Elephant Model

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Today we're going to be building an age structured model for the elephant population. This is the model that Tony described in lecture. You'll see how easy it is to set up this kind of model on a spreadsheet.

Let's begin by entering the word "year" in cell A10. And we'll run this population projection for 80 years. So we'll set up a series that runs from 1 to 80, down column A.

Now for each of these years, we're going to track the number of animals of different ages. So let's write the word 'Age'. And we'll start with zero year-olds. And then we'll enter a series for one year-old. We're going to track elephants that are age zero, one, all the way through age class fifty-nine. Just so that we can tie some words to these age classes, Tony referred to the age zero animals as 'Calves'. And he said that animals that were twelve-year old or greater were able to breed. That means that these animals, age class one through eleven, are all juveniles. And so we'll give those a heading.

First, we'll merge and center those. We'll give those a shaded color, and we'll label those 'Juveniles'. All of these other animals are breeding adults. Let's merge and center those, give them a different heading, and we'll call those 'Breeding Adults'.

Now our first year of our simulation begins with this first line, here. We're going to shade these all in green. And we're going to have to populate our model and give some starting values here. So this is year zero. And this is year one. And we need to populate and tell our model how many zero year-olds we're beginning with. This is not unlike us saying for the roc population, we began our simulations with 700 rocs. We need to know our starting place.

So for this exercise, we'll start with 40 animals there, and then we'll assume that there are 20 animals in each of the classes age 1, 2, 3, 4, and 5. And we'll assume that there are four animals throughout the rest of the age classes.

Now when I say animals, I mean females, because we were told that this is going to be a 'female-only' model. That doesn't mean males don't exist in the population - it means that our dynamics are adequately tracked just by considering the female side of the equation.

Let's drag this number four all the way across. And now we're able to compute the total, the total number of animals in our population, as the sum of all of the animals from age class 59 back down through the zero year-olds. And we start off with 356 animals - females.

Now, Tony mentioned that there is some uncertainty here. But what we're doing by entering these numbers is we're cutting through that Gordian knot, and we're not going to let that stall our effort. We'll go ahead, complete this model, and then look back at these numbers and how they affect our model outputs later on.

Now we're ready to go ahead and start entering equations. What do we need first?

Well, our model has parameters. The first parameter that we talked about was the calving interval. Tony mentioned that there was quite a bit of uncertainty in the calving interval, but we know that it's someplace between 3.1 and 3.3. That means that a female will give birth once every 3.1 to 3.3 years. Let's go ahead and enter 3.1 here, and at the same time, we'll add a note to this cell that indicates the range of values that we're going to let be acceptable within this particular entry. We can add a comment by right-clicking on the cell and then going to Insert Comment. And then we'll just write in '3.1 to 3.3'. You'll know that a cell has a comment because there'll be a red triangle in the upper-right corner, and if you hover your mouse over the top of that, you'll see the comment displayed.

Now that's the calving interval. This model has a one-year time step. We're not going to run a model that has the calving interval as the time step. So what we need to do is to take that calving interval and change it to a fecundity rate.

What would you use as an equation here to get the fecundity rate based on the calving interval?

Yeah. It's just going to be 1 divided by the calving interval, and that provides us with the fecundity rate. Now, we know that a female cannot produce 0.32 elephants in a year. But when we talk about a population model where the population size is large enough to let these averages play out, then it's okay for us to use this kind of a rate.

The next entry that we have to consider is the male-to-female ratio, or the proportion that our female--and we're talking about offspring. So if a calf produces 0.32 animals, we are going to assume that those include both males and females. And so it's important for us, since we're only considering females in this model, that we then take this number, multiply that by the proportion that actually are female, and that will give us the number of calves that we're trying to simulate.

So these represent really important parameters that go into our equation that will project the number of calves through time. We have a certain number of breeding adults, females. Those females each breed once every three or so years. On average, that represents 0.32 offspring per year. Half of those will be female.

Now in population models, we also need to be concerned about the survival rate. The first survival rate we'll consider is the survival rate of calves. And Tony mentioned that this was another very uncertain parameter estimate, ranging someplace between 0.8 and 0.9. We'll split the difference and enter 0.85 for now, but let's add another note and indicate that this is 0.8 to 0.9. Those are the ranges that we'll be considering in our modeling exercise.

And the survival rate of all of the other animals is very, very high. We really don't know what it is. But let's enter 0.9 for now, and we'll make a note to ourselves that this is a very, very high number. These are all model inputs, so we'll shade those green. And this fecundity we'll unshade, actually, because this is calculated based on what we say the calving interval is.

Now we have the information we need in order to go ahead and write equations in row 11 that will help us to project how many animals, females, will be in each time step for every single age group that there is. Let's start with the easy ones first.

Let's click on cell C11. And in C11, we're going to calculate the number of one year-olds that we expect to occur in the population, based on the number of calves in the preceding time step.

What equation would you use?

Yes, it's going to be equal to the number of zero year-olds that survived to become one year old. So we'll multiply that through by cell B4 and we'll anchor our cell B4 and press Enter. So 85 percent of 40, results in 34 animals becoming one years-old.

Now this brings up a really important point in modeling, especially when you're dealing with discrete classes and discrete time intervals.

Here we have a model where our time step is one year. And a lot can happen in a year. For a model, we need to specify explicitly, "When do we think animals are born," and "When do we think the census will occur?"

We're going to assume that in this particular exercise that our census occurs on a birthday. So when I say that there are 40 calves here, we can imagine 40 calves that were just born seconds ago. Those 40 calves we count. Pick a day, pick any day, your favorite day of the year, and let's assume that's the day the count occurs. All of those calves were born on that day. 85 percent of those died throughout the year, so when we're celebrating those calves' first birthday, then only 34 of them are there to participate in the celebration. Make sense?

Okay, how about the equation for the number of two year-olds?

Well, the number of two year-olds is equal to the number of one year-olds in the preceding time step that survived to become two year-olds. Again, we'll anchor the reference to cell B5, and we see that 90 percent of 20 is 18. The count is always happening on the actual birth day. This is called a 'post-breeding census', because we're counting them right after the births occur. Post-breeding, after the breeding has happened. So all of these are on a birth day.

How about three year-olds?

It's the number of two year-olds in the previous time step times their survival rate. And what you can see is that these equations for two year-olds and three year-olds are identical, essentially. What they say is, "Take the number of animals in the preceding age class and multiply it by the value in cell B5." This equation will work for every one of our other age classes as well. So let's just copy this formula all the way over through the age class 59. And we can drag our formula down for the total.

Now what's this total missing? Right. We forgot to count in the newborns.

Let's head back over to the 'newborn' cell. We need to enter an equation into cell B11 that will calculate how many calves are born. Now I'm going to ask you to put your video on PAUSE until we're through this, but let's just think about this for a second.

We need to count how many adults there were who were able to give birth. We need to keep in mind that this number of calves are the number of calves that are brand-new, born just seconds ago. We know that the females that are able to give birth reproduce at this fecundity rate, and we only want to count those offspring that are female, so we'll multiply that through by 0.5.

Go ahead and put your video on pause and enter that equation now.

<u>PAUSE the video</u>: Enter the equation on your spreadsheet.

We're going to go ahead and enter an equation here that assumes that we'll count the number of adults from the preceding time step. The first thing we'll do is to sum those adults with a 'Sum' function. We'll go over to the green area and we'll start counting all of those females in year zero, our starting populations. That gives us the total number of breeders. Each of those breeders reproduces at the rate in cell B2. And we only want to count those that are female, so we'll multiply those by cell B3 and we'll anchor that as well. And then we'll press Enter.

I got 30.9677 calves. Is that what you got? If you didn't get that, great. Why not?

Well, I made a mistake. And here's the mistake that I made. Let's just think through this for now. These are newborns. They're instantly born; they're born seconds ago. If I use the number of adults in year zero, and let each of those reproduce at the rates that we have specified, I'm making an overestimation of how many of these guys actually were alive to give birth. So I've over-counted the number of animals. And what I should do is grab hold of this box and pull it down one, and that gives me the right number of offspring that are able to reproduce.

Let's just think about this a couple of different ways. By using the number of adults in green, here, I've assumed that each and every one of those animals was alive to give birth to these calves. But we know that not all of those animals did make it to give birth to those calves, because the survival rate's only 0.9.

In fact, let's just work through this equation in a little bit different way. Let's count the number of animals that were, in the preceding time step, that were capable of giving birth. We'll sum those. Now, we'll correctly account for the fact that only 90 percent of those actually make it to give birth. They make it to that birth day. We'll then multiply that by the fecundity rate and by the proportion of offspring that are female. And we see that these numbers now match.

So in this case, I used the number of females in the preceding time step, but then correctly adjusted that number by the survival rate. In this case, I did the same thing, but by just summing up the number of animals in the same time step, I've already included the mortality rates that we had been concerned about. This is called a post-breeding census. We have to be really careful about making explicit our assumptions about when we count and when the timing of births occur, when we're dealing with a model with discrete time steps.

At this point, my model's pretty much finished. I'm going to go ahead and hide the decimal points for the calves. And now I can take all of these numbers--first, change those to numbers, and then hide the decimal places. Then we can copy this all the way through to the end of our projection. That's in row 90. So we'll find the end of this, and we can fill down to row 90, and there we have our population projection.

Now let's take a look at what the total population is doing through these time steps. We can just double-click on the bottom corner of our Total cell. We are now able to record some outputs for our model.

First, let's take a look at what the population size is doing over time. We can just grab the series called Total, and we'll go and make a chart from that particular series of data. We'll just choose a line option; we see that our population size is declining through time.

When you add a chart, the Chart Tools tab appears, and here, under the Layout tab, we'll be able to add our axes and legends. Choose the button called Axis Title; for the horizontal axis, we're going to label this 'Year'. For the vertical axis, we're going to label this 'Population Size'. If you ever want to change the way that things are oriented, just click on the legend and then choose the right way you'd like to display your axes.

Now this year actually starts at year zero. So once again, we'll choose our chart. Now we'll head to the Design tab. We'll choose Select Data. The entry that we want to change is the horizontal axis. We want it to start at zero. So if we change the axis, we'll get a new dialogue box. We can shrink this dialog box down by clicking on the red arrow, and now let's go ahead and find our proper axes, and then we can press OK.

This is a graph of our elephant population size through time. This is a declining population. When we model populations with these time steps in this kind of way, we often talk about the relationship between a population size in one year and its previous year. And that is the name ‘lambda’. That ratio is called lambda, L-A-M-B-D-A. And it’s just entered as the population size at time step t + 1 divided by the size at time step t. So it’s a ratio of two numbers. Now in this case, you really do want to display the decimal points, because you want to see exactly what this ratio is. If these two numbers were really exactly the same, so I’ll enter 356, then lambda will be exactly one. If the population is declining, let’s enter a smaller number here, 340, then lambda becomes less than one. And if the population is increasing, then lambda is greater than one.

We often find it useful to explain this lambda by recording the proportion of change. And that is just going to be what’s the difference, the proportion, that has changed. And we can get that by just subtracting one minus this particular value. Now when we do that, we notice that we have a sign difference here. We can fix really quickly by just entering a negative up in our equation bar. And now we see that this population has changed by a certain proportion. If it’s a population that’s declining, this proportional change is reflected as a negative number.

So lambda, again, is less than one. It dropped by 0.04, so this number is 95 percent of this number. We can talk about proportional change in terms of percentage by just multiplying by 100. That’s equal to the proportional change times 100. And we see that our population has declined by negative 4.49 percent.

So it’s a handy way to talk about population change, by looking at this lambda. So remember, lambda greater than one means the population’s increasing. Lambda equals one means the population’s stable. Lambda less than one means the population’s declining. It’s a ratio of two numbers. That ratio gives us the proportional change as well as the percent change. We can copy these down for the rest of our projections.

Let’s go ahead and clean up these headings a little bit, as well as our column sizes. Let’s go ahead and graph lambda over time. We’ll just go ahead and select all of the values down column BK. And again, we’ll insert a graph, that’s a line graph, and we’ll be projecting lambda through time.

In this case, lambda does begin with year one because we can’t have a ratio of population sizes from year zero. We don’t need this legend, so we can delete that. What we’ll want to do is to fix the axis here, as well as shrink the number of decimal points that we’re displaying. We want to fix the axes because, as we change some of our inputs, the spreadsheet has a tendency to automatically readjust these axes, and that makes it hard to compare your results directly.

So let's fix those now. Just right-click on the axis, choose Format Axis. We're going to first choose the Number option, and we'll show only two decimal places. Then we'll also want to fix the minimum and the maximum. And let's fix the minimum at 0.93, and we'll fix the maximum at 1.1. Then we can press Close.

This graph shows lambda over time, and what you can see is at the beginning of our projections, lambda goes up and then down and then up again. But then as we continue to run our model through time, there's a tendency for it to flatten out and become stable. This is one of the properties of these age-based models. Tony will talk about this in depth in our next video.

For now though, let's just add two more outputs to our spreadsheet. We'll label the section called 'Outputs'. And what we are interested in doing is recording the final lambda. And that's going to be a lambda that was recorded after things have stabilized. And we also want to record the final population size. These are both down in the far right-hand corner of our spreadsheet, so let's go find them. The final lambda is at the bottom of the lambda column, so after lambda has stabilized. And I'm sitting right on the top of it with my graph. There's the number we want, right there. Cell BK90. And the final population size is the cell to the left of that, cell BJ90. So lambda is in cell BK90. Population size is in cell BJ90. These are both outputs, so we'll shade those in blue.

Now we're ready to head back over to Tony, who is going to talk to us more about properties of these age-based models. See you next time.

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