe the new graph.

Q4. Sketch the graph on the axes provided. Label each axis with the scale and units.

See Appendix B

Q5. Describe in full the graph and explain its meaning.

The graph is a horizontal line with a y-intercept of 10 indicating that the deer population remains constant.

Q6. If the death rate were greater than the birth rate, what would happen to the deer population?

The deer population would decrease.

Q7. Change the death rate to some number between 0.25 and 1.0. Run the model and sketch the resulting graph on the axes provided. Label each axis with the scale and units.

See Appendix C

Q8. If the death rate were smaller than the birth rate, what would happen to the deer population?

The deer population would increase.

Q9. Change the death rate to some number between 0 and 0.25. Run the model and sketch the resulting graph on the axes provided. Label each axis with the scale and units.

See Appendix C

Q10. In the real world, birth rates and death rates vary from year to year. List three factors that would affect birth rates and/or death rates for a population of deer.

Available food, hunting and disease are possible answers.

Adding and Varying Food Supply

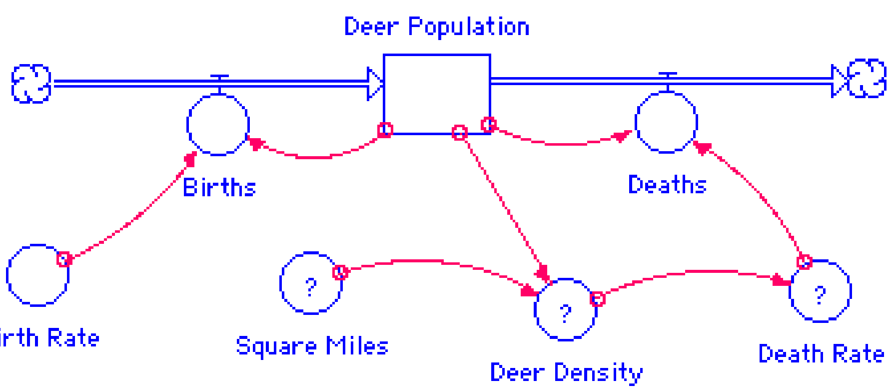
The amount of food available in a particular area governs the number of deer that can live there. As the deer population in a particular area increases, the food available for each deer decreases, leading to a higher death rate due to starvation or disease. If you show that the death rate converter in your model is affected by available food, you can simulate the effect of a varying food supply on a deer population. To do this, you need to consider the size of the area in which the deer live and the carrying capacity for that area.

20. Add two converters. Name them Square Miles, representing the area where the deer live and Deer Density, defined as the number of deer per square mile.

21. Add connectors to show which components of your model are needed to define Deer Density.

22. Add a connector to show the relationship between Deer Density and Death Rate.

Your model should look like this:



23. Double-click on question marks to enter the following information:

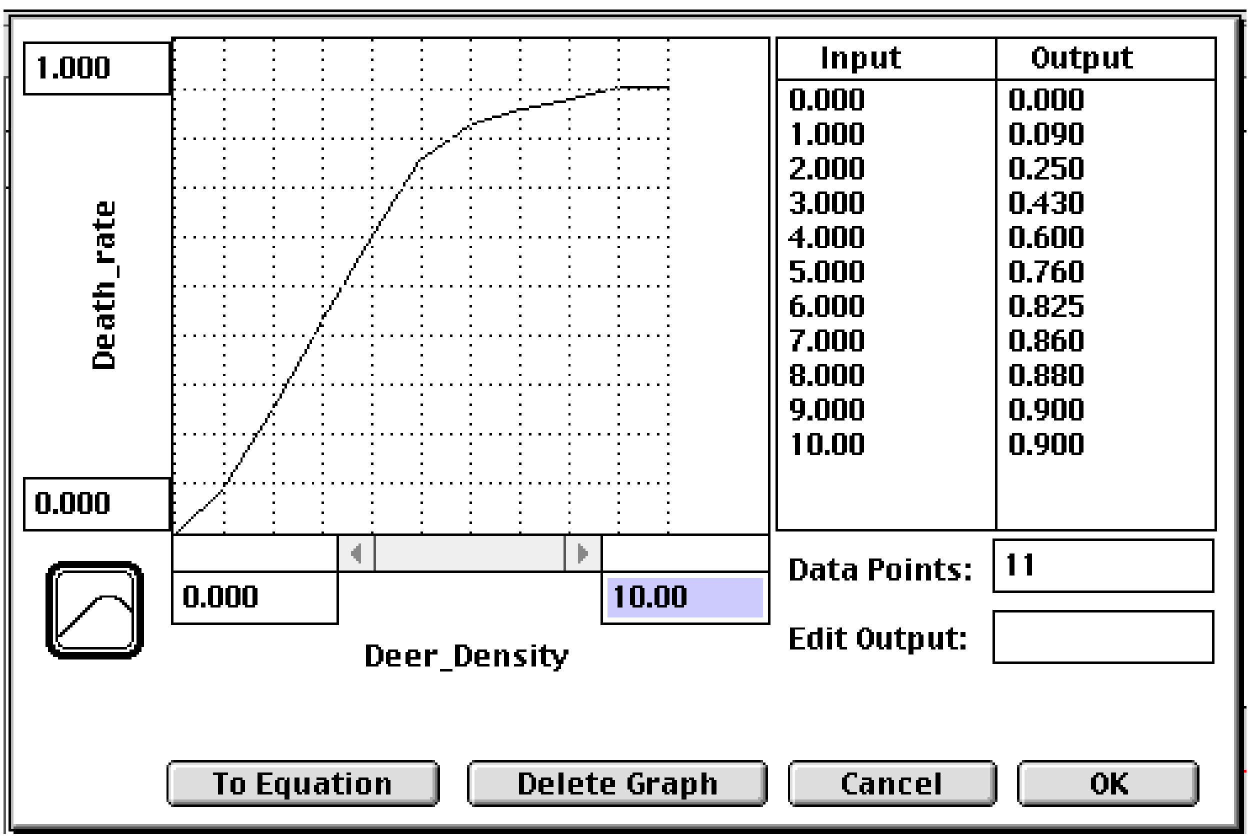
Square_Miles	**100**
Deer_Density	**Deer_Population/Square_Miles**

Q11. In Maryland, the typical suburban area can support approximately 2 deer per square mile. What is the carrying capacity for a 100 square mile forest? How many years do you think it will take for a herd of 10 deer to reach its carrying capacity?

The carrying capacity is 200 deer. Student predictions for the years will vary.

24. When the deer density rises above 2 deer per square mile, the death rate increases because of starvation and disease. When the deer density is less that 2, the death rate is less than 0.10. To enter this information in your model, you will enter data from which STELLA® will create an input graph.

- Double-click on the converter for Death Rate. Select Deer_Density from Required Inputs. Click Become Graph.
- Set the maximum value on the y-axis at 1.0. Press Return.
- Set the maximum value on the x-axis at 10.0. Press Return.
- Enter the values shown in the Output column below.



25. Run the model and examine the graph.

26. After 12 years, the population appears to be maintaining exponential growth. Change the Length of Simulation by going to the Time Specs window under the Run menu. Change 12 to 36 in the box labeled To. Click OK and run the model again.

Q12. Sketch the graph on the axes provided. Label each axis with the scale and units.

See Appendix D

Q13. Describe in full the curve. Explain the meaning of the graph.

The curve begins by slowly increasing for the first 7 years. Then it grows more and more quickly for the next 9 years. Finally it starts leveling off and reaches equilibrium. This means that the deer population grows at an ever increasing rate for about 16 years, but then density-dependent limiting factors cause the rate of growth to slow down.

Q14. What term describes the population curve?

Logistics curve or S-curve

Q15. The population curve has three growth phases. Name each one and give a brief description of its meaning.

Lag phase - slow growth because there are so few deer initially

Exponential growth phase - the growth rate is ever increasing

Carrying capacity - the growth rate slows down and the population stabilizes

Q16. Determine from the graph the apparent carrying capacity for deer in the environment you are modeling. How many years did it take for the deer to reach their carrying capacity?

The carrying capacity is 200 deer. It took approximately 27 years.

Model Modifications:

The logistics curve that the model generated represents an idealized picture of the population. Since the death rate became equal to the birth rate at the carrying capacity, it was impossible for the deer population to exceed its carrying capacity. In reality, populations are able to grow beyond their ideal carrying capacity. When they do so, some internal environmental force like starvation or disease or an external force like human hunters reduces the population by eliminating its weakest members. The population then begins to grow again. You can represent this oscillating behavior by using the Random function provided by your STELLA model.

28. Double-click on the Deaths flow. Enter the expression:
Deer_Population*random(Death_Rate-0.1, Death_Rate+0.1).

29. Under Time Specs, change dt to 0.25 and extend the time to 50.

By letting dt = 1/4 of a year, we will be allowing deaths to happen every season, rather than just once a year. Every three months, some deer will die. The fractional death rate will be a random number between one-tenth less and one-tenth more than the death rate read from the input graph.

30. Run the model.

> **Q17.** Describe in full the curve. Explain its meaning.
>
> **See Appendix E for the graph.**
>
> **Instead of being a smooth S-curve, the curve has frequent variations oscillating around the carrying capacity of 200. It still has the three growth phases.**

Extension: Adding predators

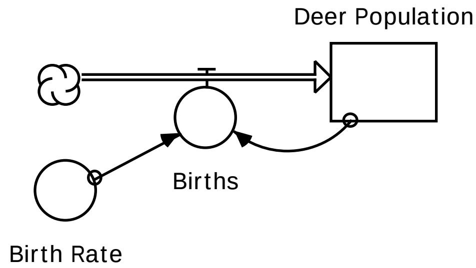
Mountain lions, wolves, coyotes and, from Minnesota to New England, bobcats are all predators of deer. Incorporate predators into your model by adding a predator stock and the accompanying flows and converters.

> **Q18.** What information would you need to know to build an accurate model?
>
> **Birth and death rates for the predator and number of prey that each predator eats.**

> **Q19.** What do you predict will happen to the deer population as a result of your choices for the predator portion of your model?
>
> **Answers will vary. Students may observe that the deer population will not reach its carrying capacity due to deaths from predation.**

> **Q20.** Create a new graph showing both deer and predator populations. Run the model. Sketch the graph on the axes provided. Label each axis with the scale and units.
>
> **Answers will vary.**

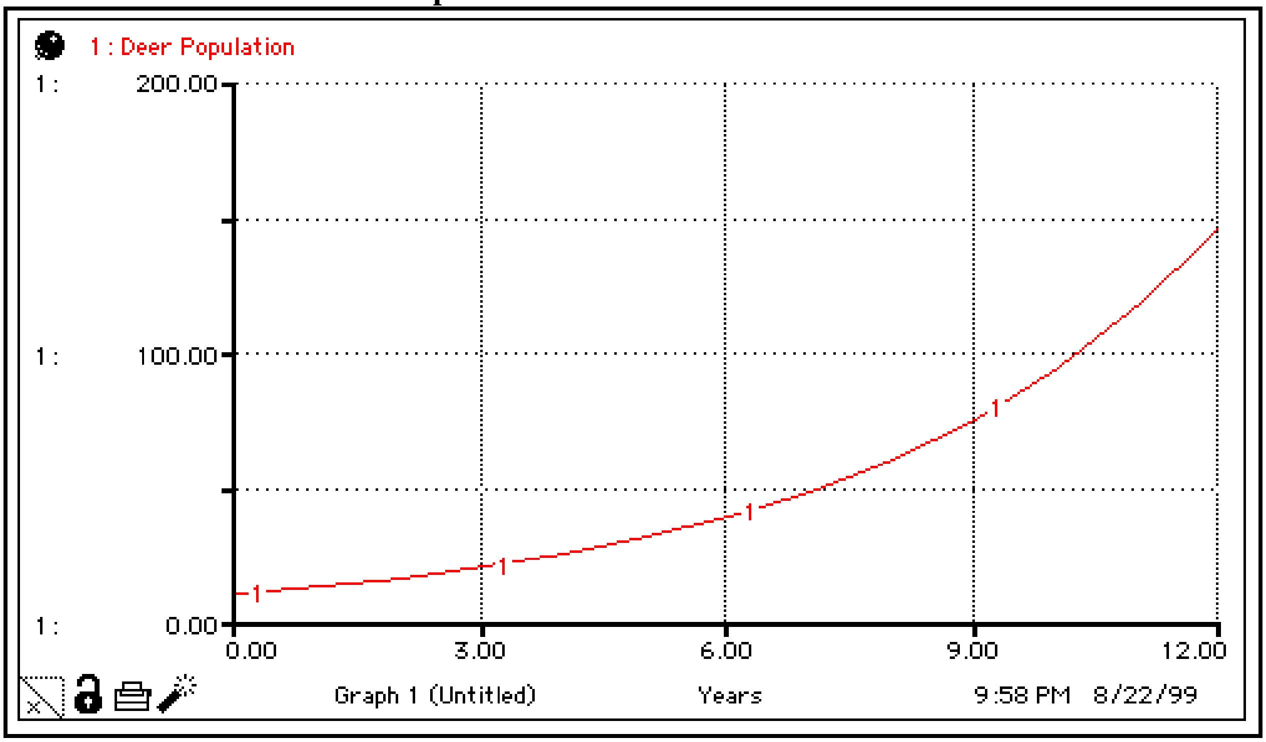
Appendix A
STELLA® Model - Births



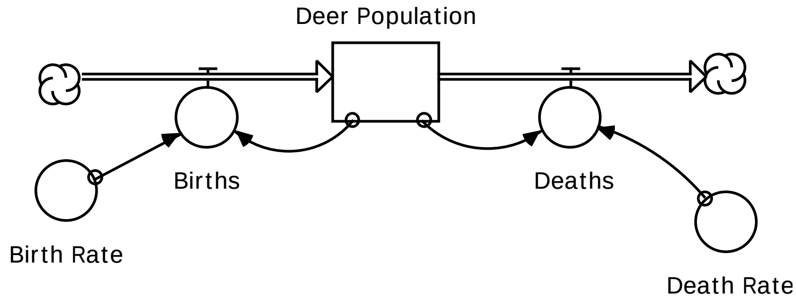
Deer_Population(t) = Deer_Population(t - dt) + (Births) * dt
INIT Deer_Population = 10

INFLOWS:
Births = Deer_Population*Birth_Rate
Birth_Rate = .25

Population with Birth Rate = 0.25



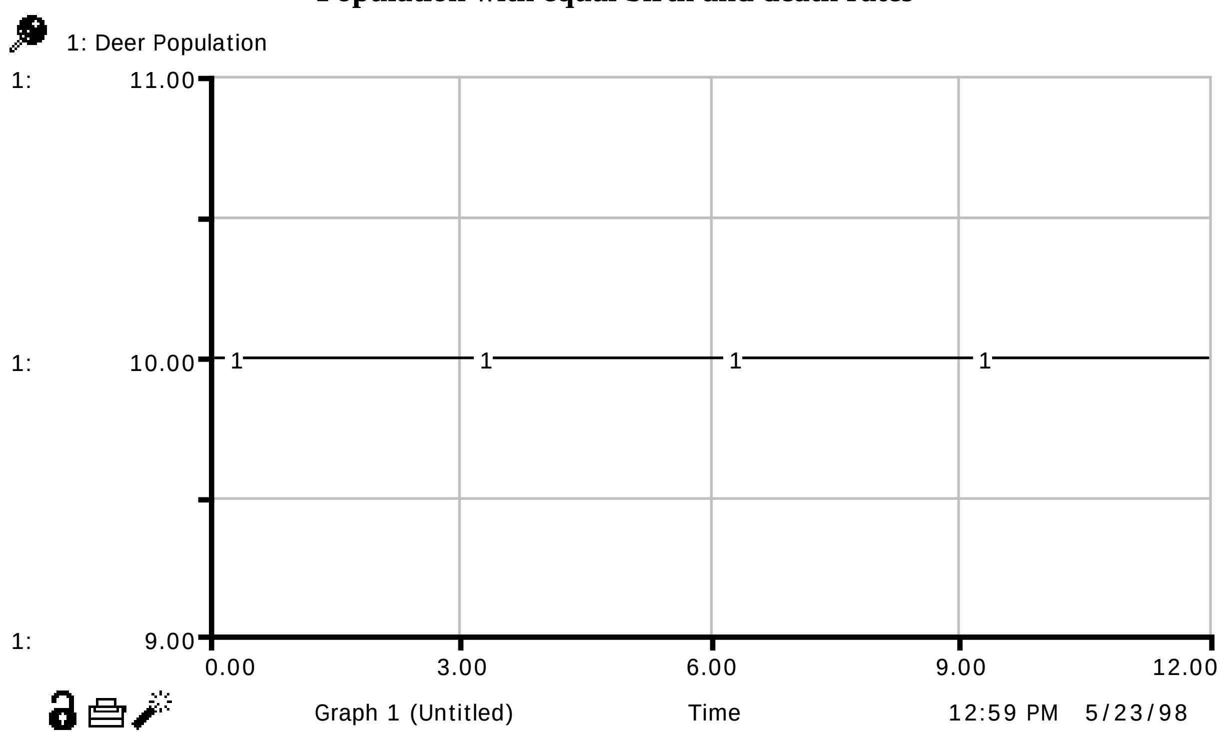
Appendix B
STELLA® Model - Adding Deaths



Deer_Population(t) = Deer_Population(t - dt) + (Births - Deaths) * dt
INIT Deer_Population = 10

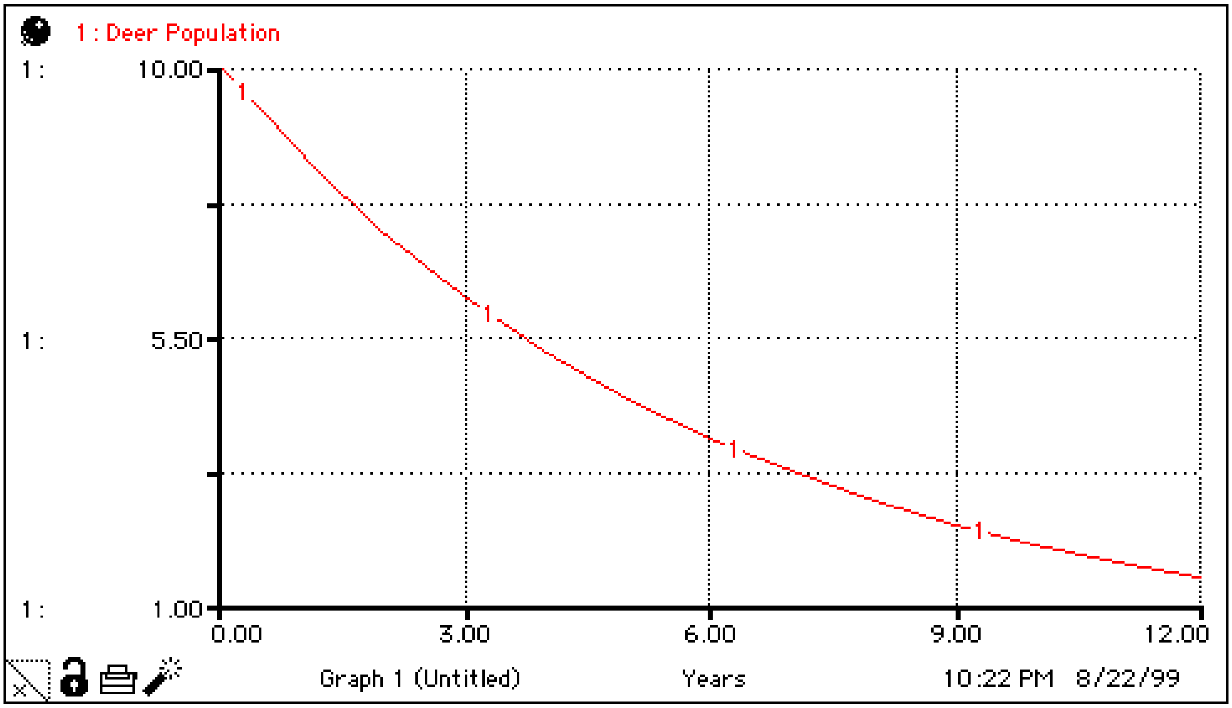
INFLOWS:
Births = Deer_Population*Birth_Rate
OUTFLOWS:
Deaths = Deer_Population*Death_Rate
Birth_Rate = .25
Death_Rate = .25

Population with equal birth and death rates

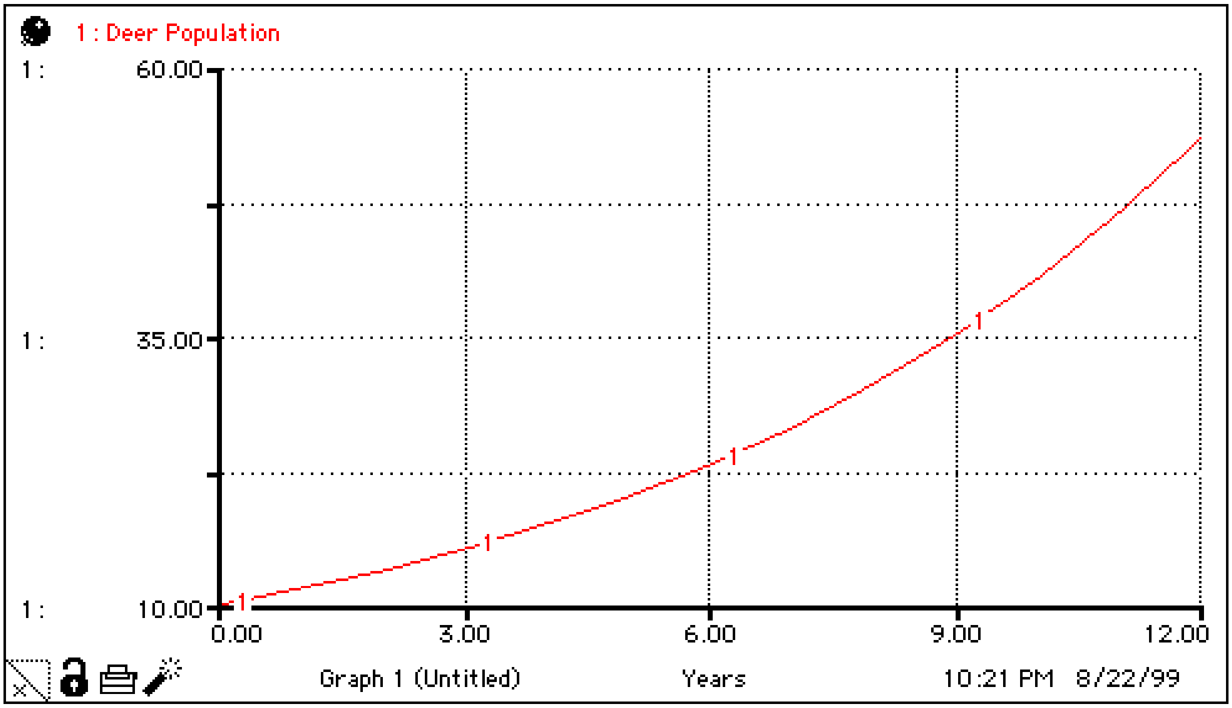


Appendix C
STELLA® Model - Deaths and Births Unequal

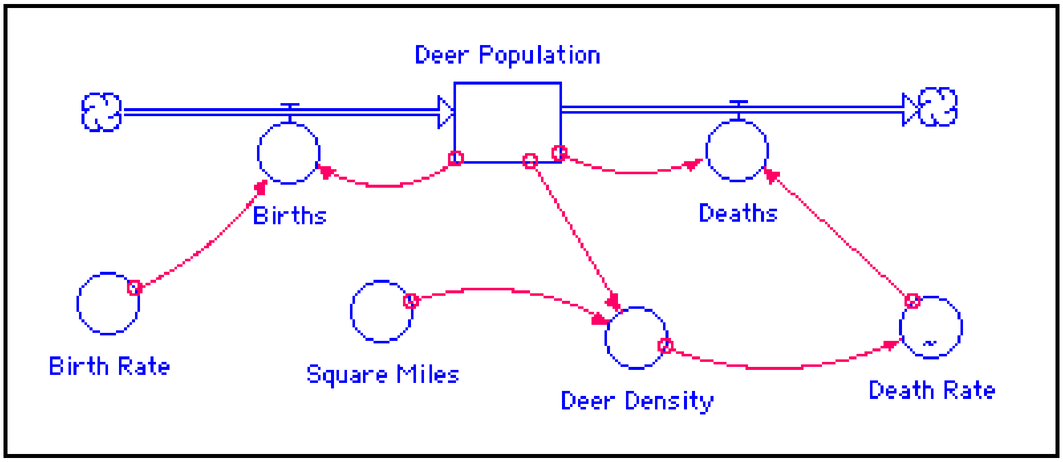
Birth rate = 0.25, Death rate = 0.40



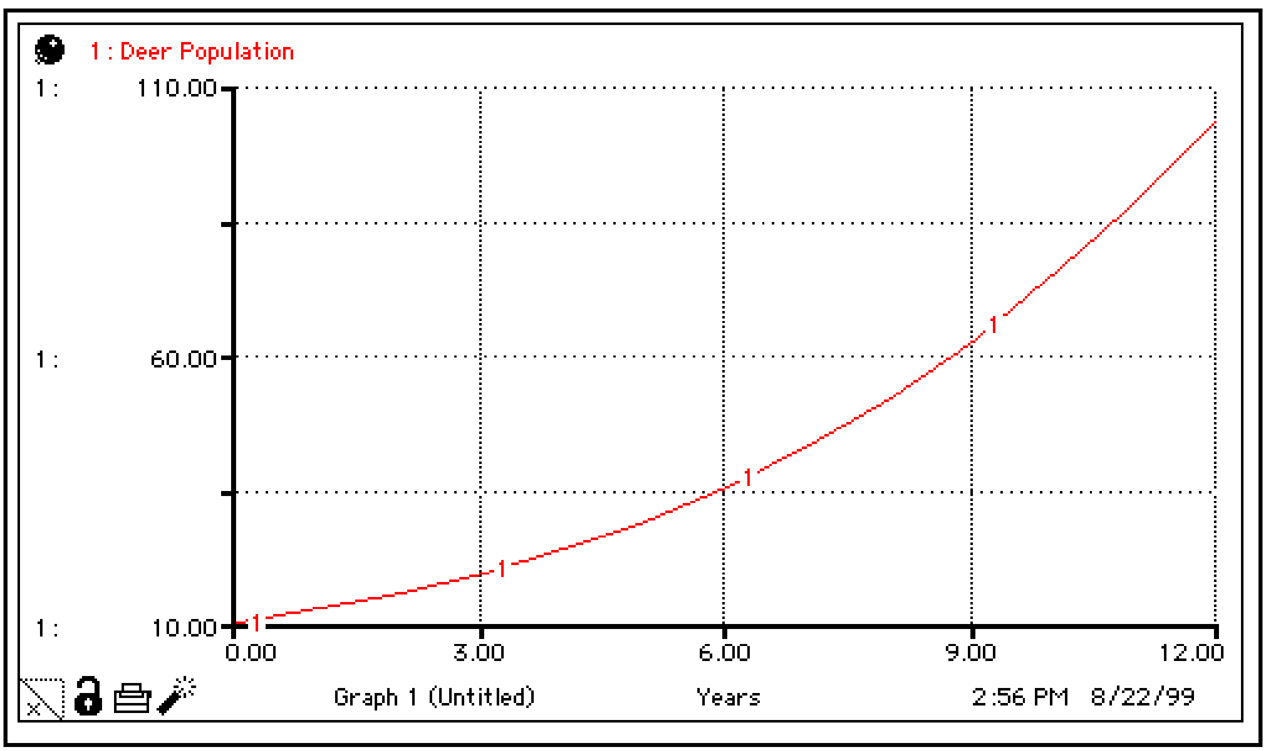
Birth rate = 0.25, Death rate = 0.10



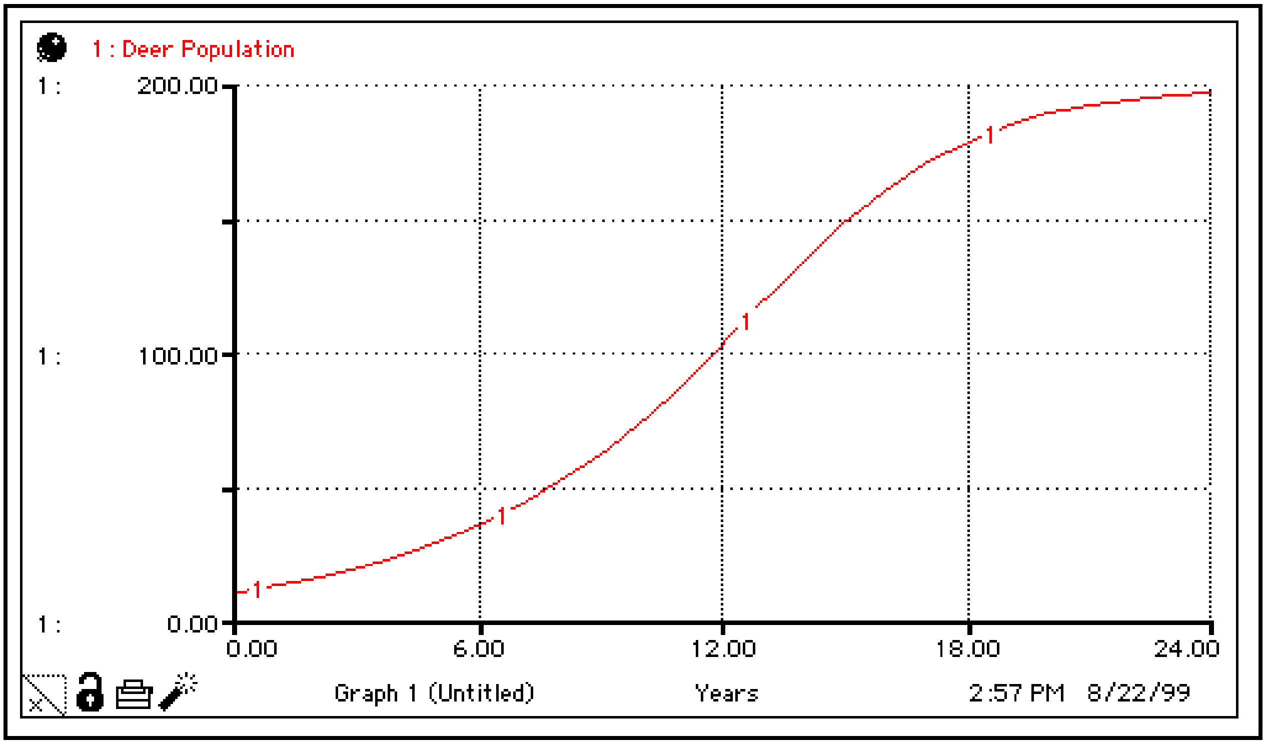
Appendix D
STELLA® Model - Adding Deer Density
(Carrying Capacity = 200)



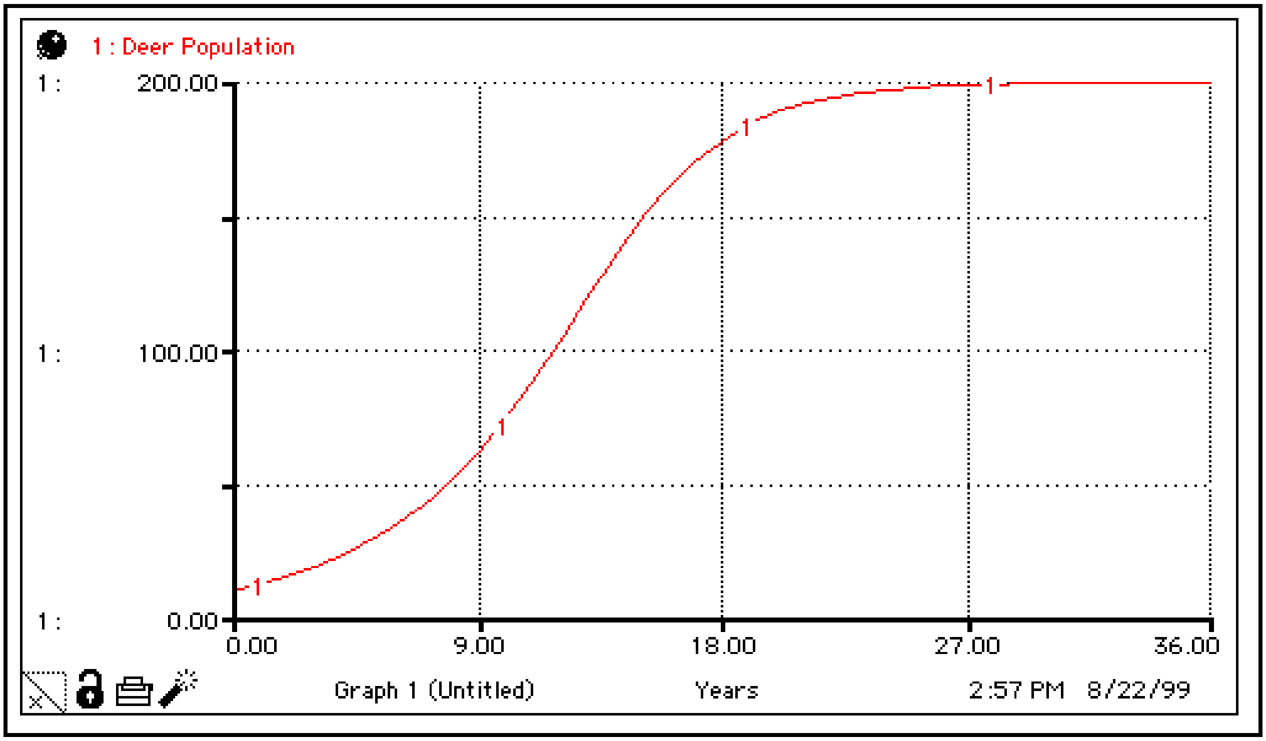
Growth for 12 Years



Growth for 24 Years



Growth for 36 years



Appendix E
STELLA® Model - Randomizing Deaths for 50 years