POPULATION MODELS

Demographic Stochasticity

Tony Starfield

recorded: March, 2011

We're back in the 21st Century now. And the consulting companies that started out in Baghdad are still going strong 1,000 years later, only they're now based in Washington, D.C. And the story of the Roc model that the company did for the Caliph 1,000 years ago is part of the mythology of the company. But if you think Rocs are purely history, you're in for a surprise. Because it's just been discovered that there are two Rocs still alive in Saudi Arabia.

How did they find them? Well the records from the first Iraq war, Desert Storm, have just been declassified, and you might recall that during that war, there were hundreds of satellites focused on that part of the world looking for scud missiles and other information that could be useful to the troops. And one of the secrets of those records is that there are two Rocs in a remote part of the Arabian Desert - two young Rocs. How do we know that they're young because nobody's ever seen a Roc before? We know they're young because they haven't nested yet.

And with this discovery, the king of Saudi Arabia and world conservationists are, of course, very excited and have come to your companies in Washington, D.C. to ask a simple question, "If we have two Rocs now, how many Rocs can we expect to have in 200 years?" Notice we don't think [bigger?] anymore. We don't try and project forward 1,000 years. But from the point of view of planning, perhaps in terms of tourism or making sure sufficient nesting sites are conserved, it's useful to look ahead for the next 200 years. So you are being asked to develop a model to project the current population of two for another 200 years. What are you going to do?

Never ever grab an old model and apply it to a new situation. When you've got a different situation, you need to redesign your model world. So let's think about, in the context of these two Rocs in the 21st Century, let's think about what we need to put into the model world.

Silver bullets. People have forgotten how to make silver bullets, but I don't think you need to worry about that.

Roc flu. Well it's hard to imagine an epidemic in a population of two, three, four or five birds.

And probably the mere fact that these birds are still alive shows that they're part of a genetic strain that is immune to Roc flu.

Mountaintops. Well there are still a number of mountaintops that are in the wilds of Saudi Arabia. And part of the problem might be, in fact, to decide how many of them to conserve. So don't worry about nesting sites.

Sailors. Well this could be a touchy subject. Obviously, there are plenty of sailors around, but does one want to cope with the fact that Rocs are busy eating sailors? Presumably, one might be able to monitor the Roc nests very, very carefully and put a sailor substitute in at the appropriate time. But let's not worry about that. We don't need to worry about sailors.

So what's left in your model? Very little. In fact, if you think about it and develop your new model, you're going to get back to the simplest possible model that we could've developed back 1,000 years ago.

And if you recall, that model looks like this. It basically says that the population 100 years from now is going to be C times the population now. And the best estimate we had for C, which was the average clutch size, was 1.06. Think about that number, 1.06. It was an average clutch size. Talking about an average clutch size 1,000 years ago when you had populations of hundreds of Rocs was a reasonable thing to do. But does it have any meaning at all when you have two Rocs? Obviously not.

So we're now faced with a kind of paradox, and that is that one very often needs to know more about an endangered species where there are very few numbers of that species in a population and when one has much larger populations. In larger populations, you can get by with averages. In very small populations, you need to know more about the biology of that particular animal. And that's difficult to find out because you've got a very small population.

So if you think about it, the information you really need is not an average clutch size. You need to know something about the probability of a Roc laying one egg or two eggs or three eggs or four eggs. And that's information you don't have. Or do you?

Remember back to the advice your companies gave to the Caliph 1,000 years ago. Remember you told the Caliph to invest in a research project to monitor 100 nests and count the number of eggs. Well that was done. And if you go through the archives of your company that were

brought from Iraq or from Baghdad when you moved to Washington, D.C., you will find that you actually have the results from that experiment. Let me show them to you.

A hundred nests, as you advised, were monitored. And it was discovered that there were never more than two eggs in a nest. In fact, out of the 100, 18 had two eggs. 70 had one egg. And it was discovered that 12 nests had no eggs at all, even though the Rocs were sitting on those nests and appeared to be brooding.

Well how would we use those data? On the basis of those data, how can we decide how to model the number of eggs laid by each Roc? And just by asking that question, notice that I'm suggesting now that we use what is called an **individual-based model**. We're going to model every single animal in the population and make decisions about their survival and fecundity.

So let's look back again at those numbers. What they are telling us is that the probability of having no eggs is about .12. The probability of one egg is .7. And the probability of two eggs is .18.

So what I can do is, I can draw a line going from 0 to 1, and on it, I can mark the points, .12 and .82. If you think about it, the length of this first segment is exactly .12. The length of the second segment is .7. And the length of the third segment is .18.

And if I were, then, to generate a random number from a uniform distribution between 0 and 1, and if it landed, say, in the third segment, I would say I would have two eggs. If it landed in the first segment, I would say no eggs. And, on average, if I developed a large number of random numbers, I would end up with probabilities, if we ascertain from the experiments that were done 1,000 years ago.

So what I'm suggesting is that we need to build an individual-based stochastic model. How would we do that?

One would have to end up with something that looks rather like this in, for example, going from the year 2000 to the year 2100. Suppose that in the year 2000, we have these two young Rocs. Call them A and B. We could give them names if you like. What we need to do is generate a random number and decide how many eggs Roc A lays. And suppose, for the sake of argument, that it lays one egg. Then we generate another random number for Roc B. And suppose Roc B lays two eggs. We now know that there are a total of three new Rocs in the new generation.

And so what we're going to do 100 years from now is create three new Rocs. Call them lower case a, b, and c. That basically is a step in our calculation. It's one slice of the salami.

And now to go from the year 2100 to the year 2200, we would again calculate how many eggs each of these lay. And from that, we would know how many Rocs we have in the year 2200.

And if we repeated that over and over again, we would come up with probabilities that show you what the probability is of having no Rocs in 200 years time, one Roc, two Roc, up to a maximum of--what could you have? Eight Rocs. And that would be useful information for the king of Saudi Arabia and for conservationists planning for the future infrastructure for Rocs over the next 200 years.

Okay. So what have we done? We've basically developed a model that enables us to keep track of every single individual of the population. And there are some people out there who would say, "Why don't you do that always? Why did you do that when you had 600 Rocs, for example?" And the answer's very simple. It's because you don't need to do it. You're adding unnecessary complexity to your model if you haven't got a good reason for making it individual based. In this case, you do have a good reason.

What I'd like to do, though, is talk a bit about how this ties in with some of the terms that people use when they're talking, for example, about population viability analyses.

I want to draw a distinction between **environmental stochasticity** and **demographic stochasticity**.

If you think back 1,000 years, Roc flu required a stochastic model. But that was environmental stochasticity. It was something from outside the population: disease, drought, hurricanes that occurred on a probabilistic basis that affected the population.

What we have introduced here is what's called demographic stochasticity, and that is because the stochasticity relates to the survival and fecundity rates of the population. In this case, it related to the fecundity via the number of eggs laid in a clutch. Both environmental and demographic stochasticity are very often part of a routine population viability analysis. And I thought it would be useful for you to know those terms.

While we're talking about routine population viability analyses and standard programs that people often use. Once we've pointed out that there's nothing special about a population viability analysis, it is just a model. And when you use a standard program, you should design your model world and think about what you need to put into it in exactly the same sort of way.

What we are going to do now is take the example of the Rocs and see how to put it on a spreadsheet. But before we do that, I should mention that very often, individual-based models are far too complicated to put on spreadsheets. But, fortunately, this example is simple enough so that you could see how it could be done.

< 00:14:35 END >