**Isle Royale Worksheet 2**

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# Modeling the early moose population

Although the wolves arrived on Isle Royale in 1949, the moose arrived much earlier. This worksheet will lead you through the process of developing a model of the moose population when it is unaffected by wolves. Although we have no records of moose population prior to 1949, biologists believe that a small herd migrated to the island around 1900, grew to around 500 and leveled off, so let’s pretend that this is the graph of moose population in the first half of the 20th century:

Figure 1

## Modeling the first 20 years of moose population growth

Let’s start by building a model of the early phase, when the herd was small, food was abundant and hardly any moose died. Here is the target graph, extracted from the one in Figure 1:

Figure2

That is, you should build a model that makes the following assumptions:

* The population is 20 in the first year (1900).
* Births are the only change in the population. Deaths, immigration and emigration do not occur.
* The number of births each year is... *what?*

The third assumption is a problematic. In reality, the number of births is determined by the number of female moose of child-bearing age, their health, and many other factors. However, following Occam’s Razor, we want to start with the simplest assumption and see if it can explain the data. Looking closely a the graph, it appears the moose population increased from 20 to 24 during the first year, and to 28 during the second year, so let’s make the simple assumption that 4 moose are born each year and see if the resulting curve matches the first 20 years of the curve shown in Figure 2.

* Please go to <http://dragoon.asu.edu/> and click on More Problems.  
  Put in your name, select Student mode, and select “Moose population 1”.  
  Create a model for the moose population as described above.

Although your models’ graph is somewhat similar to figure 2, it should be a straight line whereas figure 2 shows a distinct upward curve. By 1919, the actual most population is rising faster than the model’s prediction of 4 moose per year.

If you think about how the herd grows, it doesn’t make sense that a large herd (e.g., 100 moose) would have the same number of births as a small herd (e.g., 20 moose). The number of births in a year ought to be proportional to the size of the herd that year. That is, in the first year, when the number of births is 4, that represents 20% of the size of the herd. So when the herd is at 100 moose, then 20% of the herd is 20, so about 20 births would occur. This makes much more sense biologically. As the size of the herd increases, the number of female moose of child-rearing age increase, so more moose calves should be born. The graph above confirms our intuition; it does seem that 20 would be pretty close to the number of births when the herd is at 100 moose. So let’s try the 20% assumption out in our model.

* Please go to <http://dragoon.asu.edu/> and click on More Problems.  
  Put in your name, select Student mode, and “Moose population 2”.  
  Create a model for the moose population as described above.

Your model’s graph does match the actual moose population for the first 20 years or so, so your modeling has been a success. Congratulations! Here’s what one student’s model produced:



Figure 3

## Modeling the first 50 years of moose population dynamics

Although our model matches the moose population for the first 20 years, the model’s predictions do not match the actual moose population for the remaining years, as you can see by doing the following exercise:

* Please go to <http://dragoon.asu.edu/> and click on More Problems.  
  Put in your name, select Student mode, and “Moose population 3”.  
  This contains the same model as you just completed, but the time span has been change from 20 years to 50 years. Click on Show Graph (at this writing, a bug in Dragoon may cause an error message here, preventing you from seeing the graph; the bug may be fixed by the time you use Dragoon). When you have studied the graphs, DO NOT close Dragoon because you will need to edit the model in a moment. Just return to reading this section.

Because the model accurately reflects the assumptions but the model’s graph does not match the actual population’s growth, at least one of the assumptions must be wrong. Which one?

The assumption “No deaths occur” might be reasonable for the first 20 years but clearly it is not reasonable for longer periods. Suppose we change assumption 2 to be:

1. Two moose die each year.

This is simple, but it has the same problem as our first model of births. As the herd gets larger, the number of deaths per year should get larger. So let’s consider changing assumption 2 to be:

1. 5% of the moose die each year.

This seems reasonable. One moose dies in the first year when the herd is at 20; when the herd reaches 100, then 5 moose die. This seems more plausible intuitively than having a fixed number of moose die each year.

* Please return to Moose population 3, the model you just viewed. If you have closed it, then reopen it from dragoon.asu.edu. Create a model of the moose population that includes both births and deaths. When you have completed the model and viewed the graphs, return to here.

This model of moose deaths seems to have harmed the models’ predictions. Now the model’s graph and the target graph for the moose population don’t match.

Given some more facts about moose behavior, we can solve this mystery. As we read earlier, the moose eat trees such as balsam fir. It’s a small island, so there are a limited number of trees. If the moose population gets too big, then they strip the lower branches bare during the first few months of winter and there is little food left for the rest of the winter. So the larger the moose population, the more moose die from starvation. As the herd gets bigger, eventually the starvation rate equals the birth rate, and the net growth rate is zero. How big would the herd be at this point? From the graph above, it seems that the net growth rate is zero when the herd reaches about 500 moose. So when the population is around 500, the death rate due to starvation equals the birth rate, and the net growth rate is zero. When the population is near 0, then the death rate is near zero so the net growth rate equals the birth rate. To represent this assumption mathematically, we want a formula that equals the birth rate when population is 500, and it equals 0 when the population is 0. And we want the formula to be simple. So here it is:

Moose death rate = moose birth rate\*(moose population / 500)

When the moose population is 500, the quantity inside the parentheses is 1, so the death rate and birth rate are equal, so the net growth is zero and the population is stable at 500—this occurs around 1945 and onwards. When the population is near 0, then the death rate is near zero, so the net growth rate is equal to the birth rate—this occurs around 1900.

We are just about ready to create a model, but one detail remains. Scientists do not like arbitrary numbers, such as 500, in their models, so they give them a name that conveys the number’s function in the model. In this case, the ecologists use the name “carrying capacity” for the 500. It represents the size of the moose population that the Isle Royale can “carry” stably. On a smaller island, the carrying capacity might be 200 moose. The carrying capacity for snowshoe hares on Isle Royale might be 1050. So carrying capacity varies with the species and the environment. By naming the constants in the model, scientists have created a convenient new concept that can now be explored further.

Whenever you are considering putting a numerical constant into your Dragoon model, please create a fixed value node instead, and give it a name that conveys the function of the constant in your model. This is good scientific practice. Thus, a better formulation of the above equation is:

Moose death rate = moose birth rate \* (moose population / carrying capacity)

* Please go to dragoon.asu.edu, enter your name and open Moose population 4. This contains the model that you just created, which includes both births and deaths of the moose. Please modify it to include carrying capacity. When you have completed the model and viewed the graphs, return here.

As you can see, the match between the models’ graph and the actual moose population is good. Granted, the actual moose population has some unexplained variations, but the variations appear to have no pattern. That is, the curves are not drifting apart or differing in any other organized fashion. This suggests that our model has captured the major pattern and the rest is noise. So let us declare this model to be finished. At the next class meeting, we will model the wolf population and how it interacts with the moose population.