

Easter Island Population Model

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Consider the problem that happened on Easter Island. In about 400 AD there was a fairly stable population of natives (say 200) on the island. The island was also heavily forested. Around 1000 AD a second wave of immigrants (natives from the surrounding area) landed on the island (say another 200) and remained. There were plenty of coconut palm trees to support the population. These palm trees served as the main food source and the natural resource from which a strong rope could be fashioned. This rope, it is hypothesized, may have played a part in transporting some large stone statues from a volcanic rock quarry (near the volcano Rano Raruku) to other parts of the island, where they remain today.

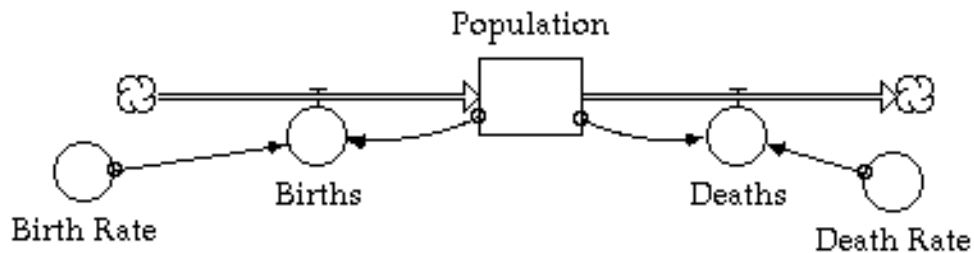
At the beginning the population flourished. People used the palm trees with no thought about eventual depletion of the resource. By the 19th century there were only 110 people left on the island. Deforestation was not the only component contributing to the collapse of the population, but recent studies indicate that it was a major component. There are almost no coconut palm trees remaining on the island.

We want to model the effect of the deforestation on the population of Easter Island starting about 1000 AD until about 1600 AD.

The Diagram

A. The population structure.

- Set up a standard population structure (similar to the one set up in the population tutorial).



- The *population* will begin with 400 persons. We do not have actual data to support a *birth rate*, but it seems appropriate to assume that each couple had about 5 children who lived to reach maturity. Using a reproduction period of about 26 years, determine the decimal fraction that should represent the *birth rate* per year _____ Also, since people died at a much earlier age at that time it is possible that 40% of the population would be couples of reproducing age.
- Define *births* in the model. *Births* = _____
- Define *deaths* in the model. *Deaths* = _____.
- We will not set up the *death rate* yet. A graph will be used to define the *death rate*, and this graph will depend on some factors not yet discussed.

B. The Food Structure.

- Now let's determine how to add the food source (coconut trees) to the model. Recall that there was a specific amount of food (trees) to begin with. An initial figure of 20000 trees would be reasonable (The island is 14 miles X 7 miles. This would mean that there were over 200 trees per square mile.) This was a non-renewable resource, since the natives did not replant the trees they destroyed. Since the amount of food will decrease with time, *food* (trees) should be modeled by a _____?(stock/flow)
- Since the *food* is only decreasing we need a flow that is _____ (out of/ into) the *food* icon. Call this flow consumption. Draw these two new structures under the population section of the diagram.

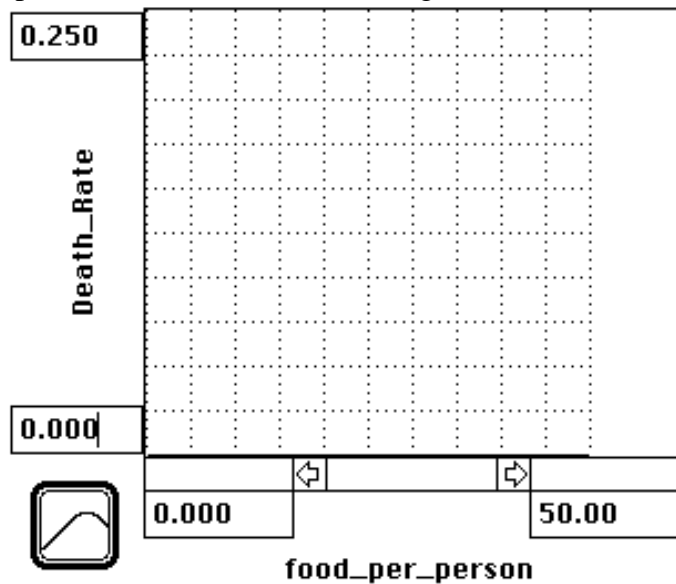
C. Defining the Death Rate

8. In addition to the natural death rate, the eventual reduction of available food will cause the *death rate* to increase. Actually, it is the amount of *food per person* that will affect the increase in the *death rate*. So put in a converter between the *population* stock and the *food* stock. Call it *food per person*. Connect *population* to *food per person*. Connect *food* to *food per person*. Since we believe that a change in the amount of *food per person* will affect the *death rate*, connect the *food per person* converter to the *death rate*.
9. Define the equation for *food per person* in the model.
food per person = _____
10. The *death rate* will need to be defined as a graph since we plan to have the fraction change based on the amount of food that is available. Double click on *death rate*. Click on *food per person*. Click on become graph. If the population starts out at 400 and there are 20000 trees on the island at the beginning of the simulation time, it is reasonable to set the upper limit for the food (trees) per person to 50. Why?

The lower limit is 0. The *death rate* (vertical axis) maximum could be set to .25. This is an arbitrary figure. If the fraction maximum is set to a larger fraction there will be a definite change in the overall population over time. You may want to experiment with other values later. For now just set the upper limit for the *death rate* to .25. The lower limit is 0.

11. Set the number of data points to 11. Now draw the graph to represent the pattern of deaths. If people have a great deal of food the death rate will occur only from natural causes (at least for our model). So when the *food per person* is at 50 we expect a low *death rate*, of .010, since the environment is very friendly in most other ways. This will be the case as long as there is enough food, say even as low as 20 unit of *food per person*. So set the *death rate* to .01 for all points from 20 to 50. When it gets lower than that it begins to affect the death rate, slowly at first. At 15 units of food maybe the *death rate* increases to .02. Then at 10 units it increases to .035. At 5 units it increases to .10. At 0 units it increases to .20. Remember that our food source was coconut palm trees. Why is it reasonable to assume that when the food in the model is 0 units per person we have 25% deaths instead of 100% deaths?

Sketch in the graph that represents the *death rate* from the given information.



C. Connecting Population and Food.

12. As the population increases the consumption of food will (incr/decrease)_____ Draw a connection from *population* to consumption.

13. It makes sense that the consumption should be in food per year, since it is a flow and all flows must be in 'stock units' per 'time'. We know that population will affect how much food is consumed each year, so consumption will need to have *population* as part of its definition. The other part that makes sense is how much food each person is consuming each year. This is the converter we still need to add. Add a converter called *food per person per year* just below and to the right of the *food* stock. It will also be defined as a graph. Connect *food per person per year* to consumption. Define consumption in your model. (Recall: Consumption is how much food all the people will eat each year.)

Consumption = _____

14. The component that will influence the amount of food a person can consume each year is the amount of food per person that is available. So connect *food per person* to *food per person per year*. Define *food per person per year* by double clicking on it. Click on *food per person*. Then click on become graph. Set the number of data points to 11. The maximum *food per person* is 50 units (trees) . The minimum *food per person* is 0. Assume that the most food, on average, one person could consume per year is .045.* Set the maximum *food per person per year* to .1 as a convenient round number larger than .045. The minimum *food per person per year* is 0. Use the table below to define the *food per person per year*. Notice that as *food per person* declines, the amount of *food per person per year* will also decline.

Food per Person	Food/Person per Year
0	0
5	.012
10	.027
15	.038
20	.042
25	.045
30	.045
35	.045
40	.045
45	.045
50	.045

The Simulation

Define the time specification for the model to be 600 years. Set the DT to 1.

1. a. We are interested in looking at the graph of the *population* and the *food*. Define a graph to include each of these components. Set up appropriate vertical scale values for each. To do this consider:

Food will have a maximum value of _____.

Population could have a maximum value of _____.

(If you don't know the maximum value for *population*, run the simulation once and then check the MAX box for the definition of *population* in the graph pad.)

Print out the graph. **Print** out the diagram. **Print** out the equations.

b. Set up a second graph to include *population*, *death rate*, and *food per person*. Set the minimum y-scale for *death rate* to 0 and the maximum to 1. Set the minimum for *food per person* to 0 and the maximum to 50. **Print** out a new graph.

Looking at the new graph printout, why do you think the population started to decline?

* Consumption means eating the fruit and destroying part of a set of trees to use in the construction of rope.

2. Define a table to include *food* and *population* components. At what point in time did the population double? _____ triple? _____
 When did the population start to decline? _____
 What was the largest value for the population? _____
 How many people were left after 600 years? _____
 How many trees were left after 600 years? _____

3. Toward the end of the 600 year phase the natives on Easter Island became cannibals. Also, in about 1400 a Peruvian slave ship landed on the island and took about 1000 natives on board to be used as slaves. Many of these natives died. Add the slave ship component to the model. Print the diagram, graph, and equations for this new model.

Give a possible explanation for what happens in the graph. Is it what you expected to happen ? Why or why not ?

4. What would happen if trees were being replanted at a rate of 50 per year. (Actually this is somewhat unrealistic since fruit bearing trees could not replace other trees immediately. It would take a few years of maturing before they would bear fruit - a problem that we could actually figure into our model - but we won't right now). Add this new factor into the food section of the model and rerun the simulation. Set the maximum *y* value for trees to 25000. Print out the new graph.

Extra Credit:

A. The few captured slaves who lived eventually returned to the island again, but brought with them the smallpox. The epidemic killed off all but 110 of the remaining natives on the island. Add the epidemic component to the model. Print the diagram, graph, and equations for this new model.

B. 1. If you were going to try to change the rate of decline in the population what factors (that you can control) might you try to alter? _____

2. Experiment with changes in the model to get:
 a. The population to die off faster. What did you do ? _____

b. The population to remain at a steady level. What did you do ? _____

c. The population to increase to a higher level before it starts to decline. What did you do ?
